<u>Progress Report on the Bay Delta Conservation Plan</u>
April 28, 2006 - November 18, 2010

The members of the Bay Delta Conservation Plan (BDCP) Steering Committee provide this memorandum reporting on our progress in developing a plan to achieve the co-equal goals of restoring the ecosystem and water supply reliability of the Sacramento-San Joaquin River Delta. The November 18, 2010 draft of the plan, which is a work in progress as described in paragraph 4 below, is attached. This is the first time the draft plan has been compiled in one place and provides an opportunity for the Steering Committee and members of the public to review and formulate opinions about how to best proceed with further development and revisions of the plan in 2011.

1. Under our Planning Agreement (2006, amended 2009), the BDCP is intended to establish a conservation strategy for the Delta infrastructure and operations of the State Water Project and Central Valley Project, as well as the powerplant operations of Mirant Corporation. It is specifically intended to assure that these and any other covered activities comply with the requirements of the federal and state Endangered Species Act, Natural Community Conservation Planning Act, and other applicable laws, over a plan term up to 50 years.

2. The Steering Committee consists of the California Department of Water Resources, the U.S. Bureau of Reclamation, federal (*ex officio* members) and state permitting agencies, water contractors, environmental organizations, and other stakeholders. Pursuant to the Delta Reform Act of 2009, the Delta Stewardship Council participates as an Interested Observer. As provided in the Planning Agreement, meetings of the Steering Committee are open to the public. Since formation, the Steering Committee has met 122 times to review scientific analyses, other planning documents, and draft plan chapters, while taking public comments into account. The Steering Committee convened various subcommittees and workgroups, and commissioned independent scientific reviews, which substantially assisted in plan development. On a parallel track, lead State and Federal agencies initiated environmental review under the National Environmental Policy Act and California Environmental Quality Act. The cumulative investment by members, consultants, other stakeholders and members of the public in this planning process exceeds several hundred thousand hours of time, reflecting the extraordinary importance – and difficulty – of preparing such a complex conservation plan that includes redesigning the Delta water supply infrastructure (built several generations ago) to advance co-equal goals in this highly altered ecosystem.

3. The November 18, 2010 draft represents the progress toward a conservation strategy intended to achieve the co-equal goals, as described in "Points of Agreement" (2007) and "An Overview of the Draft Conservation Strategy for the BDCP" (2009). The approach includes integrated elements: new conveyance infrastructure and operational criteria, restoration of habitat for covered species and their communities, measures to address stressors other than water supply operations, and provisions for adaptive management over the plan term.

4. The Steering Committee has reviewed various drafts of most plan chapters over the course of the past four years. As of November 18, 2010, the draft plan includes chapters and sub-chapters

that have undergone varying levels of input and review by the Steering Committee, including portions that have been reviewed and revised multiple times as well as new and revised language that has not yet been reviewed. On the whole, some elements of this plan are clearly defined, while others are incomplete, disputed among members, or otherwise under development, as indicated in editorial notes to reviewers in the chapters.

5. The Steering Committee believes that we have made substantial progress towards a complete plan. As stated in the Points of Agreement and Overview, and again in this draft, an integrated conservation strategy that addresses habitat and other stressors, as well as operational rules for the water supply projects, will be necessary to restore the ecosystem.

6. Recognizing the vital importance of this effort, the Steering Committee will continue to work on the remaining elements of this plan. Editorial notes in the plan chapters highlight those elements. One critical task is resolution of scientific issues related to the complex set of analytical methods to evaluate the benefits for covered species (Chapter 5). Once these issues are resolved, the analysis will be used to test the effectiveness and indicate the need for potential modifications of the conservation strategy. Related tasks include further development of plan objectives for ecosystem benefits (Chapter 3.3), regulatory assurances (Chapter 6.3), and iterative use of the effects analysis to refine the conservation measures. In addition, the Steering Committee must review and revise the current draft to assure that all prior comments on all chapters have been adequately addressed and resolved.

7. Our Planning Agreement as amended in 2009 provides that the draft plan and the associated draft Environmental Impact Statement/Report will be completed in 2011. The members of the Steering Committee commit to continue to work in a cooperative and open process to assist in the expeditious completion of a science-based and legally sufficient draft plan that will achieve the co-equal goals of Delta ecosystem restoration and water supply reliability.

Working Draft

Bay Delta Conservation Plan

November 18, 2010

*[**Note to Reviewers**: This November 18, 2010 working draft of the Bay Delta Conservation Plan (BDCP) contains chapters and major chapter sections that are in different stages of development by the SAIC Consultant Team and review by the BDCP Steering Committee. The BDCP Steering Committee members have submitted comments to various drafts of the chapters and chapter sections during development, which may or may not have been incorporated into this November 18, 2010 draft. Addressing such comments will be part of the continuing process of developing the BDCP. While the text of this document is subject to change and revision as the BDCP planning process progresses, the document has been drafted and formatted to appear as it may in a completed draft HCP/NCCP. Although the document includes declarative statements (e.g., the Implementation Office will…), it is nonetheless a "working draft" that will undergo further modification based on input from the BDCP Steering Committee, state and federal agencies, and the public.]*

Prepared for:

The BDCP Steering Committee

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Acronyms and Abbreviations

µS/cm	water salinity
AACE	Association for the Advancement of Cost Estimating
ACID	Anderson-Cottonwood Irrigation District
ADNWR	Antioch Dunes National Wildlife Refuge
af	acre-feet
AFRP	Anadromous Fish Restoration Program
AIP	Alternative Intake Project
AMM	avoidance and minimization measures
AN	above normal
ARG	American River Group
B2IT	CVPIA Section 3406 (b)(2) Integration Team
BA	biological assessment
BCC	Birds of Conservation Concern
BCDC	Bay Conservation and Development Commission
BDCP	Bay Delta Conservation Plan
BLM	Bureau of Land Management
BMP	best management practices
BO	biological opinion
C	Celsius
CAISO	California Independent System Operator
CaSIL	California Spatial Information Library
CBDA	California Bay-Delta Authority
CCF	Clifton Court Forebay
CCPP	Contra Costa Power Plant
CCWD	Contra Costa Water District
CDC	California Department of Conservation
CDEC	California Data Exchange Center
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
cf	cubic feet
CFR	Code of Federal Regulations
cfs	cubic feet per second
CI	confidence interval
CM	Conservation Measure
cm	centimeter
CMSP	Caswell Memorial State Park
CNCCPA	California Natural Community Conservation Planning Act
CNDDB	California Natural Diversity Database
CNPS	California Native Plant Society
COA	Coordinated Operations Agreement
CPAD	California Protected Areas Database
CPS	Coastal Pelagic Species
CPUE	catch per unit effort
CSFMRA	California Chapter of the American Society of Farm Managers and Rural Appraisers
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act

Acronyms and Abbreviations (continued)

CVRWQCB	Central Valley Regional Water Quality Control Board
CWP	circulating water pumps
CWT	coded wire tags
CZ	conservation zone
D-1641	Decision 1641 (a State Water Board decision)
DAU	Detailed Analysis Unit
DBEEP	Delta-Bay Enhanced Enforcement Program
dBPEAK	instantaneous peak sound pressure level
dBRMS	sound pressure level
dBSEL	sound exposure level
DBW	California Department of Boating and Waterways
DCC	Delta Cross Channel
DDT	dichlorodiphenyltrichloroethane
DFG	California Department of Fish and Game
DHCCP	Delta Habitat Conservation and Conveyance Program
DMC	Delta Mendota Canal
DOQQ	digital orthophoto quarter quadrangles
DOSS	Delta Operations for Salmon and Sturgeon
DPM	Delta Passage Model
DPR	Department of Pesticide Regulation
DPS	distinct population segment
DRERIP	Delta Regional Ecosystem Restoration Implementation Plan
DRMS	Delta Risk Management Strategy
DSM2-QUAL	Delta Simulation Model, Quality Module
DSRAM	Delta Smelt Risk Assessment Matrix
DWR	Department of Water Resources
EBC	existing biological conditions
EC	electrical conductivity
EDAW	Eckbo, Dean, Austin & Williams
EDCP	*Ergeria densa* Control Program
EDCs	endocrine disrupting compound
EEZ	exclusive economic zone
EFH	essential fish habitat
EHW	extreme high water
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
ELT	early long-term
EPA	Environmental Protection Agency
ERP	Ecosystem Restoration Program
ESA	Endangered Species Act
ESU	evolutionarily significant unit
EWA	Environmental Water Account
F	Fahrenheit
FAV	floating aquatic vegetation
FERC	Federal Energy Regulatory Commission
FL	Fork Length
FMP	Fisheries Management Plan
FMWT	fall mid-water trawl

Acronyms and Abbreviations (continued)

FR	Federal Register
FSA	Farm Service Agency
ft	feet
ft/sec	feet per second
FY	Fiscal year
g	grams
g/L	grams per liter
g/TAF	grams per thousand acre feet
GIS	geographic information system
gMW	gross megawatts
gpm	gallons per minute
HCP	habitat conservation plan
HEC-RAS	Hydrologic Engineering Centers River Analysis System
HGMP	Hatchery and Genetic Management Plan
HSI	habitat suitability indices
HTI	Hydroacoustic Technology Incorporated
HVAC	Heating, Ventilating, and Air Conditioning
I	interstate
IA	Implementing Agreement or Implementation Agreement
ICF	isolated conveyance facility
IEP	Interagency Ecological Program
IFIM	Instream Flow Incremental Method
INDP	Interim North Delta Program
IO	Implementation Office
IOS	Interactive Object-oriented Simulation
IRAs	Important Related Actions
ISDP	Interim South Delta Project
JPE	juvenile production estimate
JPOD	Joint Points of Diversion
KF	Knights Ferry
kg	kilograms
kg/year	kilograms per year
km	kilometer
L	liter
lbs/TAF	pounds per thousand acre feet
LiDAR	Light Detection and Ranging
LT	long-term
LLT	late long-term
LSZ	low salinity zone
m	meter
M&I	municipal and industrial
m^3	cubic meters
maf	million acre feet
MCP	minimum convex polygon
MCY	million cubic yards
MeHg	methylmercury
mg/L	milligrams per liter
MGD	millions of gallons per day
MHHW	mean higher high water

Acronyms and Abbreviations (continued)

MLLW	mean lower low water
mm	millimeter
MMU	minimum mapping unit
MSCS	Multi-Species Conservation Strategy
MW	megawatts
NA	not applicable
NAA	No Action Alternative
NAIP	National Agriculture Imagery Program
NBA	North Bay Aqueduct
NCCP	Natural Community Conservation Plan
NCCPA	Natural Community Conservation Planning Act
ND	no data
NDD	North Delta diversion
NEPA	National Environmental Policy Act
NGO	nongovernmental organization
ng/L	nanograms per liter
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPFMC	Northern Pacific Fishery Management Council
NPPA	Native Plant Protection Act
NRC	National Research Council
NRCS	Natural Resources Conservation Service
NT	near-term
NWI	National Wetlands Inventory
NWR	National Wildlife Refuge
O&M	operations and maintenance
OBB	Orange Blossom Bridge
OCAP	Operations Criteria and Plan
OMB	Office of Management and Budget
OMR	Old and Middle River
OSCP	Oil Spill Contingency Plan
PBT	parentage based tagging
PCB	Polychlorinated biphenyl
PCE	primary constituent element
PCS	Pacific Coast salmon
PG&E	Pacific Gas & Electric
pH	potential of hydrogen
PHABSIM	Physical Habitat Simulation Model
POD	Pelagic Organism Decline
POP	Plan of Protection
PP	proposed project
PP_ELT	proposed project for early long-term
PP_LLT	proposed project for late long-term
ppb	parts per billion
PPP	Pittsburg Power Plant
ppt	parts per thousand
PRE	Potential Regulated Entity
psu	practical salinity unit

Acronyms and Abbreviations (continued)

PTM	particle tracking model
RBDD	Red Bluff Diversion Dam
RD	Reclamation District
Reclamation	Bureau of Reclamation
RIMS	Response Information Management System
RM	river mile
RMA	Resource Management Associates
RMS	root-mean-square
ROA	Restoration Opportunity Area
ROD	Record of Decision
RPAs	Reasonable and Prudent Alternatives
RWQCB	Regional Water Quality Control Board
S&P	Standard & Poor's
SAC	Sacramento River flows
SacEFT	Sacramento Ecological Flows Tool
SAIC	Science Applications International Corporation
SALMOD	salmonid egg mortality model
SAV	submerged aquatic vegetation
SBI	Swaim Biological, Inc.
SC	Steering Committee
SDD	South Delta diversion
SDWSC	Stockton Deep Water Ship Channel
sec	second
SFCWA	State and Federal Contractor Water Authority
SFEI	San Francisco Estuary Institute
SJR	San Joaquin River
SJRA	San Joaquin River Agreement
SJRTC	San Joaquin River Technical Committee
SKT	Spring Kodiak trawl
SMPA	Suisun Marsh Preservation Agreement
SR	Sacramento River
SR	state route
SRCD	Suisun Resource Conservation District
SRTTG	Sacramento River Temperature Task Group
SRWQM	Sacramento River Water Quality Model
SSURGO	Soil Survey Geographic Database
STN	summer tow-net survey
SWE	snow water equivalent
SWG	Smelt Working Group
SWP	State Water Project
SWPPP	Stormwater Pollution Prevention Plan
SWRCB	State Water Resources Control Board
SWRI	Surface Water Resources, Inc.
TAF	thousand acre-feet
TFCF	Tracy Fish Collection Facility
TIGER	Topologically Integrated Geographic Encoding and Referencing
TL	total length
TMDL	total maximum daily load

Acronyms and Abbreviations (continued)

ug/L	micrograms per liter
USACE	U.S. Army Corps of Engineers
USBR	Bureau of Reclamation
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VAMP	Vernalis Adaptive Management Program
VFD	Variable-frequency drive
VSP	Viable Salmonid Population
WAPA	Western Area Power Administration
WUA	weighted usable area
YBFEP	Yolo Bypass Fishery Enhancement Plan
yd	yard
YOY	young of the year

CHAPTER 1. INTRODUCTION

1.1 BACKGROUND

The Bay Delta Conservation Plan (BDCP or "Plan") addresses the increasingly significant and intensifying conflict between the ecological needs of a number of at-risk species adversely affected by a range of human activities and the need for adequate and reliable water supplies from the Sacramento-San Joaquin River Delta (Delta) for people, communities, agriculture, and industry. The Plan sets out a comprehensive conservation strategy for the Delta designed to advance the co-equal planning goals of restoring ecological functions of the Delta and improving water supply reliability to large portions of the state of California. The BDCP reflects the outcome of a multi-year collaboration between public water agencies, state and federal fish and wildlife agencies, non-governmental organizations, agricultural interests, and the general public.

The BDCP is expected to result in long-term regulatory authorizations under state and federal endangered species laws for the operations of the State Water Project (SWP) and the Central Valley Project (CVP), as well as the operations of certain power plants owned by Mirant Delta LLC (Mirant). The Plan will further provide the basis for durable regulatory assurances. Specifically, the goal of the BDCP is to serve as a natural community conservation plan (NCCP) under the state's Natural Community Conservation Planning Act (NCCPA),[1] and a habitat conservation plan (HCP) under Section 10 of the federal Endangered Species Act (ESA). The Plan will also provide the basis for biological assessments that support new ESA Section 7 consultations between the Bureau of Reclamation (Reclamation), the U.S. Fish and Wildlife Service (USFWS), and the National Marine Fisheries Service (NMFS). The BDCP is further intended to meet the standards set out in the recently-enacted Sacramento-San Joaquin Delta Reform Act, which provides for the incorporation of the BDCP in a comprehensive management plan for the Delta (known as the "Delta Plan").[2]

Unlike past regulatory approaches, which have relied almost exclusively on iterative adjustments to the operations of the SWP and CVP, the BDCP prescribes actions that will produce fundamental, systemic and long-term physical changes to the Delta. These changes will involve substantial alterations to water conveyance infrastructure and water management regimes in combination with extensive restoration of habitat and actions to reduce the impacts of various biological stressors. It is expected that these actions will significantly enhance Delta productivity and ecological processes so as to provide for the conservation of multiple species and natural communities, while improving water supply reliability for the export contractors. To further advance this holistic approach and enhance opportunities for success, the BDCP has been designed to accommodate and respond over time to new information and greater scientific understanding of the Delta.

[1] The BDCP has also been designed to meet the regulatory standards of the California Endangered Species Act.
[2] Add citation for the Delta Reform Act.

The BDCP sets out an integrated Conservation Strategy to achieve the overarching planning goals of ecosystem restoration and water supply reliability (Section 1.2, *BDCP Planning Goals and Conservation Objectives*) and meet a range of specific biological goals and objectives (Section 3.3, *Biological Goals and Objectives*). The BDCP includes a description of each element of the Conservation Strategy and the rationale for its inclusion in the Plan. The BDCP further describes the expected contribution of each plan element toward advancing both the overall planning goals and specific biological goals and objectives. The Conservation Strategy was informed by findings and conceptual models developed over time through prior scientific efforts, including those conducted by the CALFED Science Program, and supplemented by data and analysis developed through the BDCP process. The Conservation Strategy is based on the best available science and was built upon the following scientific tenets:

- Increase the quality, availability, spatial diversity, and complexity of aquatic habitat within the Delta;
- Create new opportunities to restore the ecological health of the Delta by modifying the water infrastructure to convey water around the Delta, reducing reliance on conveyance of water through artificial and natural channels in the Delta to export pumping plants in the southern Delta;
- Directly address key ecosystem drivers unrelated to freshwater flow patterns rather than manipulation of Delta flow patterns alone;
- Improve connectivity among aquatic habitats, facilitate migration and movement of covered fish among habitats, and provide transport flows for the dispersal of planktonic material (organic carbon), phytoplankton, zooplankton, macroinvertebrates, and fish eggs and larvae;
- Improve synchrony between environmental cues and conditions and the life history of covered fish and their food resources within the upstream rivers, Delta, and Suisun Bay, including the hydrologic seasonal synchrony within the watershed, seasonal water temperature gradients, salinity gradients, turbidity, and other environmental cues;
- Reduce sources of direct mortality and other stressors on the covered fish and the aquatic ecosystem within the Delta;
- Improve habitat conditions for covered fish in upstream river reaches, within the Delta, and downstream within the low salinity zone of the estuary in Suisun Bay through the integration of water operations with physical habitat enhancement and restoration;
- Minimize adverse effects on terrestrial wildlife and plants resulting from implementation of measures to benefit aquatic species;
- Expand the extent and enhance the functions of existing natural communities and habitat of covered wildlife and plants that is permanently protected;

- Restore habitat to expand the populations and distributions of covered wildlife and plant species; and
- Rely, to the extent possible, on natural physical habitat and biological processes to support and maintain covered species and their habitat.

The BDCP covers the Sacramento-San Joaquin Delta, as defined by California Water Code Section 12220 (“statutory Delta”), as well as certain additional areas in which conservation measures set out in the Conservation Strategy will be implemented (Section 1.4.1 *Geographic Scope of the Plan Area*) (Figure 1-1). The geographic scope of the Plan Area also encompasses the areas in which the activities that have been proposed for regulatory coverage under the Plan are expected to occur.

Because the infrastructure of the state and federal water projects, however, form an integrated system that extends beyond the boundaries of the Delta, the implementation of the BDCP will affect water operations and species and habitat both inside and outside of the Delta. While the geographic scope of Plan Area generally does not include areas upstream and downstream of the Delta, the Plan will take into account and address the upstream and downstream effects of covered activities, both beneficial and adverse.

1.1.1 BDCP Steering Committee and the Planning Agreement

In January 2006, a number of stakeholders with diverse interests in the Delta, including public water agencies, environmental and conservation organizations, and other parties, agreed to a Statement of Principles that called for the development of a comprehensive conservation plan for the Delta[3]. The parties to that agreement envisioned a plan that would advance the recovery of fish and wildlife species affected by certain water supply-related activities and provide long-term assurances regarding the operation of existing and future water-related facilities and other activities associated with the SWP and the CVP.

In July 2006, several of these parties entered into a memorandum of agreement (MOA) entitled For Supplemental Funding for Certain Ecosystem Actions and Support for Implementation of Near-Term Water Supply, Water Quality, Ecosystem, and Levee Action.[4] The MOA set out the financial commitments of the parties to carry out actions to satisfy existing regulatory requirements related to the operation of the SWP and the CVP and to develop a conservation plan for the Delta that would support new regulatory authorizations under state and federal endangered species laws for current and future activities related to the SWP and CVP.

[3] Appendix H1, Jan 2006 Statement of Principles

[4] Appendix H2, MOA For Supplemental Funding for Certain Ecosystem Actions and Support for Implementation of Near-Term Water Supply, Water Quality, Ecosystem, and Levee Action, July 2006.)

DRAFT

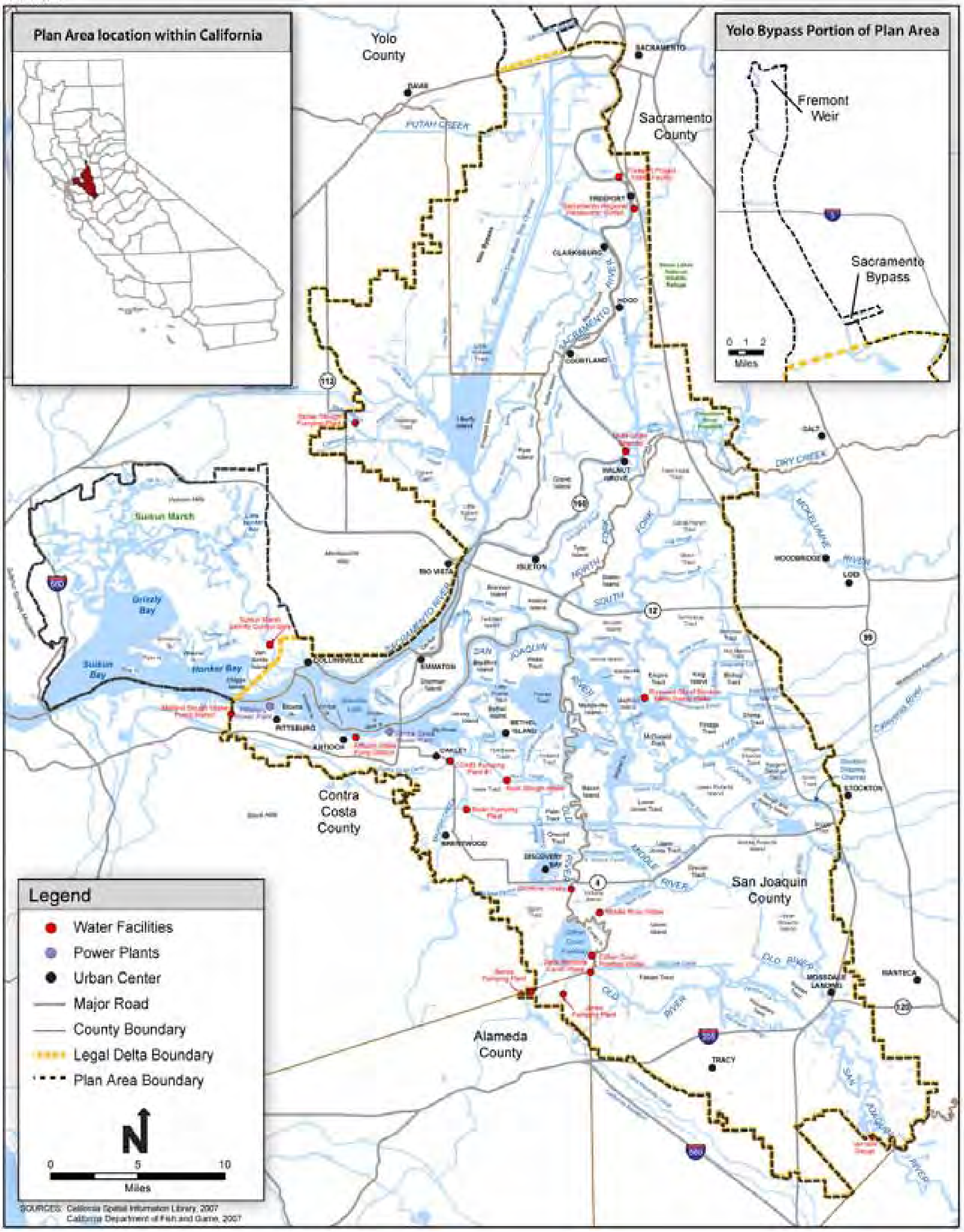

Figure 1-1. BDCP Plan Area

1

At the same time, the California Resources Agency (currently the "California Natural Resources Agency") convened a diverse group of stakeholders and regulatory agencies to help guide the development of a comprehensive conservation plan for the Delta, which became known as the BDCP. The resulting BDCP Steering Committee consisted of parties to the Statement of Principles and MOA as well as other interested groups and additional state and federal agencies, all of whom indicated their commitment to engage in a process to advance the co-equal goals of ecosystem restoration and water supply reliability (Table 1-1). The meetings of the BDCP Steering Committee were intended to serve as the principal forum within which key policy and strategy issues pertaining to the development of the BDCP would be discussed and considered. In December 2006, the original members of the Steering Committee entered into a formal Planning Agreement, consistent with requirements of the NCCPA,[5] for the development of the BDCP. The Steering Committee was expanded after December 2006, as noted in Table 1-1. The Planning Agreement, among other things, defined the goals, commitments, and expectations of the parties regarding the BDCP planning process. It also reiterated the goal of the Steering Committee to develop a conservation plan that would meet the requirements of the ESA and the NCCPA. Section 1.5, *Overview of the Planning Process*, provides a summary of the role of the Steering Committee and the various groups and teams that supported the Committee.

Table 1-1. BDCP Steering Committee Members and Planning Agreement Signature Dates

Entities	***Original Signature Date***	***Amendment Signature Date***
State and Federal Agencies		
California Natural Resources Agency	October 24, 2006	October 27, 2009
California Department of Water Resources	November 14, 2006	December 3, 2009
State Water Resources Control Board (*ex officio*)	See Note	See Note
U.S. Bureau of Reclamation	November 13, 2006	October 30, 2009
U.S. Army Corps of Engineers (*ex officio*)	See Note	See Note
Potential Regulated Entities (PREs)		
Kern County Water Agency	December 6, 2006	January 29, 2010
Metropolitan Water District of Southern California	November 2, 2006	December 3, 2009
Mirant Delta, LLC	December 6, 2006	October 5, 2009
San Luis & Delta-Mendota Water Authority	December 6, 2006	December 6, 2009
Santa Clara Valley Water District	November 20, 2006	November 30, 2009
Westlands Water District	December 6, 2006	December 1, 2009
Zone 7 Water Agency	October 26, 2006	November 30, 2009
Environmental Organizations		
American Rivers	November 8, 2006	January 21, 2010
Defenders of Wildlife	March 15, 2007	January 29, 2010
Environmental Defense Fund	October 30, 2006	January 21, 2010
Natural Heritage Institute	October 25, 2006	November 3, 2009
The Nature Conservancy	November 14, 2006	December 1, 2009
The Bay Institute	July 26, 2007	December 7, 2009
Other Member Agencies		
California Farm Bureau Federation	March 30, 2007	November 11, 2009
Contra Costa Water District	August 3, 2007	January 4, 2010
Friant Water Authority	March 9, 2009	November 18, 2009
North Delta Water Agency	March 12, 2009	October 5, 2009

[5] Appendix H3, BDCP Planning Agreement and amendments

Table 1-1. BDCP Steering Committee Members and Planning Agreement Signature Dates (continued)

Entities	*Original Signature Date*	*Amendment Signature Date*
Fishery Agencies		
California Department of Fish and Game (*ex officio*)	October 24, 2006	October 5, 2009
U.S. Fish and Wildlife Service (*ex officio*)	November 6, 2006	December 3, 2009
National Marine Fisheries Service (*ex officio*)	November 14, 2006	December 3, 2009
Other *Ex Officio* Member Agencies		
Delta Stewardship Council		
Note: The SWRCB and USACE are not signatories of the Planning Agreement.		

1.2 BDCP Planning Goals and Conservation Objectives

The overarching goals of the BDCP are to advance the restoration of the ecological functions and productivity in the Delta and improve the reliability of water supplies provided by the SWP and CVP, as first stated in the Statement of Principles and reaffirmed in the BDCP Planning Agreement. The Planning Agreement further articulated specific planning goals to guide the development of the BDCP and further ensure its consistency with the broader goals of the program. The planning goals for the BDCP are as follows:

- Provide for the conservation and management of covered species within the Plan Area;
- Preserve, restore and enhance aquatic, riparian and associated terrestrial natural communities and ecosystems that support covered species within the Plan Area through conservation partnerships;
- Allow for projects to proceed that restore and protect water supply, water quality, and ecosystem health within a stable regulatory framework;
- Provide a means to implement covered activities in a manner that complies with applicable state and federal fish and wildlife protection laws, including the California Endangered Species Act (CESA) and ESA, and other environmental laws, including the California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA);
- Provide a basis for permits necessary to lawfully take covered species;
- Provide a comprehensive means to coordinate and standardize mitigation and compensation requirements for covered activities within the Plan Area;
- Provide a less costly, more efficient project review process which results in greater conservation values than project-by-project, species-by-species review; and
- Provide clear expectations and regulatory assurances regarding covered activities occurring within the Plan Area.

Throughout the planning process, the Steering Committee worked to develop a plan consistent with these planning goals. The BDCP reflects these goals and provides the basis for conservation and regulatory outcomes identified in the Planning Agreement.

The BDCP process was also guided by a preliminary set of conservation objectives that were first expressed in the Planning Agreement. These preliminary conservation objectives included the following:

- Provide for the protection of covered species and associated natural communities and ecosystems that occur within the Plan Area;
- Preserve the diversity of fish, wildlife, plant and natural communities within the Plan Area;
- Minimize and mitigate, as appropriate, the take of proposed covered species;
- Preserve and restore habitat and contribute to the recovery of covered species;
- Reduce the need to list additional species;
- Set forth species-specific goals and objectives;
- Set forth specific habitat-based goals and objectives;
- Implement an adaptive management and monitoring program to respond to changing ecological conditions; and
- Avoid actions that are likely to jeopardize the continued existence of covered species or result in the destruction or adverse modification of critical habitat.

These planning goals and preliminary conservation objectives set the initial direction for the BDCP planning process. As the planning process progressed, the Steering Committee began to identify specific biological goals and objectives that the BDCP would be expected to meet during its implementation. These specific biological goals and objectives are described in Section 3.3, *Biological Goals and Objectives*, and are set out in a hierarchical framework that distinguishes between ecosystem-level goals and objectives, natural community goals and objectives, and species-specific goals and objectives. The biological goals reflect broad principals while the biological objectives identify more specific targets that the Plan should meet to achieve its overall biological goals. These objectives include measureable metrics or criteria to enable ongoing assessment of the Plan's effectiveness throughout its implementation.

1.3 Regulatory Context

1.3.1 Regulatory Purpose of the BDCP

The BDCP provides the basis for regulatory compliance with ESA and the NCCPA for a range of activities related to the operation of the SWP, CVP, and the Mirant power plants that occur within the Plan Area, including the diversion and export of water from the Delta and its tributaries. The BDCP advances a comprehensive solution to the persistent regulatory challenges that have faced the SWP and CVP. This comprehensive solution includes systemic changes to water conveyance infrastructure and broad-scale restoration and enhancement of ecological resources. This approach is intended to result in long-term regulatory stability for the state and federal water projects, while furthering the goals of water supply reliability and ecological restoration.

The BDCP has been prepared as a joint HCP/NCCP, which will support the issuance of incidental take authorizations from USFWS and NMFS pursuant to Section 10 of the ESA and take authorizations from the California Department of Fish and Game (DFG) under Section 2835 of the NCCPA to the non-federal applicants.[6] The BDCP has also been designed to meet the standards of Section 2081 of the California Endangered Species Act (CESA). The BDCP will further provide the basis for biological assessments (BA) to support the issuance of incidental take authorizations from USFWS and NMFS to Reclamation pursuant to Section 7 of the ESA, for its actions in the Delta.[7]

To meet these regulatory objectives, the BDCP sets out a comprehensive Conservation Strategy that will address the adverse effects of SWP and CVP actions that occur within the Plan Area on aquatic and terrestrial species, including those listed under the ESA or CESA as threatened, endangered, or candidates for listing, as well as on critical habitat, if any, that has been designated for these species pursuant to the ESA (Chapter 3 *Conservation Strategy*). The biological assessment for CVP-related activities in the Delta will adopt the BDCP Conservation Strategy as it relates to those federal actions and will serve as a companion document to the BDCP. It should be noted that the BDCP does not attempt to distinguish precisely between the effects on covered species attributable to the CVP covered activities and those of the SWP. Rather, the BDCP includes a comprehensive analysis of the effects associated with both the SWP and the CVP within the Plan Area and proposes a Conservation Strategy that adequately addresses the totality of those effects. On the basis of the BDCP and the companion biological assessment, USFWS and NMFS are expected to issue Section 10 permits and a new joint biological opinion that supersedes biological opinions existing at that time as they relate to SWP and CVP actions covered by the BDCP.

The BDCP affords an opportunity to move beyond the cycle of litigation that has compelled incremental and disruptive adjustments to the operations of the existing water supply infrastructure and toward a stable regulatory environment. The succession of federal court decisions over the past several years regarding the intersection of the federal and state endangered species acts and the operation of the state and federal water projects did little to settle conflicts over species conservation and water supply needs. Rather, these decisions translated into additional restrictions on water supplies to 25 million Californians in the Bay Area, Central Valley, and Southern California. These water supplies had been previously constrained because of a worsening environmental crisis in the Delta, prior court-ordered pumping restrictions, and state-wide drought conditions. The recent legal proceedings are but part of a history of legal

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[6] 16 U.S.C. § 1539.; California Fish and Game Code (Fish & Game Code) § 2835 *et seq*.

battles that have served to further reinforce the need for comprehensive, legally-defensible regulatory solutions to the environmental and water supply challenges associated with the Delta.

1.3.2 The Federal Endangered Species Act

The United States Congress passed the Endangered Species Act (ESA) in 1973 to provide a means for conserving the ecosystems that endangered and threatened species require in order to prevent species extinctions. The ESA has three major components relevant to the BDCP: the Section 7 requirement that federal agencies ensure, in consultation with the federal fish and wildlife agencies, that their actions are not likely to jeopardize the continued existence of species or result in modification or destruction of critical habitat; the Section 9 prohibition against the "taking" of listed species; and the Section 10 provisions that provide for the permitting of non-federal entities for the incidental take of listed species.

Section 7 of the ESA provides that each federal agency must ensure, in consultation with the Secretary of the Interior or Commerce, that any actions authorized, funded, or carried out by the agency are not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of areas determined to be critical habitat.[8] Section 7 requires federal agencies to engage in formal consultation with USFWS or NMFS for any proposed actions that are likely to adversely affect listed species. A biological opinion is issued by USFWS or NMFS at the completion of formal consultation. The biological opinion can conclude that the project as proposed is either likely or not likely to jeopardize the continued existence of the species. If the biological opinion concludes "no jeopardy," the action can proceed as proposed. If the biological opinion concludes "jeopardy," USFWS or NMFS will identify "reasonable and prudent alternatives" to the proposed action that would avoid jeopardizing the species. Included in the biological opinion is an incidental take statement that authorizes a specified level of take anticipated to result from the proposed action. The incidental take statement contains "reasonable and prudent measures" that are designed to minimize the level of incidental take and that must be implemented as a condition of the take authorization.[9]

Section 9(a)(1)(B) of the ESA prohibits the take by any person of any endangered fish or wildlife species; take of threatened fish or wildlife species is prohibited by regulation. The ESA prohibits the take of any listed threatened fish or wildlife species in violation of any regulation promulgated by the USFWS or NMFS. "Take" is defined broadly to mean harass, harm, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct.[10] "Harm" is defined by regulation to mean an act which actually kills or injures wildlife, including those activities that cause significant habitat modification or degradation resulting in the killing or injuring of wildlife by significantly impairing essential behavior patterns, including breeding,

[8] 16 U.S.C. § 1536(a)(2).

[9] 50 C.F.R. § 402.14(i)(5).

[10] 16 U.S.C. § 1532 (1988).

feeding, or sheltering.[11] The take prohibitions of the ESA apply unless take is otherwise specifically authorized or permitted pursuant to the provisions of Section 7 or Section 10 of the ESA. The protections for listed plant species under the ESA are more limited than for fish and wildlife. [12]

Section 10 of the ESA specifically addresses the authorization for take by non-federal entities through the development of a HCP. For those actions for which no federal nexus exists, private individuals, corporations, state and local government agencies, and other non-federal entities who wish to conduct otherwise lawful activities that may incidentally result in the take a listed species must first obtain a Section 10 incidental take permit from USFWS or NMFS. The non-federal entity is required to develop an HCP as part of the permit application process.

Under Section 10(a)(1)(B) of the ESA, the Services may permit the incidental take of listed species that may occur as a result of an otherwise lawful activity. To obtain a Section 10(a)(1)(B) permit, an applicant must prepare an HCP that meets the following five criteria: (1) the taking will be incidental to an otherwise lawful activity; (2) the applicant will, to the maximum extent practicable, minimize and mitigate the impacts of such taking; (3) the applicant will ensure that adequate funding for the plan will be provided; (4) the taking will not appreciably reduce the likelihood of the survival and recovery of the species in the wild; and (5) other measures, if any, which the Services require as being necessary or appropriate for purposes of the plan will be met. [13]

The BDCP is intended to meet all regulatory requirements necessary for USFWS and NMFS to issue Section 10 permits to allow incidental take of all proposed covered species as a result of covered activities undertaken by the California Department of Water Resources (DWR), certain SWP contractors, and Mirant Corporation, and to issue Section 7 biological opinions to authorize incidental take for covered actions undertaken by Reclamation and CVP contractors. The BDCP assessment of direct and indirect effects (Chapter 5 *Effects Analysis*) on covered species and critical habitat provides the analyses and information necessary for Reclamation, USFWS, and NMFS to meet the analytical requirements of Section 7.

1.3.2.1 Compliance with the Services' Five-Point Policy Guidance

In June 2000, the USFWS and NMFS adopted a five-point policy designed to clarify elements of the habitat conservation planning program as they relate to biological goals, adaptive management,

[11] 50 C.F.R. § 17.3. NMFS has a similar definition that adds the concepts of spawning and migrating to examples of injury. NMFS defines "harm" as "an act which actually kills or injures fish or wildlife. Such an act may include significant habitat modification or degradation which actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including, breeding, spawning, rearing, migrating, feeding or sheltering.' (50 C.F.R § 222.102).

[12] Section 9(a)(2)(B) of the ESA prohibits removal, possession, or malicious damage or destruction of endangered plants in areas under federal jurisdiction, as well as actions that remove, cut, dig up, damage, or destroy endangered plants in areas outside of federal jurisdiction in violation of any state law or regulation, including state criminal trespass law. Protection for threatened plant species is limited to areas under federal jurisdiction. 50 C.F.R. § 17.71(a). The ESA section 7(a)(2) prohibition against jeopardy applies to plants, wildlife, and fish equally, and USFWS and NMFS may not issue a section 10(a)(1)(B) permit if the issuance of that permit would result in jeopardy to any listed species.

[13] 16 U.S.C. § 1539(a)(2)(A).

monitoring, permit duration, and public participation.[14] The five-point policy directs that the following elements be addressed in the development of habitat conservation plans:

Biological Goals and Objectives. HCPs are required to define biological goals and objectives that the plan is intended to achieve. Biological goals and objectives clarify the purpose and direction of the plan's conservation program. The BDCP sets out extensive biological goals and objectives, including specific measurable targets that the Plan is designed to meet. These targets were developed on the basis of the best available scientific information and have been used as parameters and benchmarks to guide the conservation strategies for the species and natural communities covered by the Plan. The biological goals and objectives of the BDCP are described in Section 3.3, *Biological Goals and Objectives*.

Adaptive Management. The five-point policy encourages the inclusion of adaptive management strategies in HCPs in appropriate circumstances to address uncertainty related to species covered by a plan. The agencies describe adaptive management as a "method for examining alternative strategies for meeting measurable biological goals and objectives, and then if necessary, adjusting future conservation management actions according to what is learned."[15] The BDCP incorporates an adaptive management process that is designed to facilitate and improve decision-making during the implementation of the Plan and identify adjustments and modifications, as defined in the Plan, to the conservation strategy as new information becomes available over time. The framework for the BDCP adaptive management program is set out in Section 3.7, *Adaptive Management Program*.

Monitoring. HCPs are required to include provisions for monitoring to gauge the effectiveness of the plan in meeting the biological goals and objectives and to verify that the terms and conditions of the plan are being properly implemented. The biological and compliance monitoring provisions of the BDCP are found in Section 3.6, *Monitoring and Research Program*.

Permit Duration. Consistent with the five-point policy, the USFWS and NMFS consider several factors in determining the term of an incidental take permit. The agencies, for instance, take into account the expected duration of the activities proposed for coverage and the anticipated positive and negative effects on covered species that will likely occur during the course of the plan. The agencies also factor in the level of scientific and commercial data underlying the proposed operating conservation program, the length of time necessary to implement and achieve the benefits of the operating conservation program, and the extent to which the program incorporates adaptive management strategies. The duration of the permits to be issued pursuant to the BDCP is anticipated to be 50 years.

Public Participation. Under the five-point policy, the federal fish and wildlife agencies have sought to increase public participation in the HCP process, including greater opportunity for the public to assess, review, and analyze HCPs and associated NEPA documentation. As part of this

[14] Final Addendum to the Handbook for Habitat Conservation Planning and Incidental Take Permitting, 65 FR 106, June 1, 2000 (hereinafter referred to as the "Five Point Policy")

[15] Five-Point Policy for HCPs, 65 FR 106, June 1, 2000

effort, the agencies have encouraged greater engagement of the public for most HCPs, particularly those with regional scopes. As described in Section 1.5.2, the BDCP process afforded extensive opportunities for public involvement and input throughout the development of the Plan.

1.3.3 Natural Community Conservation Planning Act

The Natural Community Conservation Planning Act (NCCPA) provides a mechanism for compliance with state endangered species regulatory requirements through the development of comprehensive, broad-scale conservation plans that focus on the needs of natural communities and the range of species that inhabit them.[16] The NCCP program has provided the basis for successful collaborations throughout California between state and federal agencies, local governments, community groups, and private interests that have resulted in long-term, habitat-based protections for regional biodiversity and related ecosystems. It has also proved to be an effective tool in achieving these protections while reducing conflicts between conservation goals and the reasonable use of natural resources and lands for economic development. The BDCP adopts the approaches set out in the NCCPA and incorporates those elements necessary to meet regulatory requirements of the Act.

Specifically, the BDCP has been developed in a manner consistent with the process identified in its Planning Agreement, including processes to ensure ample public participation and engagement throughout Plan development and review, extensive input from independent scientists, and coordination with federal fish and wildlife agencies with respect to ESA requirements. Consistent with the requirements of the NCCPA, the Plan further provides a multi-faceted approach to provide for the conservation and management of covered species and their habitats, incorporating a conservation strategy that provides for the protection of habitat, natural communities, and species diversity on an ecosystem level; establishes conservation measures, including measures sufficient to fully mitigate the effects of covered activities; integrates adaptive management strategies that can be modified based on new information developed through monitoring; and sets out a detailed implementation program, including provisions that ensure adequate funding to carry out the Plan.

The BDCP addresses all of the requirements of the NCCPA for aquatic, wetland, and terrestrial covered species of fish, wildlife, and plants and Delta natural communities affected by BDCP actions. On that basis, DFG may issue permits for the taking of the species proposed for coverage under the Plan.[17]

[16] Fish & Game Code § 2800 *et. seq*.

[17] Fish & Game Code § 2835.

1.3.4 California Endangered Species Act

The California Endangered Species Act (CESA) prohibits the take of wildlife or plant species designated as threatened or endangered by the California Fish and Game Commission.[18] "Take" is defined as any action or attempt "to hunt, pursue, catch, capture, or kill."[19] Like the ESA, CESA allows for exceptions to the take prohibitions for otherwise lawful activities. The requirements of an application for incidental take under CESA are described in Section 2081 of the Fish and Game Code. Incidental take of endangered, threatened, or candidate species may be authorized if an applicant demonstrates, among other things, that the impacts of the proposed take will be minimized and fully mitigated.[20]

Although the BDCP has been designed to comply with the NCCPA, and take authorizations are being sought under Section 2835 of the Fish and Game Code, the Plan's provisions have also been developed to be consistent with the regulatory standards of CESA. Specifically, the BDCP Conservation Strategy incorporates measures that adequately minimize and fully mitigate the effects of Covered Activities on state-listed species and includes other such measures as required by CESA. As such, the actions set out in the BDCP are expected to be sufficient to allow for findings to be made by DFG to support the issuance of incidental take authorizations under CESA.

1.3.5 The National Environmental Policy Act

The purpose of NEPA is to ensure that federal agencies consider the environmental impacts of their actions and decisions.[21] NEPA requires that the federal government use all practicable means and measures to protect environmental values and makes environmental protection a part of the mandate of every federal agency and department. To accomplish this goal, NEPA establishes a process and approach to analysis to determine the environmental impacts associated with proposed federal actions that significantly affect the quality of the human environment.

The permitting and implementation of the BDCP involve several federal actions and decisions that are subject to review under NEPA. Reclamation's actions include changes in the operation of the Delta Cross Channel, an expected agreement with DWR to provide for wheeling of CVP water through a new isolated conveyance facility, and the implementation of certain conservation measures through the BDCP Implementation Office. USFWS and NMFS will make decisions regarding the issuance of incidental take permits under Section 10(a)(1)(B) of the ESA. Reclamation, USFWS, and NMFS are joint lead agencies for the preparation of the BDCP Environmental Impact Statement (EIS). The U.S. Army Corps of Engineers (USACE) and the U.S. Environmental Protection Agency (EPA) are participating in the NEPA process as cooperating federal agencies.

[18] Fish & Game Code § 2080.

[19] Fish & Game Code § 86.

[20] Fish & Game Code § 2081(b)(2).

[21] 42 U.S.C. § 4371 *et seq*.

1.3.6 The California Environmental Quality Act

The CEQA serves as a counterpart to NEPA, and applies to all discretionary activities proposed to be carried out or approved by California public agencies. CEQA requires state and local agencies to identify significant environmental impacts of their actions and to take all feasible steps to avoid or mitigate those impacts. CEQA sets forth both procedural and substantive requirements and its procedures are intended to ensure adequate public participation and input into the decision-making process.

The BDCP is a project subject to CEQA, as are numerous BDCP-related actions that will be implemented over the term of the plan.[22] DWR serves as the lead agency for the preparation of the Environmental Impact Report (EIR), which will include analyses of DWR's proposed adoption of the plan, as well as its implementation of certain projects covered by the BDCP. Among the BDCP-related projects that will undergo review are the construction of new conveyance facilities and several identifiable habitat restoration actions, which are all described in the BDCP. DFG is participating in the preparation of the EIR as both a responsible and trustee agency. The EIR will also serve as the CEQA document for the purpose of regulatory permits issued by DFG pursuant to the BDCP.

The state and federal lead agencies will prepare a joint BDCP EIR/EIS to satisfy CEQA and NEPA concurrently.

1.3.7 Relationship with Existing Biological Opinions

The operations of the SWP and the CVP are currently subject to the terms and conditions of biological opinions issued by the USFWS and NMFS pursuant to Section 7 of the federal ESA. The biological opinion to be jointly issued by USFWS and NMFS on the basis of the BDCP and its companion biological assessments will supersede USFWS and NMFS biological opinions that exist at the time of the approval of the BDCP as they relate to the coordinated operation of the CVP and SWP to the extent that the BDCP addresses activities covered by these existing biological opinions.

1.3.8 Recent California Legislation Relating to Water and the Sacramento-San Joaquin Delta

In November 2009, the state of California enacted comprehensive legislation to address the range of challenges facing the Delta, including those involving water supply reliability and ecosystem health. The legislation advances several broad goals of the state with regards to the Delta and specifies a range of actions to be implemented to meet those goals. Among the several goals stated in the legislation is the following:

[22] California Public Resources Code (CPRC) section 21000 *et seq*. and CEQA Guidelines 14 CCR 15000 *et seq*.

> *Achieve the two co-equal goals of providing for a more reliable water supply for the California and protecting, restoring, and enhancing the Delta ecosystem. The co-equal goals shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place.*[23]

The codification of these co-equal goals has served to reinforce the nearly-identical BDCP planning goals adopted by the Steering Committee and used throughout the planning process to help guide the development of the Plan.

The Delta legislation includes the Sacramento-San Joaquin Delta Reform Act of 2009,[24] which provides for the establishment of an independent state agency, the Delta Stewardship Council, to further the co-equal goals of ecosystem restoration and a reliable water supply. The Council, which became operational on February 3, 2010, is charged with the development and implementation of a comprehensive management plan for the Delta (Delta Plan), and is vested with the authority to review actions of state and local agencies and advise on their consistency with the Delta Plan.

The Council is also required to consider the inclusion of the BDCP in the Delta Plan. The Delta Reform Act sets out the conditions under which the Council is to incorporate the BDCP into the Delta Plan. To be considered for inclusion in the Delta Plan, the BDCP must comply with the requirements of the NCCPA and CEQA, which includes a review and analysis of various specified alternatives to the proposed Plan. Upon approval of the BDCP as an NCCP and as an HCP under the ESA, the Council is required to incorporate the BDCP into the Delta Plan. However, the determination by DFG that the BDCP meets the requirements of the NCCPA may be appealed to the Council.

1.3.9 Relationship between the BDCP and Other Federal and State Laws and Regulations

The BDCP has been developed as a conservation plan that complies with state and federal endangered species laws. However, the Plan or the actions described herein will need to conform to the requirements of various other state and federal laws and regulations not specifically addressed by the Plan. Prior to the implementation of many of the conservation actions set out in the BDCP, regulatory authorizations and approvals will need to be obtained from state and federal under applicable laws. Such authorizations will likely involve some or all of the following statutes: California Water Code sections 1000 *et seq*. (water rights), Water Code sections 13000 *et seq*. (water quality), California Fish and Game Code sections 1600 *et seq*. and 5900 *et seq*. (channel modification, fish screens), Clean Water Act Section 404 (placement of dredge and fill), Rivers and Harbors Act Section 408 (work on levees), Rivers and Harbors Act Section 10 (navigation), and the Migratory Bird Treaty Act (migratory birds).

[23] SBX 7 1.

[24] Division 35, California Water Code.

1.3.9.1 Section 404 of the Clean Water Act

In 1972, Congress passed the Federal Water Pollution Control Act, commonly known as the Clean Water Act (CWA), with the goal of “restor[ing] and maintain[ing] the chemical, physical, and biological integrity of the Nation’s waters.”[25] In furtherance of this goal, the CWA prohibits the discharge of any pollutants into navigable waters, except as allowed by permit issued under certain sections of the CWA.[26] Specifically, Section 404 authorizes USACE to issue permits for and regulate the discharge of dredged or fill materials into wetlands or other “waters of the United States.” Under the CWA and its implementing regulations, “waters of the United States” are broadly defined to consist of rivers, creeks, streams, and lakes extending to their headwaters, including adjacent wetlands.[27]

Responsibility for the implementation of Section 404 of the CWA is shared by the U.S. EPA and USACE. EPA is generally responsible for establishing policy and guidance regarding the implementation of the program. For instance, EPA developed the guidelines that are used to evaluate the sufficiency of Section 404 permit applications, and has played the lead role in determining the scope of the federal government’s jurisdiction over aquatic resources, including the reach of the term “waters of the United States.” EPA also determines the eligibility of a state to assume responsibility for portions of the Section 404 program.[28] On the other hand, USACE is responsible for the day-to-day administration of the Section 404 permit program.
Many of the actions that will be implemented under the BDCP will result in the discharge of dredged or fill materials into “waters of the U.S.” and will need to be authorized by USACE. These BDCP actions will receive such authorizations through both General Permits and Individual Permits. Typically, General Permits apply to specific classes of activities that have been determined to cause no more than minimal impact to the aquatic environment (e.g., construction of road crossings, installation of utility lines, and operations and maintenance activities).[29] Individual Permits are designed for activities that have the potential to have more than a minimal effect on jurisdictional waters or that otherwise do not qualify under the conditions of a General Permit. Substantively, USACE must evaluate applications for Individual Permits to determine their consistency with the requirements of the Section 404(b)(1) Guidelines[30] and USACE’ regulations.[31]

[25] 33 U.S.C. § 1251(a).

[26] *See* 33 U.S.C. §§ 1311, 1342, and 1344.

[27] 33 C.F.R. § 328.3(a)(3).

[28] The 1977 amendments to the CWA provided that States can assume the federal 404 program provided that the State has a “comparable” program. State program assumption of 404 is only available for non-navigable waters so that even in States where the program has been assumed, the federal government retains control over activities in navigable waters. Only two States, Michigan and New Jersey, have assumed the 404 program to date. In States with assumed 404 programs, the State authorization is the only one required.

[29] 33 C.F.R. § 325.5(c).

[30] 40 C.F.R. Part 230.

[31] 33 C.F.R. Part 325.

1.3.9.2 Section 401 of the Clean Water Act

Pursuant to Section 401, states can certify or deny federal permits or licenses that might result in a discharge to state waters, including wetlands.[32] Section 404 permit applicants must obtain a "water quality certification" from the state water quality agency indicating that the proposed activity complies with all applicable state water quality standards, limitations, and restrictions. In California, the Regional Water Quality Control Boards (RWQCB) issue water quality certifications within their jurisdictions. Appeals to the decisions of the RWQCBs are heard by the SWRCB.

1.3.9.3 Section 10 of the Rivers and Harbors Act

Certain BDCP actions will require authorizations under Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. 403) which requires authorization from the Secretary of the Army for the construction of any structure in or over any navigable water of the United States or the construction of structures or alteration of capacity in any port, canal, navigable river, or other water of the United States.[33] "Navigable waters" under Section 10 of the Rivers and Harbors Act are defined as "those waters of the United States that are subject to the ebb and flow of the tide shoreward to the mean high water mark and/or are presently used, or have been used in the past, or may be susceptible to use to transport interstate or foreign commerce."[34]

1.3.9.4 Section 14 of the Rivers and Harbors Act ("Section 408")

Section 14 of the Rivers and Harbors Act of 1899 (33 U.S.C. 408; commonly referred to as "Section 408") provides protection for federal projects in waterways such as sea walls, dikes, levees, and piers from being moved, altered, or destroyed, in a manner that impairs the usefulness of the structure. Under Section 408, the Chief of Engineers may grant permission to alter an existing federal project if it is not injurious to the public interest and does not impair the usefulness of the project. Certain BDCP actions, such as those that affect federal project levees and weirs, will require authorizations under Section 408.

1.3.9.5 California Fish and Game Code Section 1600 et seq.

California has adopted regulations to address impacts to many of the resources subject to Section 404 of the CWA. Although not entirely overlapping, these programs intersect frequently. Project proponents are required to obtain separate authorizations from USACE and DFG.

Section 1602 of the California Fish and Game Code requires any person, state or local governmental agency to provide advance written notification to DFG prior to initiating any activity that would: (1) divert or obstruct the natural flow of, or substantially change or remove material from the bed, channel, or bank of any river, stream, or lake; (2) result in the disposal or

[32] 33 U.S.C. § 1341.

[33] 33 C.F.R. § 401 *et seq*.

[34] 33 C.F.R. § 329.4

deposition of debris, waste, or other material into any river, stream, or lake.[35] The State definition of "lake, rivers, and streams" includes all rivers or streams that flow at least periodically or permanently through a bed or channel with banks that support fish or other aquatic life, and watercourses with surface or subsurface flows that support or have supported riparian vegetation.[36]

Certain actions that will be implemented under the BDCP will require Streambed Alteration Agreements under Section 1602. As part of that process, DFG will review notifications submitted by the BDCP Implementation Office to determine if the proposed project would impact existing fish and wildlife resources that are directly dependent on a lake, river, or stream. If DFG determines that the proposed activity will not substantially adversely affect an existing fish and wildlife resource, it will notify the Implementation Office that no Streambed Alteration Agreement is required and the project may proceed.[37] If DFG determines that the project may substantially adversely affect an existing fish and wildlife resource, it will require, as part of a Streambed Alteration Agreement, reasonable measures necessary to protect the fish and wildlife resource.[38]

1.3.9.6 Migratory Bird Treaty Act

The Migratory Bird Treaty Act (MBTA) of 1918 implements four international treaties for the conservation and management of bird species that may migrate through more than one country.[39] The MBTA makes it unlawful to take, possess, buy, sell, purchase, or barter any migratory bird listed in 50 Code of Federal Regulations (CFR) Part 10, including feathers or other parts, nests, eggs, or products, except as allowed by implementing regulations.[40] For federally listed migratory bird species covered under the BDCP for which an ESA Section 10(a) permit has been issued, the Implementation Office may also obtain an MBTA permit for those species.

1.3.9.7 Water Rights under the California Water Code

The California Water Code[41] prescribes detailed procedures that govern the appropriation of water from a lake, river, stream, or creek. After the enactment of the State Water Commission Act in 1914, the state required any person or agency seeking to use surface water, without an existing riparian right, to apply for and receive approval for such use from the State Water Resources Control Board (SWRCB). Water rights permits granted by the SWRCB include detailed descriptions of the amounts, conditions, and construction timetables under which the proposed water project must comply. Prior to permit issuance, the SWRCB must take into account all prior rights and the availability of water in the basin. The Board must also consider

[35] Fish & Game Code § 1602.

[36] 14 C.C.R. § 1.72.

[37] Fish & Game Code § 1602(a)(4)(A)(i).

[38] Fish & Game Code § 1603(a).

[39] 16 U.S.C. § 703 *et seq*.

[40] 50 C.F.R. § 21.

[41] Division 2, Wat. Code section 1000 *et seq*.

the flows needed to preserve instream uses such as recreation and fish and wildlife habitat. The Board may impose additional conditions to ensure that these criteria are satisfied and it may use its continuing authority to enforce and revise the conditions of water right permits over time. The SWRCB is also empowered to revoke a permit or issue cease and desist orders if conditions of the permit are not being met.

At any time after receiving a water right permit, a permittee may seek permission from the SWRCB to change the point of diversion, place of use, or purpose of use from that specified in the permit. The proposed change cannot involve a new right or cause injury to any other legal user of water. The implementation of the BDCP will require a change in points of diversion specified in the DWR and Reclamation water right permits. As such, DWR and Reclamation will need to petition the SWRCB to change the point of diversion. Prior to approving these petitions, the SWRCB must find that the change will not cause injury to any legal user of the water involved or result in harm fish or wildlife. Other right holders and the public will have an opportunity to object to the proposed change by filing a protest form with the SWRCB. If a protest is filed, the Board must hold a hearing on the petition and will either grant or refuse permission to make the change, as the facts may warrant. Because the SWRCB has discretion to approve the requested petition, it must comply with the California Environmental Quality Act.

1.3.9.8 Porter-Cologne Water Quality Control Act

The Porter-Cologne Water Quality Control Act (Porter-Cologne)[42] sets out a comprehensive regulatory, planning, and management program to protect water quality and beneficial uses of the state's water. The Act established the State Water Resources Control Board's authority to preserve and enhance the quality of California's water resources, and to ensure proper allocation and efficient use of water.

Under Porter-Cologne, the SWRCB is required to prepare a Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan). While the Regional Water Boards have primary responsibility for formulating and adopting water quality control plans for their respective regions, the SWRCB also is authorized to develop and adopt water quality control plans. In such instances, the water quality control plan adopted by the SWRCB supersedes regional plans developed for the same waters, to the extent they conflict.

The Bay-Delta Plan consists of three primary components: (1) the beneficial uses (of water) to be protected; (2) the water quality objectives for the estuary; and (3) the implementation programs to meet the water quality objectives. Beneficial uses include uses such as domestic, agricultural and industrial supply; power generation; recreation and aesthetic use; navigation; and preservation and enhancement of fish, aquatic, and wildlife resources. Water quality objectives or standards reflect the levels of water quality constituents that have been determined to be necessary to protect beneficial uses. Implementation plans describe actions to be taken to achieve the objectives and set out programs for monitoring, management, and enforcement.

42 Water Code § 13000 *et seq*.

The SWRCB is vested with primary regulatory authority over flows, water quality, and other water rights issues in the Bay-Delta. As such, many of the actions described in the BDCP, including modifications to the water conveyance system, will require the approval of the SWRCB. The SWRCB's participation in the development of the BDCP and in the environmental review process is intended to ensure consistency between the actions described in the BDCP and those required by the SWRCB as part of its water quality control planning and implementation activities.

1.4 SCOPE OF THE BDCP

This section describes the geographic scope of the BDCP, the types of activities that the Plan covers, and the duration sought for regulatory permits that are issued by the Fish and Wildlife agencies pursuant to the Plan.

1.4.1 Geographic Scope of the Plan Area

The geographic scope of the Plan Area encompasses the Sacramento-San Joaquin Delta and additional areas in which conservation measures may be implemented pursuant to the Plan. Take authorizations issued under the BDCP will extend to covered activities that occur within the Plan Area.

The BDCP Conservation Strategy is primarily focused on the statutory Delta, as defined in California Water Code Section 12220. However, certain areas outside the statutory Delta contain desirable locations for conservation actions that advance the goals and objectives of the Plan (Figure 1-1).[43] Areas such as Suisun Marsh, Suisun Bay, and upstream areas of the upper Yolo Bypass and the area that encompasses the Fremont Weir, for instance, provide important sites for habitat restoration to support goals and objectives for natural communities and covered species (Figure 1-1). In addition, the Conservation Strategy includes measures that will be implemented outside of the statutory Delta to support or complement regional conservation planning efforts underway in Yolo, Solano, Contra Costa, San Joaquin, and Sacramento counties. As such, the geographic scope of the Plan Area will also encompass habitat lands that are conserved through BDCP actions taken in conjunction with these other regional conservation programs. To the extent appropriate, these conservation actions will be implemented through cooperative agreements, or similar mechanisms, between the BDCP Implementation Office and local agencies, interested non-governmental organizations, landowners, or other parties.

To accommodate the range of conservation measures necessary to meet the goals and objectives of the BDCP, the scope of the Plan Area may be expanded during the implementation of the Plan. The flexibility to expand the boundaries of the Plan during plan implementation will allow for greater opportunity to maximize conservation benefits associated with the measures set out in

[43] The BDCP Planning Agreement, recognized the likelihood that the BDCP Conservation Strategy would include actions that would be implemented outside of the Statutory Delta to further advance the goals and objectives of the plan

the Conservation Strategy. Adjustments to the Plan Area, however, would occur only under certain defined circumstances and within identified areas, as set out in the Conservation Strategy.

Because the SWP and CVP water infrastructure is operated as an integrated system, the effects of implementing the BDCP will extend beyond the Delta, both upstream and downstream, and will implicate water operational parameters as well as species and their habitats. Therefore, the BDCP effects analysis (Chapter 5 *Effects Analysis*) takes into account these upstream and downstream effects, both positive and negative, to ensure that the overall effects of the BDCP are sufficiently described, analyzed and addressed. Areas potentially affected by the implementation of the BDCP located outside of the geographic scope of the plan, have been included in the analysis of effects to ensure that all of the potential effects within the "action area," as defined by Section 7 of the ESA, have been adequately assessed.

1.4.2 Natural Communities

Natural communities are distinct and reoccurring assemblages of plants and animals associated with specific physical environmental conditions and ecological processes. A natural community occurs across a landscape where similar ecological conditions exist. The Wildlife and Natural Areas Conservation Act defines natural community as "a distinct, identifiable, and recurring association of plants and animals that are ecological interrelated" (California Fish and Game Code subsection 2702[d]). Individual species occur within the context of natural communities and it is within these communities that species interact with other species and the physical environment. The NCCPA states that the purpose of natural community conservation planning is "to sustain and restore those species and their habitat …that are necessary to maintain the continued viability of those biological communities impacted by human changes to the landscape." [44]

To adequately address the natural communities in the Delta that support covered species and native biodiversity, the BDCP includes measures that sustain and enhance ecological processes and provide for the protection and restoration of a broad range of natural communities. Conservation measures have been designed to improve ecological functions and restore species habitat in the following natural communities:

- Tidal Perennial Aquatic;
- Tidal Mudflat;
- Tidal Brackish Emergent Wetland;
- Tidal Freshwater Emergent Wetland;
- Valley/Foothill Riparian;
- Nontidal Perennial Aquatic;
- Nontidal Freshwater Perennial Emergent Wetland;

[44] Fish & Game Code § 2801(h)(i).

- Alkali Seasonal Wetland Complex;
- Vernal Pool Complex;
- Other Natural Seasonal Wetland;
- Managed Wetland;
- Grassland; and
- Inland Dune Scrub.

Although not considered a natural community, cultivated croplands are nonetheless taken into account in the BDCP Conservation Strategy because, in certain instances, they provide value as habitat for covered species. Cultivated croplands addressed by the BDCP have been divided into subtypes, each of which provide varying benefits to different covered species or groups of covered species. These cultivated cropland subtypes are as follows:

- Alfalfa;
- Irrigated Pasture;
- Rice;
- Other cultivated crops;
- Orchards; and
- Vineyards.

Collectively, the covered natural communities encompass the habitat used by covered species within the Plan Area.

1.4.3 Covered Species

The ESA and the NCCPA set forth specific criteria that must be satisfied to support the issuance of regulatory authorizations that provide for the incidental take of species. The term “covered species” refers to those species for which incidental take authorizations may be issued under the BDCP pursuant to state and federal endangered species laws. The proposed BDCP covered species are identified in Table 1-2.

The BDCP seeks regulatory coverage for those species that will potentially be adversely affected by those activities covered by the Plan. As such, the list of species proposed for coverage is limited to those species currently protected under state or federal wildlife laws, and those species that are likely to receive the protection of those laws in the future. The list of covered species is not intended to include all species that occur within the Plan Area or all species and habitats that will directly or indirectly benefit from implementation of the BDCP. Rather, the covered species list reflects the range of species for which regulatory authorizations are needed under state and/or federal law for any take associated with the activities covered by the BDCP. Species not covered under the BDCP will benefit from the measures that provide for the conservation of natural communities that encompass both common and rare species.

1.4.3.1 Species Evaluated for Coverage

The species evaluated for potential coverage under the BDCP include a broad range of fish and wildlife species that are likely to occur within the geographic scope of the Plan and are currently considered to be rare, sensitive, threatened or imperiled, or likely to be so in the future (Appendix C, *Evaluation of Species Considered for Coverage*). Many of the species on the list have been granted protected or special status, including those that have been listed under the state and/or federal endangered species acts or other laws or regulations. This list further included species that have been recognized by the scientific community as warranting concern due to their rarity or ecological importance. Among the species included on the list are those with the following special status:

- Listed as threatened or endangered under the ESA;
- Proposed or candidates for listing under ESA;
- Listed as threatened or endangered under CESA;
- Candidates for listing under CESA;
- California species of special concern identified by DFG;
- California fully protected species under California Fish & Game Code sections 3511 (birds), 4700 (mammals), 5050 (reptiles and amphibians), and 5515 (fish);
- USFWS birds of conservation concern;
- NMFS species of concern;
- Plants listed as rare under the California Native Plant Protection Act (NPPA); or
- Plants included in the California Native Plant Society (CNPS) List 1A, 1B, or 2.

1.4.3.2 Evaluation and Selection Criteria

The evaluation process relied primarily on four criteria to determine which special-status species would be included on the list of species proposed for coverage under the BDCP. The selection criteria, which are discussed in detail in Appendix C, *Evaluation of Species Considered for Coverage*, are as follows:

- Listing status of the species.
- Likelihood that the species is present in the Plan Area or other areas within the geographic scope.
- Potential for the species to be adversely affected by BDCP covered activities, including the implementation of conservation measures.

- Level of information available to determine potential impacts to species and to identify effective conservation measures.

Those species that met all four of these criteria are proposed for coverage under the BDCP (Table 1-2). The results of the evaluations conducted for each species are set out in Appendix C, *Evaluation of Species Considered for Coverage*.

Table 1-2. BDCP Proposed Covered Species and Associated Habitats

[***Note to reviewers:*** *This table provides the current list of proposed covered species. Additional species may be added and some of the species presented here may be removed from the covered species list as per continuing development of the BDCP.]*

No.	***Common Name/ Scientific Name***	***Status (Federal/ State/CNPS)***[1]	***Natural Communities Supporting Species Habitat***
Fish (11 species)			
1	Central Valley steelhead *Oncorhynchus mykiss* DPS	T/-/- DPS Critical Habitat, Recovery Plan[11]	Tidal perennial aquatic, tidal mudflat, tidal brackish emergent wetland, tidal freshwater emergent wetland
2	Sacramento River winter-run Chinook salmon *Oncorhynchus tshawytscha* Evolutionarily Significant Unit (ESU)	E/E/- ESU Critical Habitat, Recovery Plan[11, 12]	Tidal perennial aquatic, tidal mudflat, tidal brackish emergent wetland, tidal freshwater emergent wetland
3	Central Valley spring-run Chinook salmon *Oncorhynchus tshawytscha* ESU	T/T/- ESU Critical Habitat, Recovery Plan[11, 13]	Tidal perennial aquatic, tidal mudflat, tidal brackish emergent wetland, tidal freshwater emergent wetland
4	Central Valley fall- and late fall-run Chinook salmon *Oncorhynchus tshawytscha*	-/SSC/- Recovery Plan[13]	Tidal perennial aquatic, tidal mudflat, tidal brackish emergent wetland, tidal freshwater emergent wetland
5	Delta smelt *Hypomesus transpacificus*	T/T/- Critical Habitat, Recovery Plan[13]	Tidal perennial aquatic, tidal mudflat, tidal brackish emergent wetland, tidal freshwater emergent wetland
6	Longfin smelt *Spirinchus thaleichthys*	-/T/- Recovery Plan[13]	Tidal perennial aquatic, tidal mudflat, tidal brackish emergent wetland, tidal freshwater emergent wetland
7	Sacramento splittail *Pogonichthys macrolepidotus*	-/SSC/- Recovery Plan[13]	Tidal perennial aquatic, tidal mudflat, tidal brackish emergent wetland, tidal freshwater emergent wetland
8	White sturgeon *Acipenser transmontanus*	-/-/-	Tidal perennial aquatic, tidal mudflat, tidal brackish emergent wetland, tidal freshwater emergent wetland
9	North American green sturgeon *Acipenser medirostris* Southern DPS	T/SSC/- Southern DPS *Proposed* Critical Habitat, Recovery Plan[13]	Tidal perennial aquatic, tidal mudflat, tidal brackish emergent wetland, tidal freshwater emergent wetland
10	Pacific lamprey *Entosphenus tridentatus*	-/-/-	Tidal perennial aquatic, tidal mudflat, tidal brackish emergent wetland, tidal freshwater emergent wetland

Table 1-2. BDCP Proposed Covered Species and Associated Habitats (continued)

No.	Common Name/ Scientific Name	Status (Federal/ State/CNPS)[1]	Natural Communities Supporting Species Habitat
11	River lamprey *Lampetra ayresii*	-/-/-	Tidal perennial aquatic, tidal mudflat, tidal brackish emergent wetland, tidal freshwater emergent wetland
Mammals (6 species)			
12	San Joaquin kit fox *Vulpes macrotis mutica*	E/T/- Recovery Plan[2]	Grassland, agricultural habitats
13	Riparian woodrat *Neotoma fuscipes riparia*	E/SSC/- Recovery Plan[2]	Valley/foothill riparian
14	Salt marsh harvest mouse *Reithrodontomys raviventris*	E/E,FP/- Recovery Plan[3, 4]	Tidal brackish emergent wetland, managed wetland, grassland
15	Riparian brush rabbit *Sylvilagus bachmani riparius*	E/E/- Recovery Plan[2]	Valley/foothill riparian
16	Townsend's big-eared bat *Corynorhinus townsendii*	-/SSC/-	All natural communities
17	Suisun shrew *Sorex ornatus sinuosus*	-/SSC/- Recovery Plan[3]	Tidal brackish emergent wetland, managed wetland
Birds (12 species)			
18	Tricolored blackbird *Agelaius tricolor*	-/SSC/-	Tidal brackish emergent wetland, tidal freshwater emergent wetland, valley/foothill riparian, alkali seasonal wetland complex, managed wetland, other natural seasonal wetland, grassland, agricultural habitats
19	Suisun song sparrow *Melospiza melodia maxillaris*	-/SSC/- Recovery Plan[4]	Tidal brackish emergent wetland, tidal freshwater emergent wetland, managed wetland
20	Yellow-breasted chat *Icteria virens*	-/SSC/-	Valley/foothill riparian
21	Least Bell's vireo *Vireo bellii pusillus*	E/E/- Recovery Plan[5]	Valley/foothill riparian
22	Western burrowing owl *Athene cunicularia hypugaea*	-/SSC/-	Grassland, alkali seasonal wetland complex, vernal pool complex, managed wetland, other natural seasonal wetland, agricultural habitats
23	Western yellow-billed cuckoo *Coccyzus americanus occidentalis*	C/E/-	Valley/foothill riparian
24	California least tern *Sternula antillarum browni*	E/E/- Recovery Plan[6]	Tidal perennial aquatic
25	Greater sandhill crane *Grus canadensis tabida*	-/T,FP/-	Agricultural habitats, alkali seasonal wetland complex, vernal pool complex, managed wetland, other natural seasonal wetland, grassland
26	California black rail *Laterallus jamaicensis coturniculus*	-/T,FP/- Recovery Plan[4]	Tidal brackish emergent wetland, tidal freshwater emergent wetland, nontidal freshwater perennial emergent wetland
27	California clapper rail *Rallus longirostris obsoletus*	E/E,FP/- Recovery Plan3, 4	Tidal brackish emergent wetland

Table 1-2. BDCP Proposed Covered Species and Associated Habitats (continued)

No.	*Common Name/ Scientific Name*	*Status (Federal/ State/CNPS)*[1]	*Natural Communities Supporting Species Habitat*
28	Swainson's hawk *Buteo swainsoni*	-/T/-	Valley/foothill riparian, agricultural habitats, grassland, alkali seasonal wetland complex, vernal pool complex, managed wetland, other natural seasonal wetland
29	White-tailed kite *Elanus leucurus*	-/FP/-	Valley/foothill riparian, agricultural habitats, grassland, alkali seasonal wetland complex, vernal pool complex, managed wetland, other natural seasonal wetland
Reptiles (2 species)			
30	Giant garter snake *Thamnophis gigas*	T/T/- Recovery Plan[6]	Tidal perennial aquatic, tidal freshwater emergent wetland, nontidal perennial aquatic, nontidal freshwater perennial emergent wetland, alkali seasonal wetland complex, vernal pool complex, managed wetland, other natural seasonal wetland, grassland, agricultural habitats
31	Western pond turtle *Actinemys* (formerly *Clemmys* and *Emys*) *marmorata*	-/SSC/-	Tidal perennial aquatic, tidal freshwater emergent wetland, tidal brackish emergent wetland, nontidal perennial aquatic, nontidal freshwater perennial emergent wetland, valley/foothill riparian, alkali seasonal wetland complex, vernal pool complex, managed wetland, other natural seasonal wetland, grassland, agricultural habitats
Amphibians (3 species)			
32	California red-legged frog *Rana draytonii*	T/SSC/- Critical Habitat, Recovery Plan[8]	Valley/foothill riparian, nontidal freshwater perennial emergent wetland, tidal freshwater emergent wetland, nontidal perennial aquatic, managed wetland, grassland, alkali seasonal wetland complex, vernal pool complex, other natural seasonal wetland, agricultural habitats
33	Western spadefoot toad *Spea hammondii*	-/SSC/- Recovery Plan[9]	Grassland, alkali seasonal wetland complex, vernal pool complex, other natural seasonal wetland, nontidal perennial aquatic
34	California tiger salamander *Ambystoma californiense* Central Valley Distinct Population Segment (DPS)	T/T/- Central Valley DPS Critical Habitat	Vernal pool complex, alkali seasonal wetland complex, other natural seasonal wetland, grassland
Invertebrates (8 species)			
35	Lange's metalmark butterfly *Apodemia mormo langei*	E/-/- Recovery Plan[15]	Inland dune scrub
36	Valley elderberry longhorn beetle *Desmocerus californicus dimorphus*	T/-/- Recovery Plan[14]	Valley/foothill riparian, grassland
37	Vernal pool tadpole shrimp *Lepidurus packardi*	E/-/- Critical Habitat Recovery Plan[9]	Vernal pool complex

Table 1-2. BDCP Proposed Covered Species and Associated Habitats (continued)

No.	Common Name/ Scientific Name	Status (Federal/ State/CNPS)[1]	Natural Communities Supporting Species Habitat
38	Conservancy fairy shrimp *Branchinecta conservatio*	E/-/- Critical Habitat Recovery Plan[9]	Vernal pool complex
39	Longhorn fairy shrimp *Branchinecta longiantenna*	E/-/- Recovery Plan[9]	Vernal pool complex
40	Vernal pool fairy shrimp *Branchinecta lynchi*	T/-/- Critical Habitat Recovery Plan[9]	Vernal pool complex
41	Midvalley fairy shrimp *Branchinecta mesovallensis*	-/-/- Recovery Plan[9]	Vernal pool complex
42	California linderiella *Linderiella occidentalis*	-/-/- Recovery Plan[9]	Vernal pool complex
Plants (21 species)			
43	Alkali milk-vetch *Astragalus tener* var. *tener*	-/-/1B Recovery Plan[9]	Vernal pool complex
44	Heartscale *Atriplex cordulata*	-/-/1B	Alkali seasonal wetland complex, vernal pool complex, grassland
45	Brittlescale *Atriplex depressa*	-/-/1B	Alkali seasonal wetland complex, vernal pool complex, grassland
46	San Joaquin spearscale *Atriplex joaquiniana*	-/-/1B	Alkali seasonal wetland complex, vernal pool complex, grassland
47	Slough thistle *Cirsium crassicaule*	-/-/1B	Valley/foothill riparian
48	Suisun thistle *Cirsium hydrophilum var. hydrophilum*	E/-/1B Critical Habitat Recovery Plan[4]	Tidal brackish emergent wetland
49	Soft bird's-beak *Cordylanthus mollis ssp. mollis*	E/R/IB Critical Habitat Recovery Plan[4]	Tidal brackish emergent wetland
50	Dwarf downingia *Downingia pusilla*	-/-/2	Vernal pool complex
51	Delta button-celery *Eryngium racemosum*	-/E/1B	Alkali seasonal wetland complex, vernal pool complex, valley/foothill riparian, grassland
52	Contra Costa wallflower *Erysimum capitatum var. angustatum*	E/E/1B Critical Habitat Recovery Plan[15]	Inland dune scrub
53	Boggs Lake hedge-hyssop *Gratiola heterosepala*	-/E/1B Recovery Plan[9]	Vernal pool complex
54	Carquinez goldenbush *Isocoma arguta*	-/-/1B	Alkali seasonal wetland complex, grassland
55	Delta tule pea *Lathyrus jepsonii var. jepsonii*	-/-/1B Recovery Plan[4]	Tidal brackish emergent wetland, tidal freshwater emergent wetland, valley/foothill riparian
56	Legenere *Legenere limosa*	-/-/1B Recovery Plan[9]	Vernal pool complex
57	Heckard's peppergrass *Lepidium latipes var. heckardii*	-/-/1B	Vernal pool complex
58	Mason's lilaeopsis *Lilaeopsis masonii*	-/R/1B	Tidal mudflats, tidal brackish emergent wetland, tidal freshwater emergent wetland, valley/foothill riparian
59	Delta mudwort *Limosella subulata*	-/-/2	Tidal mudflats, tidal brackish emergent wetland, tidal freshwater emergent wetland, valley/foothill riparian

Table 1-2. BDCP Proposed Covered Species and Associated Habitats (continued)

No.	Common Name/ Scientific Name	Status (Federal/ State/CNPS)[1]	Natural Communities Supporting Species Habitat
60	Antioch Dunes evening-primrose *Oenothera deltoides ssp. howellii*	E/E/1B Critical Habitat Recovery Plan[15]	Inland dune scrub
61	Side-flowering skullcap *Scutellaria lateriflora*	-/-/2	Valley/foothill riparian
62	Suisun Marsh aster *Symphyotrichum* (formerly *Aster lentus) lentum*	-/-/1B	Tidal brackish emergent wetland, tidal freshwater emergent wetland, valley/foothill riparian
63	Caper-fruited tropidocarpum *Tropidocarpum capparideum*	-/-/1B	Grassland

[1]Status:
Federal
E = Listed as endangered under ESA
T = Listed as threatened under ESA
C = Candidate for listing under ESA

State
E = Listed as endangered under CESA
T = Listed as threatened under CESA
R = Listed as rare under the California Native Plant Protection Act
SSC = California species of special concern
FP = Fully protected under the California Fish and Game Code

California Native Plant Society (CNPS)
1B = rare or endangered in California and elsewhere
2 = rare and endangered in California, more common elsewhere

[2]U.S. Fish and Wildlife Service. 1998. Recovery plan for upland species of the San Joaquin Valley, California. Region 1, Portland, OR. 319 pp.

[3]U.S. Fish and Wildlife Service. 1984. Salt marsh harvest mouse and California clapper rail recovery plan. Portland, OR.

[4]U.S. Fish and Wildlife Service. 2009. Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California. Sacramento, California. xviii+636 pp.

[5]U.S. Fish and Wildlife Service. 1998. Draft recovery plan for the least Bell's vireo. U.S. Fish and Wildlife Service, Portland, OR. 139 pp.

[6]U.S. Fish and Wildlife Service. 1985. Recovery plan for the California least tern, Sterna antillarum browni. U.S. Fish and Wildlife Service, Portland, OR. 112 pp.

[7]U.S. Fish and Wildlife Service. 1999. Draft Recovery Plan for the Giant Garter Snake (Thamnopsis gigas). U.S. Fish and Wildlife Service, Portland, Pregon. ix+192 pp.

[8]U.S. Fish and Wildlife Service. 2002. Recovery Plan for the California Red-legged Frog (Rana aurora draytonii). U.S. fish and Wildlife Service, Portland, Oregon. viii+173 pp.

[9]U.S. Fish and Wildlife Service. 2005. Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon. Portland, Oregon. xxvi + 606 pages.

[10]California Tiger Salamander distinct population segments are federally listed as endangered in Sonoma and Santa Barbara counties.

[11]National Marine Fisheries Service. 2009. Public Draft Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of Central Valley Steelhead. Sacramento Protected Resources Division. October 2009.

[12]National Marine Fisheries Service. 1997. NMFS Proposed Recovery Plan for the Sacramento River winter-run Chinook Salmon. NMFS Southwest Region. Long Beach, CA.

[13]U.S. Fish and Wildlife Service. 1995. Sacramento-San Joaquin Delta Native Fishes Recovery Plan. U.S. Fish and Wildlife Service, Portland, Oregon.

[14]U.S. Fish and Wildlife Service. 1984. Valley elderberry longhorn beetle Recovery Plan. U.S. Fish and Wildlife Service, Portland, Oregon. 62 pp.

[15]U.S. Fish and Wildlife Service. 1984. Revised recovery plan for three endangered species endemic to Antioch Dunes, California.

[16]U.S. Fish and Wildlife Service, Portland, Oregon

1.4.4 Covered Activities and Associated Federal Actions

The BDCP is intended to provide the basis for the issuance of regulatory authorizations under the ESA and the NCCPA for a broad range of ongoing and anticipated activities in the Plan Area that are associated with the operations of the SWP and the CVP, as well as for actions related to the operation of Mirant power plants. Covered Activities and Associated Federal Actions encompass all actions that are proposed for coverage under take authorizations that are expected to be issued by the state and/or federal Fish and Wildlife Agencies on the basis of the BDCP.

These actions have been designated as either "Covered Activities," which encompass those actions that will be undertaken by non-federal parties, or "Associated Federal Actions," which refer to those actions that are authorized, funded, or carried out by Reclamation. The BDCP Covered Activities and Associated Federal Actions are described in Chapter 4, *Description of Covered Activities and Associated Federal Actions*.

1.4.4.1 Covered Activities

The BDCP Covered Activities consist primarily of activities related to the development and operation of water conveyance infrastructure associated with the SWP that will occur within the Plan Area. Specifically, those SWP-related actions covered by the BDCP involve: (1) the operation of existing and future Delta facilities to transport and deliver water for SWP purposes; (2) the construction of new water conveyance infrastructure and other facilities; and (3) the maintenance and monitoring of water infrastructure and other facilities.

The BDCP also covers the operation of the Pittsburg and Contra Costa power plants owned by Mirant. The Plan covers activities related to the intake and discharge of water from the Delta necessary to operate the plants as well as certain other maintenance activities required to ensure continued proper operation of the existing facilities.

The BDCP Covered Activities also include the conservation measures described in the Conservation Strategy for the Plan. These actions are covered by the BDCP because they may potentially impact species protected under state and/or federal endangered species laws. Such conservation actions include the restoration of aquatic and terrestrial habitats, construction of facilities, monitoring of Covered Species, and research and study of species and habitats.

1.4.4.2 Associated Federal Actions

The BDCP associated federal actions comprise those activities that are authorized, funded, or carried out by Reclamation within the Plan Area and relate to the operation of the CVP's Delta facilities. These actions include: (1) operation of existing CVP Delta facilities to convey and export water to meet project purposes; and (2) associated maintenance and monitoring activities. While the CVP and SWP are separate systems, the projects function in an integrated and coordinated manner pursuant to the Coordinated Operations Agreement (COA). As such, Reclamation and/or the CVP contractors will utilize a portion of the conveyance capacity of a new tunnel/pipeline facility.

1.4.5 Permit Duration

DWR is seeking take permits from the state and federal Fish and Wildlife Agencies that remain in effect for a term of 50 years. A 50 year term is necessary to allow for the full implementation of the BDCP Conservation Strategy and to maximize the ecological benefits of the Plan. Moreover, the nature and scope of the actions to be permitted require a permit duration of 50 years.

1.5 Overview of the Planning Process

1.5.1 Role of the Steering Committee

The BDCP reflects input from a range of interested parties, public agencies, stakeholder groups, independent scientists, and the general public. The development of the Plan was primarily guided by the BDCP Steering Committee, whose membership is set out in Table 1-1, with direction from a Management Team. The Steering Committee provided direction on a range of technical, regulatory, and policy matters that shaped the Plan. The Management Team served the role of establishing agendas and facilitating meetings of the Steering Committee. The state and federal fish and wildlife agencies participated on the Steering Committee in an *ex officio* capacity. The proceedings of the Steering Committee, including the schedule and notice of meetings, topics for inclusion in meeting agendas, and the course of deliberations, were facilitated by the California Natural Resources Agency.

The Steering Committee formed a number of standing "Working Groups" and "Technical Teams," as well as ad hoc groups, to focus on approaches and solutions to specific issues related to Plan development. The focus of these groups is described below. The Working Groups dealt primarily with broad topics related to such matters as biological goals and objectives, conservation strategies, water conveyance, other stressors, and governance, and developed recommendations which were presented to the Steering Committee for consideration. Each Working Group was co-chaired by members of the Steering Committee. Technical Teams were tasked with responsibility for developing proposed approaches to technical and scientific issues. These teams were co-chaired by subject-matter experts who represented Steering Committee members, and were staffed by technical experts from both inside and outside the Steering Committee. All of these subgroups of the Steering Committee were composed of or were informed by technical experts representing a broad range of disciplines relevant to various aspects of plan development. Meetings of the Working Groups and Technical Teams were noticed on the BDCP website and open to the public.

The Working Groups and Technical Teams included the following:

- Conservation Strategy Working Group
- Biological Goals and Objectives Working Group
- Conveyance Working Group
- Other Stressors Working Group
- Implementation Structure/Governance Working Group
- Analytical Tools Technical Team
- Fish Facilities Technical Team
- Habitat and Operations Technical Team
- Habitat Restoration Program Technical Team
- Terrestrial Resources Subgroup
- Synthesis Team
- Integration Team
- Logic Chain and Metrics Technical Group

1.5.2 Public Participation and Engagement

The NCCPA requires the establishment of a process for public participation and outreach throughout the development of a plan.[45] Similarly, policies governing the ESA emphasize the importance of public involvement in the development of large-scale HCPs and encourage plan participants to facilitate the engagement of the public.[46] At the initial stage of the BDCP planning process, an outreach program was developed to provide the public a wide range of opportunities to learn about the various elements of the Plan and provide input during the course of its development.

The BDCP Steering Committee was established in May 2006, and met on a regular and ongoing basis throughout the planning process. All meetings of the Steering Committee, as well as Working Groups and Technical Teams, were open to the public. Such meetings could also be attended by teleconference, with live or archived access to presentations provided through the internet. Initially, a group email list was compiled and used to provide Steering Committee members and interested parties with Steering Committee meeting dates, times, and handouts. Later, an electronic listserv was developed and maintained to ensure that interested members of the public were notified of upcoming meetings and that draft documents pertaining to the planning process were distributed as they became available. All documents discussed by the Steering Committee, including its Working Groups and Technical Teams, were made available

[45] Fish & Game Code § 2815.

[46] 65 FR at X.

to the public on the BDCP website. At BDCP meetings, both oral and written public comments were received by the Steering Committee, and those comments received in writing were posted to the website. The notes of Steering Committee meetings also reflected comments and input offered by the public.

Throughout the planning process, representatives of the BDCP conducted approximately 200 briefings for community organizations, local jurisdictions within and adjacent to the Plan Area, environmental organizations, urban and agricultural water users groups, and recreational and commercial fishing organizations. Public presentations were made throughout the state, and information about the BDCP was regularly distributed, including updated "fact sheets" explaining the purpose of the Plan and describing its various components. To further facilitate the dissemination of information, the BDCP maintained a project website at: www.baydeltaconservationplan.com. Additional public outreach and involvement activities were conducted around major milestones in the planning process, and in compliance with NEPA and CEQA environmental review processes.

In 2008, DWR, Reclamation, NMFS, and USFWS, the lead agencies in the CEQA and NEPA environmental review processes, hosted ten scoping meetings throughout California. These meetings occurred at locations within the Sacramento Valley, the primary watershed through which stored water supplies are conveyed to and through the Delta to Project pumping facilities; other Delta communities; the San Francisco Bay Area; the San Joaquin Valley; and Southern California. Within the same year, DWR held eight landowner workshops in various Delta communities that focused in particular on the Temporary Entry Permit process and on updating these communities on the status of the BDCP planning process, and the environmental review process associated with the plan. In addition, the California Natural Resources Agency convened town hall meetings in Sacramento, Stockton, and Walnut Grove to further inform Delta communities about the BDCP and to respond to questions about the broader array of public agency efforts underway in the Delta, including the BDCP, pertaining to land use, flood protection, ecosystem restoration and governance.

In the spring of 2009, the BDCP produced and distributed a summary update about the development of the Plan to interested members of the public, including details of individual conservation measures that were being considered as part of the BDCP conservation strategy. NEPA and CEQA lead agencies also conducted 12 additional scoping meetings throughout California, seeking public input about the scope of BDCP actions and potential alternatives to the proposed action. Six of these scoping meetings were held in communities in or in close proximity to the Plan Area including Brentwood, Clarksburg, Davis, Fairfield, Sacramento, and Stockton. A Webinar was hosted in advance of these meetings to provide more in depth information about the BDCP process and to afford individuals unable to attend the workshops in person an opportunity to access to this information and interact with the BDCP representatives.

During the fall of 2009, after the release of a draft of a partial conservation strategy, four technical workshops were held in the Delta communities of Brentwood, Stockton, Walnut Grove, and West Sacramento to solicit input about the planning assumptions, biological rationale, and feasibility of draft conservation measures, as well as to seek recommendations for additional or different conservation measures. Input from the workshops was compiled and conveyed to the BDCP Steering Committee for its consideration and posted on the BDCP website. Three fact sheets were distributed that described the status of the Plan's development, the draft conservation strategy generally, and proposed water conveyance and flow and habitat restoration conservation measures more specifically.

Throughout 2010, BDCP representatives continued to conduct community briefings throughout the state, but primarily with organizations and local jurisdictions located within the Delta. As a result of these ongoing briefings, important working relationships were established with community leaders, further facilitating local engagement. In addition, informational materials about the BDCP, including fact sheets and issue summaries, evolved over time to ensure that the public was kept up-to-date with BDCP developments.

1.5.3 Integration of Science

The BDCP is built upon and reflects the extensive body of scientific investigation, study, and analysis of the Delta compiled over several decades,[47] including the results and findings of numerous studies initiated under the CALFED Bay-Delta Science program and Ecosystem Restoration Program, the long-term monitoring programs conducted by the Interagency Ecological Program (IEP), research and monitoring conducted by state and federal resource agencies, and research contributions of academic investigators.

In addition, the BDCP Steering Committee considered a number of other recent reports on the Delta, including reports of the Governor's Delta Vision Blue Ribbon Task Force (January and October 2008) and several recent reports of the Public Policy Institute of California.[48] Many elements of the BDCP conservation strategy parallel the recommendations of these other reports.

1.5.3.1 Independent Science Advisory Process

To ensure that the BDCP would be based on the best scientific and commercial data available, the Steering Committee also sought input and advice from independent scientists on the key elements of the Plan. Early in the planning process, the Steering Committee established a group of "Science Liaisons" to recommend approaches to ensure an appropriate level of independent scientific input into the development of the BDCP and to coordinate with facilitators tasked with responsibility for arranging and overseeing the independent science process. Consistent with the requirements of the NCCPA and the policy directives of the Five-Point Policy,[49] the BDCP Steering Committee directed the facilitators to convene independent scientists at several key stages of the BDCP planning process, enlisting well-recognized experts in ecological and biological sciences to produce recommendations on a range of relevant topics, including

[47] See The State of Bay-Delta Science (2008).
[48] For example, *Comparing Futures for the Sacramento-San Joaquin Delta* (Public Policy Institute of California 2008).
[49] 65 Fed. Reg. 35242.

approaches to conservation planning for aquatic and terrestrial species in the Delta and developing adaptive management and monitoring programs. Among other things, the independent scientists provided recommendations and guidance on such matters as:

- Scientifically sound conservation strategies for species and natural communities proposed to be covered by the Plan;
- A set of reserve design principles that addresses the needs of species, landscapes, ecosystems, and ecological processes in the Plan Area proposed to be addressed by the Plan;
- Management principles and conservation goals that could be used in developing a framework for the monitoring and adaptive management component of the Plan; and
- Identification of data gaps and uncertainties so that risk factors may be adequately evaluated.

Reports prepared by independent science advisors to the BDCP are provided in Appendix G, *Independent Science Advisors Reports*.

The Steering Committee assembled five different groups of independent science advisors during the development of the BDCP. The first group gathered in September 2007, to provide guidance on approaches to planning for the conservation of aquatic species and ecosystem processes in the Delta. Specifically, the group advised the Steering Committee on the following elements of the BDCP:

- The application of conservation planning principles within the Plan Area;
- Geographic and temporal scope of the BDCP;
- Addressing facets of Delta ecosystem dynamics;
- Analytical methods used in BDCP formulation, methods of analysis; and
- Adaptive management and monitoring considerations.

A second group of science advisors was convened in September 2008 to consider approaches to planning for the conservation of non-aquatic resources in the Plan Area. The group provided recommendations to the Steering Committee on such issues as:

- Non-aquatic species to be considered for regulatory coverage under the BDCP;
- Terrestrial natural communities that should be addressed under the BDCP;
- Landscape-level approaches to conservation planning for non-aquatic resources;
- Additional sources of information that should be developed to support the non-aquatic resource elements of the BDCP; and

- Conservation strategies that may be considered for addressing terrestrial and non-tidal wetland communities and dependent wildlife and plant species.

The third group of science advisors met in December 2008 and focused on matters related to the development of an adaptive management decision making process for the BDCP informed by data and information generated by monitoring and research efforts. This group built upon guidance on adaptive management that followed from the first of the independent science workshops, offering more specific advice based on progress that had since been made in the development of the BDCP.

The Delta Science Program provided assistance in assembling a fourth group of independent science advisors in February-March 2010 and a fifth group in July-August 2010 to evaluate and provide recommendations on the "Logic Chain" planning structure. The Logic Chain has been proposed as a framework for linking recovery goals for covered fish species with BDCP goals, objectives, conservation measures, monitoring, and adaptive management. Two science reports on the Logic Chain were prepared.

In the first report, dated March 19, 2010 (Appendix G5), the group assessed the value of the Logic Chain as a tool, its internal consistency, and next steps for input of information into the Logic Chain. The group stated that the Logic Chain was a useful tool for clearly articulating and linking goals, objectives, actions, and outcomes, but recommended an alternate approach that clarifies the links in the chain and reduces areas of ambiguity; distinguish between order-of-magnitude approximations of goals and objectives that are acceptable in early planning and the more detailed descriptions developed later; frame projected outcomes as testable hypotheses linked to specific conservation measures; use metrics to evaluate the success of outcomes that clearly link to biological functions and consider the judicious use of surrogate metrics; consider constraints to implementation of conservation measures; consider the potential impacts of system dynamics, variation, and change over time; and provide more detail to the adaptive management framework. As next steps, the group recommended developing logic chains for a few species initially; leaving recovery goal development to responsible regulatory agencies; focusing on development of the BDCP biological goals and objectives; and convening a workshop to develop monitoring metrics.

In the second report, dated August 23, 2010 and revised September 6, 2010 (Appendix G6 and G7), the group assessed the populated logic chains to evaluate internal logic, measurability, and linkages, and consistency in approach; recommended alternative strategies and metrics for goals and objectives and alternative ways of framing goals and objectives to be more practicable; and provided advice on constructing an integrated monitoring program linked to the logic chains. Recommendations of this science group included: simplifying the logic chain structure to reduce the number of objective statements and to focus on BDCP objectives; identify stressors that are outside of BDCP management; focus BDCP objectives on measures of individual and population-level performance, such as habitat-specific estimates of growth and survivorship, quantitative estimates of abundance, and quantitative measures of movement and/or distribution;

take care in populating the compliance and performance monitoring actions and consider three monitoring levels separately, the global goal, the "covered activity" level, and compliance; and to link implementation of conservation measures, through monitoring and evaluation, to the adaptive management program.

1.5.3.2 DRERIP Evaluation Process

The BDCP Steering Committee undertook a rigorous process to incorporate new and updated information and to evaluate a wide variety of issues and approaches as it formulated a cohesive, comprehensive BDCP conservation strategy. This effort included an evaluation conducted early in 2009 by multiple teams of experts of draft BDCP conservation measures, using the CALFED Bay-Delta Ecosystem Restoration Program's (ERP) Delta Region Ecosystem Restoration Implementation Plan (DRERIP) Scientific Evaluation Process.

In October 2008, the Steering Committee developed early drafts of BDCP conservation measures related to water operations, habitat restoration, and other stressors. The DRERIP evaluation process was used to evaluate these draft conservation measures. The DRERIP process was specifically developed to aid in planning and decision making regarding potential ecosystem restoration projects in the Delta. The process entails engaging teams of experts to work through a structured, step-by-step examination of the scientific efficacy of proposed restoration actions by analyzing both potential positive and negative outcomes which might result from a given action.

To conduct the DRERIP evaluations, the Steering Committee engaged 52 technical experts assembled into five teams to address related groupings of conservation measures. The DRERIP Technical Team meetings were limited to specific technical experts trained in the DRERIP evaluation process. The teams conducted DRERIP evaluations, from January-April 2009, on 32 draft conservation measures that could be evaluated using the process. The evaluations were conducted using a series of peer-reviewed DRERIP ecosystem and species conceptual models developed specifically for the Delta and additional relevant sources of information (e.g., published literature, recently collected data). The conceptual models describe the current scientific understanding regarding how the Delta ecosystem works and were designed to serve as a foundation for the evaluation process. A description of the BDCP DRERIP evaluations and evaluation results are presented in Appendix F, *DRERIP Evaluation Results*.

Results include an assessment of the likely magnitude of the ecological outcomes and the certainty of those outcomes that could be associated with implementation of each evaluated conservation measure. However, because the DRERIP process is designed to evaluate restoration actions independently, it does not provide for a direct assessment of the combined magnitude and certainty of positive and negative ecological outcomes that would be associated with the contemporaneous implementation of multiple conservation measures under BDCP. To address this need, the Steering Committee established a Synthesis Team comprised of Steering Committee member representatives and technical experts that participated in the DRERIP evaluations to conduct an assessment of the likely synergistic ecological effects of simultaneous implementation of multiple conservation measures based on the evaluation results for individual conservation measures. The Synthesis Team conducted the evaluation during March-April 2009 and provided recommendations to the Steering Committee for refining conservation measures, sequencing implementation of conservation measures, and adjusting DRERIP results for individual conservation measures based on their synergistic effects with implementation of other conservation measures.

DRERIP evaluation results were also used to inform development of the effectiveness monitoring for conservation measures (Section 3.6, *Monitoring and Research Program*). DRERIP evaluation results include assessments and sources of uncertainty surrounding the magnitude of ecological outcomes that could be expected with the implementation of each conservation measure. Based on these assessments, effectiveness monitoring was developed to collect the information necessary to address these sources of uncertainty and to inform the need for future adjustments to conservation measures to improve their performance over time through the BDCP adaptive management decision making process (Section 3.7, *Adaptive Management Program*).

1.6 ORGANIZATION OF THE BDCP

The BDCP consists of an Executive Summary, 12 chapters, and 14 appendices. Specifically, the plan includes the following components:

The BDCP includes an executive summary, which provides an overview of the BDCP, including descriptions of the background, purpose, covered activities, conservation strategy, and approach to plan implementation. Chapter 1 sets the context for the development of the BDCP, including the purpose and scope of the plan, the planning and conservation goals and objectives, and the expected regulatory outcomes. Chapter 1 also describes the process that guided the development of the Plan. Chapter 2 describes existing environmental conditions within the Plan Area, providing the context in which the BDCP and its various elements have been developed. Chapter 3 sets out the BDCP conservation strategy, including the biological goals and objectives of the Plan, approach to conservation adopted by the Plan, the range of conservation measures for aquatic and terrestrial species and habitats, and the monitoring and adaptive management plans.

Chapter 4 identifies the activities proposed for regulatory coverage, including existing and future actions. Chapter 5 includes an analysis of the beneficial and adverse effects of the BDCP on covered natural communities and covered species. The chapter also describes the indirect effects resulting from the implementation of the BDCP conservation strategy and the covered activities. Chapter 6 addresses matters relating to the implementation of the BDCP, including the schedule for the implementation of actions, the reporting process to ensure compliance, regulatory assurances anticipated by the entities seeking authorizations, measures to address changed circumstances, and the approach to unforeseen circumstances. Chapter 7 sets out a governance structure to ensure successful long-term implementation of the Plan. Chapter 8 estimates the costs of Plan implementation and identifies the sources of funding that will be relied on to implement the Plan.

Chapter 9 sets out the alternatives to take that were developed and considered and the reasons why they were not adopted. Chapter 10 describes the independent science advisory process and the recommendations provided by these scientists. Chapter 11 lists the preparers of the BDCP, and Chapter 12 lists the sources cited in the Plan.

CHAPTER 2. EXISTING ECOLOGICAL CONDITIONS

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CHAPTER 2. EXISTING ECOLOGICAL CONDITIONS

[***Note to Reviewers****: This is a revised version of BDCP Chapter 2, Existing Ecological Conditions. The last draft of Chapter 2 was presented to the Steering Committee at the October 7, 2010 meeting. Revisions have been made throughout the text to address comments received, to clarify concepts, and to bring the document up to date with the progress on various components of the BDCP in 2010. The BDCP Steering Committee members have submitted comments to various drafts of this chapter during development, which may or may not have been incorporated into this November 18, 2010 draft. While the text of this chapter is subject to change and revision as the BDCP planning process progresses, the chapter has been drafted and formatted to appear as it may in a completed draft HCP/NCCP. Although the chapter includes declarative statements (e.g., the Implementation Office will…), it is nonetheless a "working draft" that will undergo further modification based on input from the BDCP Steering Committee, state and federal agencies, and the public.*]

2.1 INTRODUCTION

This chapter describes the existing ecological conditions present in the Bay Delta Conservation Plan (BDCP) Plan Area, including specific information to meet the requirements of the federal Endangered Species Act (ESA) and the California Natural Community Conservation Planning Act (NCCPA). The Plan Area encompasses approximately 858,372 acres, and includes the statutory Delta as defined in the California Water Code, Section 12220, Suisun Marsh (approximately 107,837 acres), and the upper Yolo Bypass (approximately 16,762 acres) (Figure 2-1).

Section 2.2, *Historical Conditions*, provides a brief summary of the physical and biological conditions that were historically present within the Plan Area, as well as historical conditions upstream and downstream of the Delta as they relate to supporting conditions of the historical Delta. Current physical and biological conditions of the Plan Area are described in Section 2.3, *Existing Ecological Conditions,* which provides descriptions of natural processes in the Plan Area, its physical environment, and its biological communities. Section 2.4, *Biological Diversity*, provides a summary of the biological diversity within the Plan Area. Appendix A, *Covered Species Account*s, contains detailed accounts of the covered species, including information on life history characteristics, habitat requirements, and threats and stressors that are relevant to conservation efforts and recovery goals. The ecological information presented in this chapter and that provided in Appendix A provide support for the evaluation of the potential effects of covered activities on proposed covered species and natural communities and for the development of measures to address the conservation of covered species and natural communities. Common and scientific names of species mentioned in the text are provided in Appendix B, *Common and Scientific Names of Fish, Wildlife, and Plants Mentioned in the Text*.

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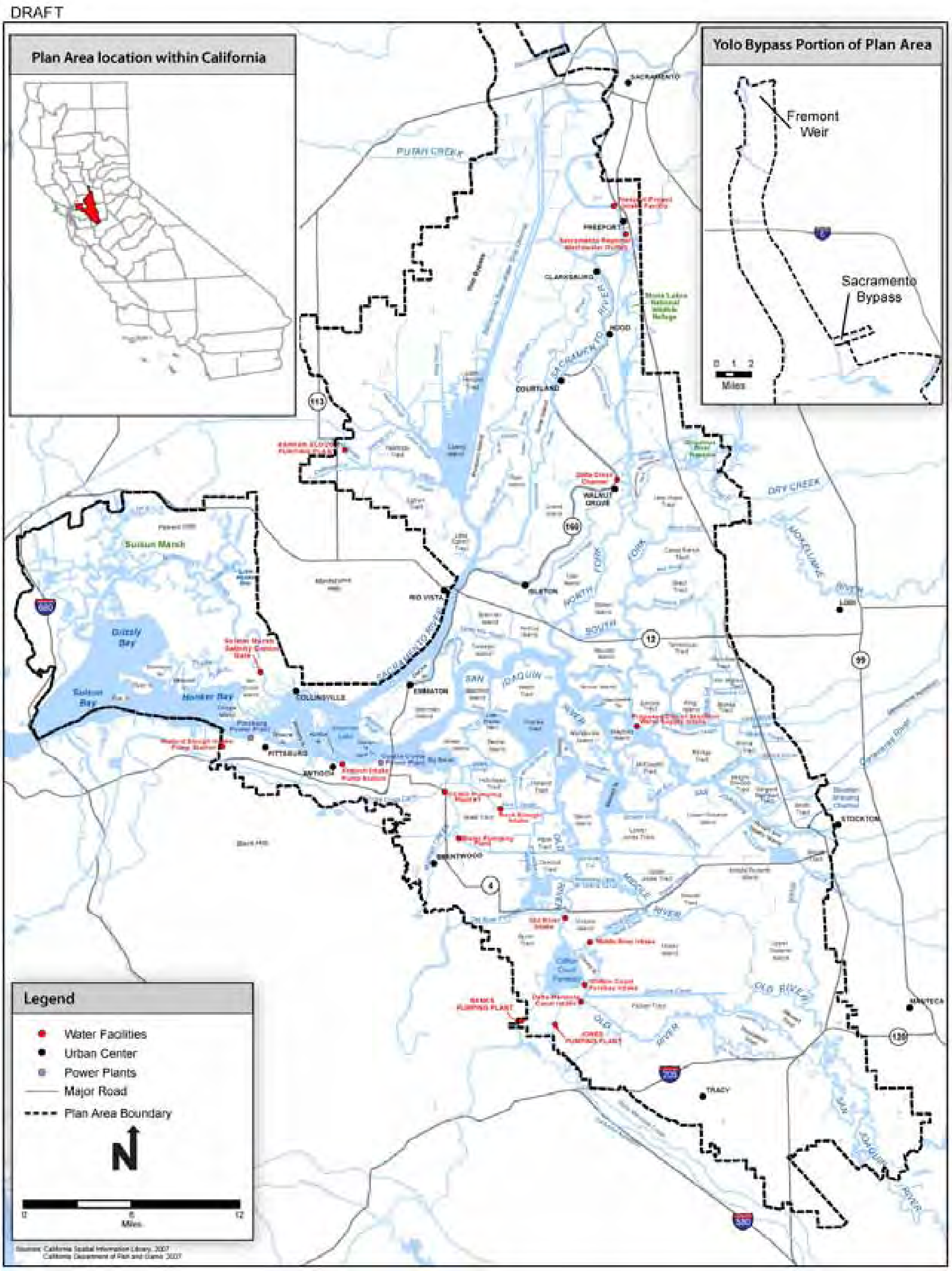

Figure 2-1. BDCP Plan Area Location

1

2.2 HISTORICAL CONDITIONS

This section provides a brief overview of historical physical and biological environmental conditions of the Plan Area and environmental conditions present upstream and downstream of the Plan Area as they relate to supporting the description of conditions within the Plan Area.

2.2.1 Hydrologic and Geomorphic Conditions

Much of the broad scale geology of the Central Valley, Delta, and Suisun Marsh was formed before the Pleistocene epoch (>2 million years ago), while finer details wrought by younger geologic formations, including the recent uplift and movement of the Coast Range and the deposition of broad alluvial fans along both sides of the Central Valley, formed during the Pleistocene epoch from 2 million to 15,000 years ago (Loudeback 1951, Olmsted and Davis 1961, Lydon 1968, Shelmon 1971, Atwater et al. 1979, Marchandt and Allwardt 1981, Helley and Harwood 1985, Sarna-Wojcicki et al. 1985, Weber-Band 1998, Unruh and Hector 1999, Graymer et al. 2002, Weissmann et al. 2005, Unruh and Hitchcock 2009). Approximately 21,000 years ago, the last glacial maximum ended and the eustatic (worldwide) sea level began to rise from the lowstand (lowest sea level bathymetric position or depth during a geologic time) of -394 feet (-120 m) in a series of large meltwater pulses interspersed by periods of constant rising elevation. The rise continued until the Laurentide ice sheet had completely melted 6,500 years ago and the rate of sea level rise slowed dramatically (Edwards 2006, Peltier and Fairbanks 2006). During this change from glacial to interglacial period, runoff brought enormous quantities of sediment from the Sierra Nevada and Coast Range that formed alluvial fans and altered stream channels in the Central Valley (Olmsted and Davis 1961, Shelmon 1971, Marchandt and Allwardt 1981, Helley and Harwood 1985, Weissmann et al. 2005).

The modern Delta formed sometime between 10,000 and 6,000 years ago when the rising sea level inundated a broad valley that occupied the Plan Area region. Despite its name, the Sacramento-San Joaquin Delta is not simply the merging of two river deltas, but is instead an elongated and complex network of deltas and flood basins with flow sources that include Cache Creek, Putah Creek, Sacramento River, Mokelumne River, San Joaquin River, and Marsh Creek. Based on current unimpaired flow estimates, the Sacramento River is the largest source of flows and has contributed an average of 73 percent of historical inflows into the Delta; the east-side tributaries including the Mokelumne River contribute about 6 percent, and the San Joaquin River contributes 21 percent (Dayflow 2007). Currently, during flood stages, approximately 82 percent of flows from the Sacramento River pass through the Yolo Bypass (Roos 2006). The flood stage flows can have many sources, including direct flows from tributaries such as the Feather and American rivers, as well as through a system of passive and active weirs (James and Singer 2008, Singer et al. 2008, Singer and Aalto 2009). The Yolo Bypass also serves as a conduit for Cache Creek and Putah Creek as their waters do not reach the Sacramento River until they pass through Cache Slough at the southern end of the Yolo Bypass. The San Joaquin River discharges into a broad network of sloughs and channels, and the Mokelumne River delta merges with the San Joaquin River delta on the eastern side of the Delta. On the southwest side of the Delta, the Marsh Creek delta merges with the San Joaquin River delta.

While flooding has always been a regular occurrence along the Sacramento River (Thompson 1957, Thompson 1960, Thompson 1961, Thompson 1965), the natural geomorphic processes and hydrological regimes were completely disrupted through the enormous increase in sediment and debris supply generated by hydraulic mining operations in the central Sierra Nevada from 1853 to 1884 (Gilbert 1917, Mount 1995). Large volumes of mining sediment remain in the tributaries today (James 2004a, 2004b). The portion of the estimated 1.5 billion cubic feet of sediment that poured into the Sacramento Valley filled river channels and increased flooding severity and peak flows (Gilbert 1917, Kelley 1989, Mount 1995, James 2004a, Hitchcock et al. 2005, William Lettis & Associates 2005, James 2006, CVRWQCB 2008, James and Singer 2008, James et al. 2009). In the 1900s another pulse of mining sediment was discharged into the Sacramento River watershed (James 1999). While it is often assumed the mining sediment has already passed through the Delta or is stored behind dams, large amounts remain within the system (James 1999, 2004a, 2004b, 2006, James and Singer 2008, James et al. 2009). Other Central Valley streams, such as the Cosumnes River, have been impacted to a lesser extent by similar mining or agriculture-derived sources of sediment (Florsheim and Mount 2003). The initial pulse of sediment made its way into the San Francisco Estuary where it filled shallow tidal bays, but with current reduced sediment loads these sediments are being eroded and transported into the Pacific Ocean (Cappiella et al. 1999, Ganju and Schoellhamer 2010).

Soils in the Plan Area are extremely variable in texture and chemical composition. Delta soils away from its margins are generally a combination of peat beds in the center of islands with relatively coarse textured inorganic sediments deposited in the channels and along the margins of the islands (William Lettis & Associates 2005, Unruh and Hitchcock 2009, Deverel and Leighton 2010). There are some ancient dune deposits on the islands and shoreline of the western Delta in the vicinity of the San Joaquin River that predate the peat beds (Carpenter and Cosby 1939, SFEI 2010). The soils in the Suisun Marsh area are generally peat or fine textured mineral soils in and along the islands closest to Suisun Bay, and fine textured mineral soils are found closer to the border of the marsh where it abuts the uplands. The soils of the Cache Slough area are primarily mineral soils that are either fine-textured and of local origin, or coarse-textured material that is a legacy of gold mining in the Sierra Nevada and streams leading from the Sierra Nevada. The uplands north of Suisun Marsh and west of the Sacramento River are generally alkaline clays (Mann et al. 1911, Bryan 1923, Thomasson Jr. et al. 1960, State of California 1987, Graymer et al. 2002). The soils of the Yolo Basin are alkaline clays on the west side, a mixture of clay, sand and peat on the bottom of the basin, and silts with sand splays on the natural levee of the Sacramento River (Anonymous 1870, Mann et al. 1911, Andrews 1970). The soils along the southwestern border of the Delta are sands to the north and alkaline clays to the south (Carpenter and Cosby 1939, Natural Resources Conservation Service [NRCS] 2009, SFEI 2010). Along the eastern border of the Plan Area, the soils are heterogeneous patches of clays, loams, and peat (Florsheim and Mount 2003, NRCS 2009).

It is estimated that prior to reclamation actions, nearly 60 percent of the Delta was inundated by daily tides. The tidal portion of the Delta consisted of backwater areas, tidal sloughs, and a network of channels that supported highly productive freshwater tidal marsh and other wetland habitats (CALFED 2000). Similar complex drainage networks, ponds, and salt panes existed in tidal brackish marshes in Suisun Marsh and along the north shore of east Contra Costa County (Suisun Ecological Workgroup 2001, Brown 2004, Grossinger 2004, SFEI 2010). The soils in these marshes were generally peat beds that accumulated and were preserved under anoxic conditions. In contrast, soils in channels and along the higher energy channel margins of islands tend to be comprised primarily of mineral sediment (William Lettis & Associates 2005, Unruh and Hitchcock 2009).

Vast areas in the Delta, Yolo Basin, Suisun Marsh, and the south shore of Suisun Bay were reclaimed (filled, leveed, diked, and drained) between the 1850s and the early 1930s, completely transforming their physical structure (Thompson 1957, 1965, Suisun Ecological Workgroup 2001, Brown 2004, Grossinger 2004, SFEI 2010). Levee ditches were built to drain land for agriculture, human habitation, mosquito control, and other human uses while channels were straightened, widened, and dredged to improve shipping access to the Central Valley and to improve downstream water conveyance for flood control. An estimated 95 percent of original tidal wetlands and many miles of sloughs in the Delta were removed by channelization and levee construction (CALFED 2000).

Under natural conditions, inflows from both the Sacramento and San Joaquin rivers were much lower from July through November compared to the December to June period (The Bay Institute 1998) and in drought periods likely lead to salinity intrusions. This difference was more dramatic in the San Joaquin River. The San Joaquin River has an upper watershed consisting of impermeable granitic rock that does not support dry season groundwater discharge. In contrast, the upper watershed of the Sacramento River is composed of permeable volcanic rock. As a result, groundwater discharge from this volcanic system historically maintained a summer base flow at Red Bluff of approximately 4,000 cfs without which the Sacramento River would have nearly dried up each fall (The Bay Institute 1998).

Water diversions in the San Joaquin Valley began earlier than those in the Sacramento Valley; and by 1870, flows of the San Joaquin River were significantly reduced (DWR 1931, Jackson and Paterson 1977). Sacramento River diversions, particularly those in late spring and summer diversions for rice irrigation, increased dramatically from 1912 to 1929, and the combination of significant drought periods and increased diversion during the annual low flow period resulted in an unprecedented salinity intrusion into the Delta in the fall of 1918 (DWR 1931, Jackson and Patterson 1977, The Bay Institute 1998, CCWD 2010). The economic impacts of these diversion-caused salt water intrusions ultimately led to the creation of the Central Valley Project (CVP) and the construction of dams for the release of freshwater flow to prevent salinity intrusion (Jackson and Patterson 1977). Construction of dams and diversions on all major rivers contributing to the Delta between the 1930s and 1960s resulted in substantial changes to Delta hydrodynamics (The Bay Institute 1998, CCWD 2010). Four dams (Shasta, Oroville, Trinity, and

Monticello) in the Sacramento Valley have a storage capacity greater than 1 million acre feet (maf) (12 maf total); an additional four dams (New Melones, Don Pedro, New Exchequer, and Pine Flat) with storage capacity greater than 1 maf (6.5 maf total) drain into the San Joaquin Valley (DWR 1993).

The main effect of this upstream water development was the dampening of the seasonal high and low flows into the Plan Area (CCWD 2010). Reclamation of the Delta and upstream water development also accentuated salinity intrusions into the Plan Area. Current water management regulations have reduced the annual fluctuations in salt water intrusion, but have also shifted the boundary between fresh and salt water significantly further into the Delta (CCWD 2010). In combination with dam construction, flood control and water operations have greatly transformed the geometry and hydrology of the Delta, as well as for downstream locations including Suisun Bay and Suisun Marsh (Section 2.3.2, *Ecosystem Processes*).

2.2.2 Biological Conditions

Prior to the Gold Rush era (c. 1850), the predominant vegetation of the Delta consisted of bulrushes and tules (*Schoenoplectus*[1] spp.), which are adapted to the range of salinity present in the Delta from freshwater to as high as 2 parts per thousand (ppt) in the western Delta in the later summer (Thompson 1957, Atwater and Belknap 1980). The area was described as a vast, sea-level “swamp” with tracts of intertidal wetland and a network of channels of various sizes. The characterization of the historical Delta as a vast tule marsh, however, is an oversimplification from an ecological standpoint, and fails to reflect the considerable habitat complexity and diversity that allowed the Delta ecosystem to support such an unusually rich and diverse native biological community (The Bay Institute 1998). Generally, the current vegetation of the Delta correlates with the historical vegetation, and the vegetation of the tidal freshwater areas of the central Delta down to about 18 inches below mean lower low water (MLLW) falls into two general categories. Tules (generally *Schoenoplectus californicus*), cattails (*Typha* spp.), and willows (*Salix* spp.) dominate the vegetation along the Sacramento River, while throughout the San Joaquin River area of the Delta bulrushes (generally *Schoenoplectus acutus*), tules, common reed (*Phragmites australis*), and willows are more often the dominant species (Atwater 1980, Simenstad et al. 2000, Watson 2006, EDAW 2007b, Hickson and Keeler-Wolf 2007, Watson and Byrne 2009).

Further west, from about the vicinity of Collinsville, the tidal brackish marsh vegetation is characterized by bulrush, tules, common reed, and cattail (Culberson 2001, Suisun Ecological Workgroup 2001, Watson and Byrne 2009, SFEI 2010). These same large species occur as clumps in the tidal channel to the marsh plain transition zone and share that zone with many other species such as saltgrass (*Distichlis spicata*), Baltic rush (*Juncus balticus*), and seaside arrowgrass (*Triglochin maritima*). The borders of the smallest channels (first order channels and mosquito ditches) are also habitat for Suisun thistle (*Cirsium hydrophilum* var. *hydrophilum*), which is a

[1] The genus was formerly *Scirpus.*

BDCP covered species. The boundary between the distant edge of the transition zone and marsh plain is gradual as there is very little change in the elevation of the marsh plain; and this is where soft bird's-beak (*Cordylanthus mollis* ssp. *mollis*), a BDCP covered species, occurs with pickleweed (*Sarcocornia pacifica,* formerly *Salicornia virginica*), saltgrass, salt marsh dodder (*Cuscuta salina*), and spearscale (*Atriplex triangularis*). The marsh plain proper is dominated by a variable mixture of pickleweed and saltgrass.

Historically, the perimeter of the Plan Area consisted of tidal and nontidal wetlands and mudflats that merged with upland vegetation types that included nontidal wetlands, meadows, oak savanna, alkali grasslands, vernal pools, and alkali sink scrub. Due to their productivity and heterogeneity, vegetation in the uplands formed complex physical habitats that consisted of herbaceous species (grasses and dicots), shrub species (willows, blackberries [*Rubus*], wild roses [*Rosa*]), and a mixture of tree species such as oak (*Quercus*), sycamore (*Platanus*), alder (*Alnus*), walnut (*Juglans*), and cottonwood (*Populus*). Mammals using these upland habitats included tule elk (*Cervus canadensis nannodes*), mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), grizzly (*Ursus arctos*), coyote (*Canis latrans*), American badger (*Taxidea taxus*), ground squirrel (many spp.), pocket gopher (*Thomomys*), cottontail (*Sylvilagus audubonii*), and black-tailed jackrabbit (*Lepus californicus*) in drier areas (Grinnell et al. 1937, Thompson 1957). Much of this flora and fauna was severely reduced with reclamation and the development of agriculture that began in the early 1850s.

High tule productivity combined with the rich organic sediments of the basins along the Sacramento and San Joaquin rivers and the channels and channel-to-marsh plain transition zones of Suisun Marsh provided large amounts of organic matter support for the aquatic food web. This organic matter input probably resulted in abundant biomass of zooplankton (detritivores, scavengers, and filter-feeding planktivores) (The Bay Institute 1998). The large and complex food web also likely supported an abundant assemblage of fishes.

Because the Delta environment and its fish species assemblage has changed significantly and was not documented prior to the changes, there is limited knowledge of the ecology of native fishes in the past (Moyle 2002). It is known that the historical assemblage of fish in the Delta was very different from the current assemblage. For example, thicktail chub was driven to extinction in the 1950s, most likely due to marsh reclamation impacts and the introduction of nonnative fish species (Schulz and Simons 1973). Also, the Sacramento perch, once very abundant in sloughs off main channels, was extirpated from the Delta for the same reasons (Rutter 1908). Conversely, a large number of nonnative species of fish have been deliberately introduced (e.g., striped bass [*Morone saxatilis*], channel catfish [*Ictalurus punctatus*], and largemouth bass [*Micropterus salmoides*]), or introduced into the system as cast offs (e.g., goldfish [*Carassius auratus auratus*]). Further, the abundance of many species of native fish was much greater historically than currently. For example, Chinook salmon (*Oncorhynchus tshawytscha*) were once very abundant throughout the Delta and Sacramento and San Joaquin rivers and tributaries, but today their abundance is low for many reasons (Appendices A2 through A4). The freshwater range of anadromous fish, such as salmonids (Salmonidae) and sturgeon (*Acipenser*) was much greater historically before the construction of dams, and the degradation of suitable habitat below dams significantly reduced the extent of spawning habitat. Fish likely fed on dominant crustaceans, such as the mysid *Neomysis*, the amphipod *Corophium*, and cyclopoid copepods (Moyle 2002), which have been replaced as dominant species by multiple nonnative copepod species, including *Limnoithona*, *Pseudodiaptomus*, and *Acanthomysis* (Sommer 2007).

2.3 Existing Ecological Conditions

2.3.1 Data Sources and Natural Community Classification

2.3.1.1 Data Sources

Background data for the BDCP were collected through an extensive search of various sources including current scientific literature, reports, technical documents, agency maintained data (e.g., CALFED Interagency Ecological Program, California Department of Fish and Game [DFG], and DWR), and BDCP documents (e.g., BDCP Independent Science Advisors Report [Reed et al. 2007]). A full list of sources of background data used for this report is provided in Chapter 12, *References*. Where data were not available, or where significant uncertainties were identified through initial data gathering and synthesis, technical experts were engaged to provide unpublished data and best professional scientific judgment. Various technical experts participated in developing, writing, and reviewing the descriptions of the natural communities (Section 2.3.4) and the accounts of covered species (Appendix A, *Covered Species Accounts*). Citations and references pertaining to individual covered species are embedded in species accounts in Appendix A.

Map data layers were compiled from existing spatial data sets, primarily produced by state and federal agencies and available on their websites, or by data transfer. The sources and types of spatial information used in this report are presented in Table 2-1.

Natural communities (Section 2.3.4) were defined and described using the CALFED Bay-Delta Program Ecosystem Restoration Program (ERP) Volume 1 and the Multiple Species Conservation Strategy (CALFED 2000), and were further refined and augmented by input from DFG staff participating in the BDCP Terrestrial Resources subgroup in 2009. In addition to the BDCP vegetation cover dataset, a vernal pool complex natural community dataset was separately generated to more effectively capture the vernal pool complex (pools and supporting uplands) community present within the Plan Area. Vernal pool complex areas that were deemed to have been significantly altered were retained as a degraded vernal pool complex vegetation type which generally falls into the grassland and the natural seasonal wetland BDCP covered natural communities (Appendix L2, *Vernal Pool Complex Mapping for the BDCP*).

Table 2-1. Spatial Data Sources

Map Layer	*Data Type*	*Data Source*
Physical geography/Delta legal boundary	Vector	CaSIL[1]
Land cover type/ vegetation community type	Vector	DFG, Yolo County, DWR
Land Use / Farmland	Vector	DWR, USDA[8]
Vernal Pool Complex	Vector	DWR, SSURGO[2], DFG
Soils	Vector	NRCS[3]
Geology	Vector	USGS[9]
Topography/Elevation	Vector/Raster	DWR, USGS, CDC[4]
Bathymetry	Raster	DWR, USGS
Hydrography	Vector	USGS, DFG, CaSIL
Road, rail and communication infrastructure	Vector	CaSIL, DWR, TIGER[5]
Levees and major water projects	Vector	DWR
Water Diversions	Vector	DFG, DWR
Major water operations	Vector	DWR, CaSIL
Land Ownership	Vector	DWR, DFG, CPAD[6]
Conservation Lands	Vector	CPAD, DFG, CaSIL
Parcel Boundaries	Vector	Solano, Sacramento, Yolo, San Joaquin, Alameda, and Contra Costa counties
NAIP[7] Aerial Imagery	Raster	USDA
Species Distribution and Habitat Range	Vector	DFG, USFWS

[1]California Spatial Information Library
[2]Soil Survey Geographic Database
[3]Natural Resources Conservation Service
[4]California Department of Conservation
[5]Topologically Integrated Geographic Encoding and Referencing
[6]California Protected Areas Database
[7]National Agriculture Imagery Program
[8]United States Department of Agriculture
[9]United States Geological Survey

2.3.1.2 Natural Community Classification in the Legal Delta

The natural communities were delineated within most of the statutory Delta portion of the Plan Area using the Vegetation and Land Use Classification map of Sacramento-San Joaquin River Delta and associated GIS shape files (Hickson and Keeler-Wolf 2007). Vegetation was classified and mapped by the California Department of Fish and Game (DFG) within the legal Delta, excluding Chipps Island and Van Sickle Island in the far western portion of the Delta, during 2005-2006 for use in conjunction with the Delta Regional Ecosystem Restoration Implementation Plan. Vegetation sampling was conducted using the California Native Plant Society Rapid Assessment Protocol.

Land cover features were mapped by DFG using minimum mapping units (MMU) as follows:

- Landuse: MMU = 2 acres (minimum width of 25 meters);
- Isolated Landuse: MMU = 1 acres (minimum width of 10 meters);
- Water: MMU = 1 acre (minimum width of 10 meters);

- Vegetation: MMU = 2 acres (minimum width of 10 meters); and
- Critical veg: MMU = 1 acre (minimum width of 10 meters).

Features were occasionally mapped below MMU or minimum width because those features were so distinct or important compared to their surroundings that omitting them would have distorted the representation of the area.

In the area sampled, a total of 377 Rapid Assessments were conducted in the field and subsequently used to develop a quantitative classification based on cluster analysis. A total of 52 vegetation alliances were identified by the clustering algorithm, including 45 plant associations defined by Sawyer and Keeler-Wolf (1995). These classification units were either directly or indirectly used to develop 129 fine-scale to mid-scale vegetation mapping units. Mapping was undertaken using heads-up digitizing, in which polygons of vegetation were delineated on-screen. Each polygon was then coded with both a vegetation type and one of 25 land use types. Base imagery used to map the vegetation was true color 1-foot resolution aerial photography from spring 2002. Additional marginal areas of the mapped area were supplemented by true color 1-meter resolution photography from summer 2005. The mapped polygons were then compared with a fine-scale vegetation mapping product of nearby Suisun Marsh to measure efficiency and accuracy for future mapping efforts in the Bay-Delta Region. A more detailed description of the classification and mapping process is available in Hickson and Keeler-Wolf (2007).

The vegetation categories produced by DFG were combined into the corresponding broad biological community classifications used in the BDCP. Polygons from the fine-scale DFG map were combined using GIS. The portion of the Plan Area not sampled by DFG during the Delta mapping project was delineated by SAIC ecologists into a GIS using U.S. Department of Agriculture National Agriculture Imagery Program 1-m resolution color aerial photography (USDA 2005). This imagery was photographically interpreted to identify the natural communities present in portions of the Plan Area that were not sampled by DFG.

2.3.1.3 Natural Community Classification in Suisun Marsh

Natural communities were delineated within Suisun Marsh using the Vegetation Mapping of Suisun Marsh, Solano County California GIS dataset from 2006 (Boul and Keeler-Wolf 2008). DFG classified and mapped vegetation within Suisun Marsh, as well as Chipps Island and Van Sickle Island. The Manual of California Vegetation (Sawyer and Keeler-Wolf 1995) was used as the classification protocol and is based on the National Vegetation Classification System (Grossman et. al. 1998). The vegetation classification process described by Keeler-Wolf and Vaghti (2000) was reapplied in 2003 and 2006 in an effort to document vegetation changes within the Suisun Marsh. The 2006 Suisun Marsh Vegetation Mapping Change Detection GIS dataset represents the most recent data, and thus was used to define vegetation cover occurring within the Suisun Marsh region. It should be noted that this dataset has registration issues when comparing it to the National Agriculture Imagery Program (NAIP) or the U.S. Geologic Survey

(USGS) standardized regional imagery. The original dataset was developed in 1999. It involved registering and "rubber sheeting" over 100 1:9,600 true color photos. The airphotos were rectified to a registered SPOT base satellite image and the mapping was then tied to these registered and mosaiced photos. Users will observe that internal alignment inconsistencies are present when comparing the mapped land cover features to standardized imagery (e.g., USGS Digital Orthophoto Quarter Quadrangles [DOQQ], NAIP). Currently, there is no work planned to refine the alignment inconsistencies at this time (pers. com. T. Keeler-Wolf 2009). This dataset represents the most comprehensive and detailed vegetation survey available for the Suisun Marsh region.

Developing the relationships and equivalencies between the Suisun Marsh mapped vegetation cover types and the corresponding natural community classifications used in the Plan Area proved problematic. Science Applications International Corporation (SAIC) staff ecologists observed that the classification of communities within the Suisun Marsh was primarily driven by changes in species compositions due to wetland management strategies being applied in the region. Because of the presence of these management strategies, vegetation classes could be found to occur within multiple BDCP natural communities types. For example, the *Distichlis spicata* vegetation type was often found within both the managed wetland and the tidal brackish emergent wetland communities. Therefore, instead of developing a procedure to link the Suisun Marsh vegetation classes to the BDCP natural communities, the spatial extents of wetland management strategies were used to categorize the 2006 Suisun Marsh mapped vegetation.

The San Francisco Estuary Institutes' EcoAtlas (SFEI 1998) GIS dataset provides a reasonable estimate of land use classifications, and was used to support the categorization of the Suisun Marsh vegetation classes into the BDCP natural communities. The SFEI EcoAtlas GIS dataset mapped the Suisun Marsh using general categories that were loosely lumped into high elevation tidal marsh, low/mid elevation tidal marsh, muted tidal marsh, managed marsh, diked marsh, farmed bayland, grazed bayland, ruderal, storage basins, deep bay or ocean, shallow bay, and tidal mudflat. These land use categories were grouped into the equivalent BDCP natural community types (Table 2-2). DFG Suisun Marsh vegetation cover types located within any of the EcoAtlas 'tidal marsh' classified areas were determined to be tidal brackish emergent wetland. DFG Suisun Marsh vegetation cover types located within areas classified as either "managed marsh," "diked marsh," or "storage basin" by the EcoAtlas dataset were determined to be managed wetland. DFG Suisun Marsh vegetation cover types located within areas classified as "farmed bayland" or "ruderal" by the EcoAtlas dataset were determined to be agriculture. DFG Suisun Marsh vegetation cover types located within areas classified as "deep bay or ocean," "shallow bay," or "tidal mudflat" by the EcoAtlas dataset were determined to be tidal perennial aquatic. Lastly, DFG Suisun Marsh vegetation cover types located within areas classified as "grazed bayland" by the EcoAtlas dataset were determined to be grasslands. The resulting categorized Suisun Marsh vegetation dataset was then visually compared to NAIP 2005 aerial imagery by SAIC ecologists and refined as necessary (USDA- FSA 2005).

Table 2-2. EcoAtlas Land Use Classifications and Equivalent BDCP Natural Community Type

EcoAtlas Land Use Classification	*Equivalent Designation of BDCP Natural Community Type*
Tidal Marsh	Tidal Brackish Emergent Wetland
Managed Marsh Diked Marsh Storage Basin	Managed Wetland
Farmed Bayland Ruderal	Agriculture
Deep Bay or Ocean Shallow Bay Tidal Mudflat	Tidal Perennial Aquatic
Grazed Bayland	Grasslands

2.3.1.4 Natural Community Classification in the Upper Yolo Bypass

The Yolo County Natural Heritage Program's Regional Vegetation GIS dataset (TAIC 2008) was used to define vegetation cover for the upper Yolo Bypass that extends from the north legal Delta boundary northward to the Sacramento River. The dataset was clipped to the boundaries established for the Yolo Bypass. The vegetation classification categories assigned to the Yolo County dataset were evaluated by SAIC ecologists to determine the appropriate corresponding BDCP natural community with which each vegetation category should be associated.

The Delta vegetation cover dataset, the Suisun Marsh vegetation cover dataset, and the Upper Yolo Bypass vegetation cover dataset were merged to generate a single compilation vegetation cover dataset for the Plan Area.

2.3.1.5 Vernal Pool Complex Dataset Development

In addition to the BDCP vegetation cover dataset, a vernal pool complex natural community dataset was separately generated to more effectively capture vernal pool characteristics present within the Plan Area. On the east side of the Delta, the potential region of the vernal pool complex near Stone Lakes was identified using existing vernal pool GIS data sets, CNDDB records, management plans, South Sacramento HCP vernal pool maps, expert knowledge, and Google Earth aerial imagery (DWR 2007a, Kleinschmidt Associates 2008, DFG 2007, Google Inc. 2009). The areas of the region that were not clearly impacted by intensive agriculture or development were then inspected using Light Detection and Ranging (LiDAR) imagery to determine the extent of ground disturbance and the presence of appropriate pool and swale microtopography. The entire area identified within field boundaries was then digitized as vernal pool complex. Mapping of the remainder of the Delta, Yolo Bypass, and areas along the northern edge of Suisun Marsh was accomplished by identifying areas with alkaline soils and the appropriate geomorphic characteristics and drainage condition. Those areas were cross-checked through CNDDB records, maps produced for the East Contra Costa HCP/NCCP, and various management plans and then intersected with the appropriate vegetation type.

Google Earth and LiDAR imagery were then used to identify areas with the appropriate microtopography (Leigh Fisher Associates 2005, DWR 2007a, DFG 2007, Google Inc. 2009). The appropriate areas within fields, ditches, or other clear edges were classified as Vernal Pool Complex. A few areas with vernal pool signatures that were not identified by the soil-vegetation intersection were digitized as vernal pool complex. No MMU or scale was used during the process as the goal was to be as inclusive as possible of these often very small features. GPS-linked photographs taken during BDCP floristic field surveys in the spring and summer of 2009 were used to assess the accuracy of the mapping at several sites (DWR file data 2009). The excluded areas of low quality ephemeral habitat ranged from areas with vernal pool and swale visual signatures that display clear evidence of significant disturbance due to plowing, disking, or leveling to areas with clearly artificial basins such as shallow agricultural ditches, depressions in fallow fields, and areas of compacted soils in pasture. These areas were retained as a vegetation type that generally fell within the BDCP other seasonal wetlands community. For more detail on the vernal pool complex dataset development, see Appendix L2, *Vernal Pool Complex Mapping for the BDCP*.

2.3.2 Ecosystem Processes

The ecosystems of the Plan Area are dynamic and driven by a complex set of interacting physical, chemical, geomorphical, and biological processes that originate from internal and external causes (Figure 2-2). These processes vary at multiple spatial and temporal scales, typically along gradients rather than at well defined boundaries (Kimmerer 2004). Organisms that evolved in these ecosystems are adapted to this variability as it historically existed. Anthropogenic factors have altered the ecosystems in many ways and global climate change is expected to alter it further.

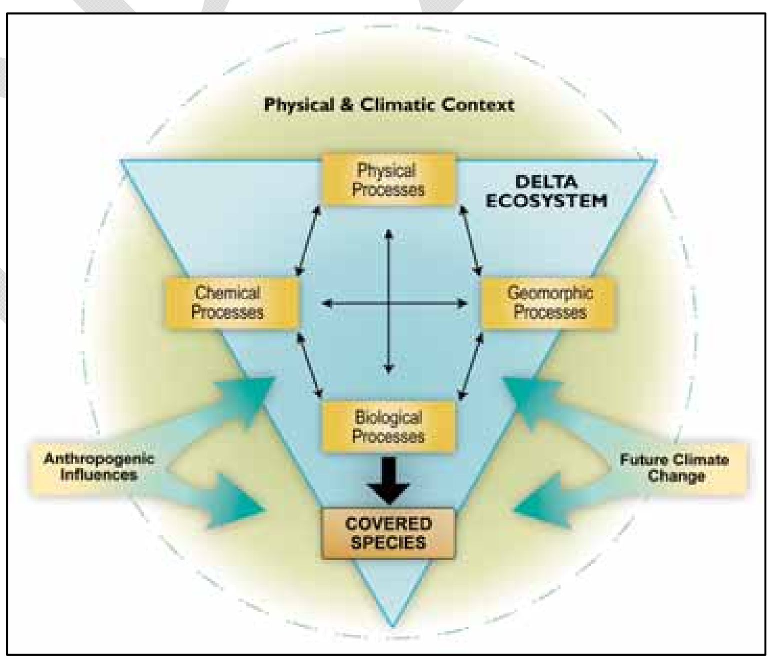

Figure 2-2. Ecosystem Processes in the Delta

2.3.2.1 Aquatic Ecosystem Processes

2.3.2.1.1 Physical Processes

Major physical factors driving ecological conditions in the Plan Area include water flow, salinity, and turbidity. The most conspicuous physical forcing factor is water flow, which varies daily, seasonally, and annually. Water flow directly or indirectly influences nearly all other ecosystem processes in the Plan Area. Large scale hydrodynamics in the Plan Area are driven largely by tides, flows, water exports, cumulative effects of local diversions, and atmospheric forcing. Local hydrodynamics are driven by water depth, channel geometry, and bathymetry at bends and channel junctions. Local conditions are not static and the cross-sections and beds of most Delta channels are dynamic and change in response to flow rates, wind, and other physical drivers.

Flow patterns are driven by the interaction between upstream (freshwater) flows entering the Delta and oceanic tides moving in and out of the Delta twice a day. While tidal flows drive the large majority of water movement in the Delta (Kimmerer 2004), they contribute little to net flow out of the Plan Area. Average tidal flow rates are 170,000 cfs, but can exceed 300,000 cfs during high tidal flow events (Mount 1995). In contrast, inflows from the upstream rivers average an order of magnitude lower. The average daily total Delta outflow from 1955-2007 was 33,715 cfs and has been as low as 4,200 cfs during dry periods (DayFlow, unpubl. data). While tidal influence dissipates at approximately the same location upstream on both the Sacramento and San Joaquin rivers (at approximately river mile [rm] 50), because freshwater inflow from the Sacramento River is much larger than inflow from the San Joaquin River (Section 2.3.3.3, *Hydrologic Conditions*) a much larger tidally driven volume of water or tidal prism moves in and out of the San Joaquin River. The overall pattern shows that hydrodynamic processes (e.g., transport, dispersion, etc.) in the western portion of the Delta are governed primarily by tidal exchange, while hydrodynamics in the northern and southern portions of the Delta are governed primarily by river flow.

In the region where fresh and oceanic waters first mix a longitudinal salinity gradient is formed. This gradient is intensively monitored and is spatially indexed by X_2, which is the distance (in kilometers [km]) from the Golden Gate Bridge at which channel bottom water salinity is 2 ppt (Jassby et al. 1995). The spatial and temporal characteristics of this gradient vary daily and seasonally and are driven by freshwater inflow and tidal action. The location of X_2 shifts upstream during a flood tide and downstream during an ebb tide. Similarly, X_2 is located farther downstream during high Delta outflows and farther upstream during periods of low outflows. Theoretically, within the salinity gradient, an estuarine salinity field and density gradient, also called a salt wedge, may form in which denser salt water is located at the bottom farther upstream and freshwater is located at the surface farther downstream; however, due to turbulent mixing, this rarely occurs in the Delta or Suisun Bay (Kimmerer 2004).

Temporal and spatial patterns in flow can directly affect the concentration and distribution of nutrients and contaminants, water density, salinity gradients, and floodplain inundation frequency and duration (Kimmerer 2004). Flow patterns also directly affect the transport of dissolved and suspended particles, including nutrients, gases, organic matter, toxics, sediment, and organisms (Kimmerer 2002, Jassby 2008). Although concentrations of particles do not necessarily increase with higher flows (but often do because of resuspension), the overall load (i.e., delivery) of particles increases with higher flow rates. The residence time of particles, the duration that they occur in a defined area, is inversely related to water flow rates. There are both positive and negative effects of increased residence time, depending on the effect of the particle on the biological process. Longer residence time of nutrients and organic matter may have beneficial effects on biological processes, whereas longer residence time of toxics may have deleterious effects on biological processes. When residence time is too great, biological consumption of dissolved oxygen at particular depths in the water column may exceed oxygen supply rates that are driven by atmospheric exchange processes and mixing at different depths and lead to anoxic conditions which are lethal for many organisms. Short residence time of nutrients and organic matter in the Delta may not provide organisms with sufficient time to use primary and secondary production that arises from these nutrients and organic matter.

Turbidity is an indirect method for quantifying how the transmission of light through water is attenuated by particles and dissolved substances, and is influenced primarily by suspended sediments and secondarily by suspended and dissolved organic material and plankton (Kimmerer 2004). Although still high relative to other aquatic ecosystems, turbidity in the western region of the Delta (in and near the Low Salinity Zone [LSZ]) has declined tenfold over the past three decades (Lehman 2000, Kimmerer 2004). This may be due to reduced sediment supply, reduced phytoplankton biomass, or the localized trapping of particles caused by an increase in the extent of submerged aquatic vegetation, particularly the nonnative and highly invasive Brazilian waterweed (Grimaldo and Hymanson 1999, Kimmerer 2004). This decrease is an indicator of extensive changes in the aquatic food web that may be manifested in a number of ways. Regardless of current declines in turbidity, primary productivity in the Delta is thought to be limited due to low light transmission through the still relatively turbid water column (Cole and Cloern 1984, Kimmerer 2004).

2.3.2.1.2 Chemical Processes

Major chemical processes driving ecological conditions in the Delta include the cycling of nutrients, carbon, and other organic matter. Some important dissolved inorganic nutrients include, but are not limited to, nitrogen in the form of nitrate, nitrite, and ammonium/ammonia (chemical species varies with pH), phosphorus in the form of phosphate, and silicate (Kimmerer 2004). Dissolved organic nitrogen and phosphorus are also present in the system and can be easily recycled by the consumption of organic material by animals and microbes. Sources of nitrogen and phosphorus to the Delta include sewage, urban runoff, oceanic inputs, and agricultural runoff. As noted above, it is generally accepted that, for most of the year in most locations of the Delta, primary productivity is not nutrient-limited; instead, turbitity appears to limit primary productivity as a result of low light levels (Section 2.3.2.5, *Biological Processes*) (Cole and Cloern 1984, Kimmerer 2004). High nutrient concentrations in the Delta are not necessarily beneficial and can cause blooms of harmful phytoplankton species that pose risks to both the aquatic ecosystem and humans, as has occurred in other estuaries (Anderson et al. 2002). For example, blooms of the toxic cyanobacteria, *Microcystis*, have increased since it was first documented in the Delta in 2003 (Lehman et al. 2005), and the blooms may contribute to the reduced concentrations of zooplankton (Pelagic Organism Decline [POD]) (Resources Agency et al. 2007). However, recent work suggests that nutrient concentration explains a small percentage of *Microcystis* abundance patterns (Lehman et al. 2008).

The primary sources of organic carbon for the Delta are its upstream tributaries (Jassby and Cloern 2000). Secondary sources include local phytoplankton and bacterial production and agricultural drainage within the Delta. Most organic carbon from agricultural drainage is derived from peat soils (Jassby et al. 2003). Tertiary sources include discharges from wastewater treatment plants, exports from tidal marsh areas, and possibly aquatic macrophyte production. Benthic microalgal production, urban run-off, and other sources appear to be negligible throughout the Delta.

Organic carbon concentrations are generally reported as particulate until below a threshold size, where they are considered dissolved. Within the Delta, biological production of particulate organic carbon is derived primarily from phytoplankton, although heterotrophic bacteria may contribute a significant proportion of organic carbon to the food web, particularly in the Delta and Suisun Marsh where phytoplankton biomass has declined over the past three decades (Parker et al. 2007). Unlike particulate organic carbon, most dissolved organic carbon (i.e., extremely small particles of organic matter) must be consumed and transformed into larger particles by bacteria before it can be consumed by larger organisms. Since it is a transformation of existing organic carbon and not the production of new organic carbon through photosynthesis by cyanobacteria or phytoplankton, the bacterial transformation of dissolved organic carbon does not add new organic carbon to the food web (Jassby et al. 2003).

Seasonally inundated floodplains such as those in the Yolo Bypass and adjacent to the Cosumnes River provide an allochthonous (export) subsidy of organic matter to other regions of the Delta. Some of this floodplain-generated organic carbon, such as phytoplankton, is especially labile (available to organisms) (Jassby & Cloern 2000, Moyle et al. 2007). Also, since these floodplains are shallower, have longer residence times, and are generally warmer than the mainstem river, they have greater rates of phytoplankton production than do the channels of the rivers (Sommer et al. 2001a).

The oxygen concentration of the aquatic environment is influenced by exchange with the atmosphere, photosynthesis, aerobic and anaerobic respiration, vertical exchange, water temperature, and wind and wave action (Kimmerer 2004). In general, the water in the channels of the Delta is saturated (at equilibrium with the atmosphere) with dissolved oxygen in most areas during most of the year. One common exception occurs during late summer and early fall in the Stockton Deep Water Ship Channel (DWSC) on the San Joaquin River. At that particular location the combination of low river flows, high concentrations of oxygen-demanding organisms (algae from upstream, bacterial uptake of effluent from the City of Stockton Regional Wastewater Control Facility, and other unknown sources), and channel geometry causes rates of biological oxygen demand to exceed rates of gas exchange with the atmosphere and results in a sag (locally depleted concentration) in dissolved oxygen concentration in the Stockton DWSC (Lee and Jones-Lee 2002, Kimmerer 2004, Jassby and Van Nieuwenhuyse 2005). An oxygen diffuser experiment is currently being conducted in the Stockton DWSC to meet Total Maximum Daily Load (TMDL) objectives for dissolved oxygen concentrations established by the Central Valley Regional Water Quality Control Board (2005) (above 6.0 mg/L from September 1 through November 30 and above 5.0 mg/L at all times). Low dissolved oxygen concentrations have also been documented in Old River near the Tracy Boulevard Bridge and occur in multiple dead-end sloughs near Stockton (e.g., Pixley Slough, Mosher Slough, and Five Mile Slough) (CVRWQCB 2009).

Chemical processes can also be important drivers of physical process. For example, low oxygen concentrations in areas with dense growth of tidal emergent vegetation leads to peat formation which allows the surface of the submerged soil to accumulate peat at a rate that maintains its surface at the same relative elevation to sea level. Prior to reclamation activities, natural peat formation was widespread in the Plan Area, and it remains important for maintaining the elevation of the marsh plain of Suisun Marsh. Additionally, in tidal areas of the western Delta and Suisun Marsh, salinity levels and water and soil water oxygen concentrations are both responsive to the frequency and timing of inundation and are the primary factors that determine the physical structure and species composition of tidal marsh plant communities and the rate of peat accumulation. In the Suisun Marsh, changes in salinity cause corresponding changes in species composition, which in turn cause different rates of belowground productivity that then leads to different rates of peat accumulation in the marsh plain (Culberson 2001, Culberson et al. 2004). Variation in peat accumulation rates is likely to result in variation in the rate the marsh can respond to sea level rise.

2.3.2.1.3 Geomorphic Processes

Major geomorphic processes driving ecological conditions in the Delta include sediment transport and erosion. Fluvial and tidal forces (hydrodynamics) directly influence terrestrial as well as aquatic communities. Geomorphic attributes of the Delta are largely determined by the interactions among sediment sources, water flow, and aquatic and terrestrial biota.

The rate of sediment transport into the Delta depends on the magnitude of upstream erosion and downstream transport. Sediment loads increase with higher flows both because the delivery rate is higher and because sediment concentrations in the water column increase due to greater turbulent mixing and scour, leading to resuspension of sediment (Ruhl and Schoellhamer 2004, McKee et al. 2006). Sediment can act as a sink of multiple biologically active materials, including toxics such as pyrethroids and mercury that have settled into or are bound to the sediment. These biologically active materials are then moved with resuspended sediment. Sediment inputs in the Delta are not in equilibrium with exports to the San Francisco Bay and Pacific Ocean, and there are active areas of erosion within the Delta (Ruhl and Schoellhamer

2004, McKee et al. 2006 Cappiella et al. 1999, Ganju and Schoellhamer 2010). Local sediment deposition occurs in low velocity waters, such as near emergent vegetation or in shallower backwaters. These relatively stable deposits can provide suitable substrate for colonization by plants and ultimately may develop into an emergent vegetation community that traps sediment at greater rates by impeding flow and reducing wave energy (pers. comm. C. Simenstad 2007). This vegetation-sedimentation feedback loop leads to gradients of natural community types that correspond to characteristic bathymetric profiles.

Sediment yields have declined by about 50 percent since 1957 through the depletion of erodible sediments that were deposited by mining activity in the 1800s and 1900s, sediment trapping within reservoirs, riverbank erosion protection, levees, and altered land uses (e.g., agriculture) (James 1999, 2004a, 2004b, Wright and Schoellhamer 2004, James 2006, McKee et al. 2006, James and Singer 2008, Singer et al. 2008, James et al. 2009, Singer and Aalto 2009, Ganju and Schoellhamer 2010). This sediment supply reduction may become particularly problematic under predicted future climate change models as it may prevent marsh surface elevations from tracking sea level rise (Section 2.3.2.6, *Effects of Anthropogenic Influence and Future Climate Change*).

2.3.2.1.4 Biological Processes

This section focuses on aquatic environments in the main channels of the tidal waters of the Delta (biological processes for each of the BDCP communities are discussed in the *Natural Communities* section [2.3.4] below). Primary and secondary productivity and energy transfer to higher trophic levels are the biological processes that fuel the ecosystems of the Delta. In the channel waters of the Delta, phytoplankton biomass and production are low relative to other larger estuaries around the world (Jassby et al. 2002). Historically, chlorophyll concentration, a measure of phytoplankton biomass, decreased significantly in each season except spring (April-June) from 1975-1995 (Jassby et al. 2002, 2003), and remains low (Kimmerer 2004). A major driver of this decline may be the 1986 invasion of the overbite clam (Kimmerer and Orsi 1996) (Section 2.3.2.6, *Effects of Anthropogenic Influence and Future Climate Change*). There are spatial gradients within the Delta as chlorophyll concentrations are greater in the southern and eastern Delta, presumably due to longer residence time and greater water clarity (Kimmerer 2004).

In the absence of other factors such as the overbite clam, nutrients do not limit the development of primary producers in the Delta; instead, light levels within the water column appear to control primary productivity (Cole and Cloern 1984, Kimmerer 2004). Light penetration through the water column has an inverse exponential relationship with suspended particulate matter at a given depth. Therefore, the large majority of phytoplankton production occurs near the surface. If the current pattern holds and water clarity continues to increase in the Delta as it has done over the past few decades (Lehman 2000), higher phytoplankton production is expected. However, the growth rate, depth distribution, and extent of Brazilian waterweed and other nonnative invasive aquatic plants may respond positively to increasing water clarity due to reduced particulate matter concentrations and their dense and extensive canopies may drive down light levels (Kimmerer 2004). High concentrations of ammonia and ammonium, which are derived primarily from wastewater treatment plants, may also contribute to reduced productivity in the Delta and bays of the Plan Area by suppressing the uptake of nitrate by diatoms and phytoplankton (Dugdale et al. 2007, Dugdale 2008). It has been hypothesized that this mechanism may have contributed to the unexplained long term decline in primary productivity in the Delta (Kimmerer 2008). Preliminary research supports this hypothesis (Parker et al. 2010). Glibert (in press) has found evidence that spatio-temporal patterns in ratios of ammonia, nitrate, and phosphate concentrations can explain spatial and temporal patterns in algal functional groups (i.e., diatoms, and flagellates), and cyanobacteria in the Delta, and may also explain zooplankton and pelagic fish abundance.

A high abundance of benthic microalgae occurs in shallow subtidal habitat and intertidal mudflats which compose a significant portion of aquatic habitats in the Delta. While this appears to be a potential source of primary productivity, the actual contribution of benthic microalgae to overall organic carbon production appears to be small (Jassby and Cloern 2000, Kimmerer 2004).

Benthic dwelling filter-feeders, particularly the overbite clam, may be responsible for major inter- and intra-annual variation in phytoplankton abundance in the brackish water areas of the western Plan Area. Similarly, in the freshwater areas of the central and eastern Delta the abundance of the Asian clam is inversely related to phytoplankton biomass in subsided islands that have flooded. Together, the combined grazing impacts of these clams may have a major influence in the Delta food web (Lucas et al. 2002). Conversely, grazing on phytoplankton by zooplankton does not appear to be a major sink for primary production in the Delta (Kimmerer 2004).

Within the Delta the general food web is highly complex and variable at multiple spatial and temporal scales, and no attempt has been made to fully reconstruct it. Zooplankton play a critical role in the food web as they represent an important link between primary producers and higher trophic levels. Zooplankton population sizes are very dynamic at short time scales (i.e., weeks to months) (Kimmerer 2004). They are also dynamic over longer time scales as there has been a large decline in zooplankton abundance throughout the Delta since the mid-1970s, and it is hypothesized that the decline is due to a combination of factors that include reduced organic inputs, increased water exports, reduced phytoplankton biomass, and toxic substances in the water (Kimmerer 2004).

Zooplankton community composition varies spatially where copepods are numerically dominant in the brackish water region of the Plan Area, while cladocerans dominate the freshwater region. In the LSZ between those two regions, macrozooplankton, including mysids and epibenthic amphipods, are important food items for many fish species (Kimmerer 2004) as most fish species consume zooplankton for at least part of their lives. Changes in the composition and abundance of the zooplankton community of the Plan Area that are driven by biological invasions and changing water conditions have forced native fish species to adapt to new prey species and caused a reduction of overall carrying capacity of fish in the Plan Area (Bennett 2005).

Both fish and larger epibenthic invertebrates (e.g., crabs and shrimp) have complex life cycles, and their abundances are regulated by multiple environmental factors (Kimmerer 2004). For example, many fish species, due to their anadromous life history, respond to both oceanic and

Delta conditions and transfer energy between both food webs. Additionally, a diverse species assemblage of birds, mammals, amphibians, and reptiles comprise higher trophic levels of the Delta's aquatic food web and consume a variety of invertebrate and fish species. While predation impacts by these species are significant, their overall impact on prey populations is thought to be less important than other sources of mortality (Sommer 2007).

2.3.2.1.5 Effects of Anthropogenic Influence and Future Climate Change

This section focuses on aquatic environments in the main channels of the tidal waters of the Plan Area (biological processes for each of the BDCP communities are discussed in Section 2.3.4, *Natural Communities*).

Ecosystem processes within the Delta have been greatly modified by a variety of anthropogenic influences and are predicted to continue to be modified with future sea level rise and climatic changes. The large extent of wetland reclamation, flood control infrastructure, and channel modifications have transformed the geometry of the Delta from one with a complex structure of branching channels to one of interconnected channels around leveed and diked islands. These channels have created linear and circular flow patterns that are different from the dendritic channel structure that existed before these modifications occurred (Grossinger 2004, Grossinger et al. 2008). Flow rates through the modified channels tend to be greater than in dendritic channels, reducing residence time and leading to a reduction in overall productivity of the Delta. Levees have removed important elevational gradients that historically existed at the interface between aquatic and terrestrial ecosystems.

The construction of dams and reservoirs has dampened the variation that was present in the historical hydrograph of the Delta and has changed the timing of flows through the Delta. Upstream diversions reduce flows into the Delta and in-Delta diversions, including CVP/SWP facilities and over 2,200 non-project diversions, have reduced flow out of the Delta. Operations of the CVP and SWP facilities (including the Delta Cross Channel [DCC], Victoria Canal, and the pumping stations) have altered in-Delta hydrodynamics by altering the direction of water flow such that east to west flows are lower than they were historically, and north to south flows are greater than they were historically.

Return flows from wastewater treatment plants, island drainage, and groundwater seepage have introduced toxic substances into the Delta. Barriers and new channels that were constructed and are operated to maintain water quality (e.g., Head of Old River barrier, and DCC) have significantly altered flow, transport, and mixing of suspended particles, dissolved gases, and dissolved salts in the Delta.

In conjunction with the depletion of erodible sediments from mining, riverbank protection and levees, and altered land uses, the dams and reservoirs have also greatly reduced loads of sediment transported to the Delta and suspended in the water column. Lower sediment load is of particular concern in relation to future climate change because current sediment loads may be insufficient to support a rate of accretion that will keep pace with projected sea level rise.

Nonnative invasive species introductions and population expansions have altered a variety of ecosystem processes in the Delta. The overbite clam has, since its introduction in 1986, had a substantial impact on the aquatic ecosystem (Kimmerer and Orsi 1996, Kimmerer 2004) and that impact has had a greater effect on the Delta's food web than any other known invasion since long-term monitoring in the Delta began. As described above, the clam has caused a loss of summertime phytoplankton in Suisun Bay, declines in phytoplankton in the Delta, reductions in turbidity in both regions, changes in species composition and abundance of zooplankton, alterations of pathways and efficiencies of energy transfer through the food web, and restructuring of the benthic community in downstream bays. Serial invasions and numerical dominance of multiple zooplankton species (e.g., copepods and mysids) have changed the diet composition and breadth of multiple fish species. The introductions of multiple centrarchids species (e.g., largemouth bass and sunfishes) are thought to have directly contributed to the local extinction of Sacramento perch in the Delta (Cohen and Carlton 1995). The introduction of two nonnative invasive aquatic plants, water hyacinth and Brazilian waterweed, has reduced habitat quantity and quality for many native fishes in the Plan Area. Because water hyacinth forms dense floating mats that greatly reduce light penetration into the water column, it can significantly reduce primary productivity in the underlying water column (NMFS 2004). Brazilian waterweed grows along the margins of channels in dense stands that prohibit access by native juvenile fish to shallow water habitat. In addition, the thick cover of these two invasive plants provides excellent habitat for nonnative ambush predators, such as bass and sunfish, which prey on native fish species. Brazilian waterweed is thought to reduce turbidity through a reduction in water velocity, resulting in higher local particle sediment rates, which has been hypothesized to increase predation rates on native fish (Brown and Michniuk 2007).

Toxic substances can interfere with ecosystem processes by reducing growth, reproduction, and survival of species. Herbicide applications can locally limit phytoplankton growth and production rates (Jassby et al. 2003). Many of the pesticides used to control agricultural pests are also toxic to zooplankton. Other sources of flows of toxic substances in the ecosystems of the Plan Area include wastewater treatment plants, urban run-off, and upstream sources. Although there is considerable uncertainty regarding the effects of some of these toxics on fish, at least three mechanisms have been identified through which toxics could affect fish. First, direct exposure to toxics could have negative impacts on fish, especially to more vulnerable life stages such as eggs and larvae. Second, toxic substance-induced mortality of zooplankton, a source of food for nearly all fish species at one or more life stages, could limit food to fish species and result in reduced growth rates, reproductive output, and survival rates. Third, the bioaccumulation of toxics such as mercury and selenium by the overbite clam is well documented. Because some fish (e.g., sturgeon and splittail) and aquatic birds (e.g., surf scoter, American coot, and scaup) forage on the clam, their tissue can bioaccumulate these toxics, thus reducing growth, reproduction, and survival (Luoma and Presser 2000).

If the reduced dry season flows into the Delta and increased sea level due to global climate change occur as predicted by climate models, they will combine to cause salt water intrusion and tidal influence to shift farther upstream. This shift will likely affect biological processes that are dependent on salinity (e.g., rearing habitat for delta native fishes). Reduced flow into the Delta during summer and fall could lead to substantial increases in residence time during those seasons, which would increase water temperature and reduce dissolved oxygen levels to the detriment of native fish and other organisms. With reduced flows into and out of the Delta, toxic substances may accumulate to a greater extent in channels during the summer and fall. The predicted effects of global climate change are discussed in more detail in Section 2.3.3.2, *Climate*.

2.3.2.2 Terrestrial Ecosystem Processes

Terrestrial ecosystems dominate the Plan Area. The present extent of the aquatic ecosystem, as defined by the tidal perennial aquatic natural community, is a relatively small 86,240 acre portion (11 percent) of the 858,372 acre Plan Area. Most of the terrestrial portion of the Plan Area, however, is dominated by human-modified landscape. Intensively managed agricultural lands and managed wetlands comprise 572,623 acres (73 percent) of the Plan Area. Grassland, which is primarily comprised of managed non-natural grasslands on Delta islands and levees, constitutes another 62,880 acres. Together, these three human-managed communities constitute 81 percent of the Plan Area. The ecosystem processes of these communities are almost entirely controlled by human management activities that include disturbance by tilling and disking; regulation of the water cycle by irrigation; chemical enhancement of soil fertility with fertilizers; and control of species composition with herbicides, pesticides, and cultivation.

Agricultural lands retain some natural ecosystem functions. For example, flooded rice fields provide surrogate wetland habitats for species such as the giant garter snake, a BDCP covered species. Hay crops and some annually-cultivated crops provide important foraging habitat for raptors. Winter-flooded croplands provide essential foraging and roosting habitat for the greater sandhill crane, a BDCP covered species, as well as waterfowl and shore birds. Managed wetlands provide productive seasonal wetlands interspersed with permanent wetlands. These wetlands feed large populations of waterfowl and shorebirds through the production of seeds and invertebrates; and their structure is managed to provide nesting and resting, or loafing areas. The majority of the grassland natural community is managed as vacant, typically abandoned crop lands, while a small portion is managed as a source of primary productivity to feed domestic grazing animals and for its small herbivore productivity to sustain birds of prey.

The other terrestrial and wetland natural communities in the Plan Area support more natural ecological processes and native species but constitute only a small portion of the Plan Area relative to human-managed communities. The Plan Area supports 17,338 acres of valley/foothill riparian natural community and 17,298 acres of combined tidal freshwater and tidal brackish emergent wetlands. These three natural communities constitute 4 percent of the Plan Area. The valley/foothill riparian natural community provides a number of ecological functions. It serves as the hydrologic connection between terrestrial uplands and aquatic ecosystems and provides water quality benefits by processing and filtering runoff. It is a source for organic material (e.g., falling leaves), insect food, and woody debris in waterways, and can influence channel dynamics.

Riparian forest and scrub provides habitat for the greatest diversity of wildlife of any community in the Plan Area. In the Delta, these riparian functions are greatly diminished as most riparian habitat is present on levees and within agricultural lands separated from floodplains and natural hydrodynamics and substrates. Tidal freshwater and brackish emergent wetland communities provide ecosystem functions as wildlife habitat, natural chemical filters, and buffers to wave action, and also provide resources to adjacent aquatic ecosystems through their contributions of nutrients and organic material to the shared food web. Tidal wetlands also accumulate peat, which controls the surface elevation and productivity of the Delta's wetlands. Tidal freshwater and brackish emergent wetland vegetation provides rearing habitat for fish species.

Several specialized natural communities of limited distribution in the Plan Area and statewide provide unique ecological conditions that support unique assemblages of plants and wildlife, including many rare species that are covered species under the BDCP. These communities include vernal pool complex, alkali seasonal wetlands complex, and inland dune scrub; collectively they constitute approximately 1 percent of the Plan Area.

2.3.3 Physical Environment

2.3.3.1 Geomorphic Setting

The Delta, Yolo Bypass, and Suisun Marsh are the expression of numerous spatial and temporal variations in regional and local physical processes that, in combination, have established the hydrologic and geomorphic conditions that are present today. One of the most visually-apparent physical features is the enormous north-south trending Central Valley that is almost completely surrounded by mountains and has a single westerly outlet near its midpoint. In and around this valley, tectonic activity has assembled a diverse mixture of elements and minerals, raised the surrounding mountains, and elevated or subsided various sections of the valley floor and regulated its connection to the ocean.

The Central Valley and its surrounding mountains are perched on the Sierra Nevada/Great Valley tectonic microplate, which is more or less solidly attached to the North American tectonic plate to its east. Its western boundary is being distorted by friction caused by the contrary motion of the North American and Pacific tectonic plates as they slide past and buffet each other with the microplate trapped in between (Argus and Gordon 2001, Fay and Humphreys 2008). The distortion of the western margin of the microplate has led to bursts of mountain building in the Coast Range as well as extensive networks of faults that serve to release the built up strains. Both the Coast Range and faults are features that are expressed by the microplate through a thick pavement of oddly shaped and sized blocks composed of shallower and younger layers of the earth's crust. Two of these blocks, the Suisun and the Montezuma Hills, together gave birth to the current opening of the Central Valley to the Pacific Ocean approximately 500,000 years ago and have maintained the opening in the face of extensive tectonic activity in the Coast Range on either side of the gap in the mountains (Loudeback 1951, Sarna-Wojcicki et al. 1985, Weber-Band 1998). The floor of the microplate is not uniform in thickness or rigidity and can roughly be divided into the subsiding south San Joaquin Valley, the stable north San Joaquin Valley, the subsiding Delta region, and the stable Sacramento Valley (Saleeby and Foster 2004, Mikhailov et al. 2006).

The geology of the mountain ranges that surround the Central Valley is extremely complex and beyond the scope of this document (Jennings et al. 1977, Alt and Hyndman 2000, USGS 2005). However, generally described, the geology and rock of the bordering mountains differ when comparing the southern San Joaquin Valley with the northern San Joaquin and Sacramento valleys. The Sierra Nevada range to the east of southern San Joaquin Valley consists primarily of granitic rock while the Coast Range to the west is composed of marine sedimentary rock. Northward, the Sierra Nevada is composed of volcanic lahars near the valley floor, metamorphic and mixed types of igneous rock in the foothills, granitic rocks in the mountains, and a cap of volcanic rock along the crest of the Sierra Nevada. The Coast Range consists of two bands of very different rock. Immediately along the border of the valley is the Great Valley sequence of marine sedimentary rock whereas to the west is the Franciscan complex consisting of marine sedimentary rock, metamorphic rock, igneous rock, and patches of volcanic rock.

Sediment is produced in the mountains and delivered to the Central Valley as locally and regionally heterogeneous mixtures that correspond to the geology of the four mountainous regions described above (Wakabayashi and Sawyer 2001, Curtis et al. 2005). These sediments have different physical and chemical attributes that directly affect the geomorphology of the rivers and streams both upstream and within the Delta, as well as the quality of the water that they deliver to the Delta. Additionally, the rate at which the sediments are delivered to the Delta is partially determined by whether they are detained or trapped in a subsiding region of the Valley floor. Precipitation, which produces and transports the sediment, occurs less in the south and varies from east to west as the parallel set of north-south trending mountain ranges along the longitudinal axis of the valley creates precipitation shadows on their lee faces and large orographic increases on their windward faces (Dettinger et al. 2004, National Atlas of the United States 2009). The amount and type of precipitation intercepted by the mountains is also greatly influenced by glacial/interglacial climatic variation and by periodic deviations from seasonal averages. When precipitation accumulates high in the southern and north-central Sierra Nevada as glaciers, the glaciers grind away at the granitic rock, which is delivered to the Valley as fine material in glacial meltwaters. In contrast, during warm humid periods, chemical weathering of the granitic rock leads to deep and unstable deposits of a sand-like material called grus that is delivered to the valley as deep and permeable alluvial fans (Wahrhaftig 1965, Weissmann et al. 2005). In the central and northern Sierra Nevada, glacial effects have been smaller and erosion is the primary force that delivers material from its diverse rock types to the Valley (James et al. 2002, James 2003, Curtis et al. 2005) and supplies sediment from a diversity of rock types to the Sacramento River (Singer and Dunne 2001). Along the entire Coast Range, erosion attacks the southern marine mudstone and sandstone, Great Valley sequence, and Franciscan complex and delivers fine clay material and a mixture of dissolved elements (mercury, chrome, sodium, magnesium, boron, and selenium) to the Central Valley where they settle out in broad and relatively impermeable alkaline clay plains (U. S. Bureau of Soils 1909, California State Mining Bureau 1918, Bryan 1923, Belitz 1988, Deverel and Gallanthine 1989, Peters 1991, Donnelly-

Nolan et al. 1993, Davisson et al. 1994, Graymer et al. 1994, Graymer et al. 2002, The Natural Heritage Institute 2003, Domagalski et al. 2004a, Domagalski et al. 2004b, Williamson et al. 2005, Hothem et al. 2007, Sommer et al. 2008).

Subtle surface and hidden subsurface factors also directly control the rate and type of sediment and dissolved chemical delivery to the Delta. Underlying the more recent alluvium in the San Joaquin Valley and southernmost region of the Sacramento Valley to near the Dunnigan Hills is the thick and impermeable Corcoran clay that formed the bed of Corcoran Lake which covered the San Joaquin Valley and southernmost Sacramento Valley until it drained through the new opening of the Central Valley to the Pacific Ocean approximately 500,000 years ago (Thomasson Jr. et al. 1960, Sarna-Wojcicki et al. 1985, Belitz 1988). This relatively shallow clay layer controls groundwater/surface water interactions that affect the hydrology and selenium content of the overlying San Joaquin River. Underlying the majority of the Sacramento Valley is the thick and relatively permeable Tuscan Formation that was derived from volcanic ash and mud flows (Olmsted and Davis 1961, Lydon 1968, Jennings et al. 1977, Helley and Harwood 1985, Page 1985, USGS 2005). Because the Tuscan Formation lies on top of the surface of the lower Sierra Nevada foothills before steeply dipping under the Sacramento Valley, and because it is permeable, it intercepts and stores some surface flow as well as deeply percolating water from local sources. Both the Corcoran Clay and the Tuscan Formation contain or control regional aquifers that are used as alternatives to surface flows. Because of tectonic controls and alluvial deposition that are associated with the Sierra Nevada, the San Joaquin River flows northward over its sandy bed along the western border of its valley to the Delta (Weissmann et al. 2005). In contrast, the Sacramento River shifts back and forth across its valley as it flows southward along the Willows Fault, is deflected to the east by the subsurface Colusa Dome, and is deflected to the east again by the delta of Cache Creek (Larsen et al. 2002, Singer 2008, Singer et al. 2008). Gravels are largely trapped upstream of the Colusa Dome while sand and finer sediment are carried downstream (Singer 2008).

Due to its lesser gradient, greater proportion of sand to finer sediment, and smaller flows, the San Joaquin River is a braided river with numerous sloughs as it flows northward toward the Delta. In contrast, the Sacramento River is bordered by broad and high natural levees that isolate it from seven adjacent flood basins as it flows southward to the Delta, and its single channel becomes increasingly stable as it approaches and enters the Delta (Hitchcock et al. 2005, Singer et al. 2008). The natural levees were formed when overbank flow deposited suspended sediment. When the deposits were made into floodplain waters at equal elevation to the main channel, the result was steep levees with coarse material that rapidly graded into fine deposits in the floodplain (Adams et al. 2004). Alternatively, when sediment was deposited by floodplain waters at lower levels than the main channel, the result was more gently sloped broad levees where sediment texture fined less rapidly (Adams et al. 2004). The banks of the levees can be stabilized by vegetation (Thompson 1961, Stainstreet and McCarthy 1993, Larsen et al. 2002, Adams et al. 2004) and channels or crevasses connecting the channel to the river can exist for hundreds to thousands of years (Rowland et al. 2009). The Sacramento River levee from the upper end of the Yolo Basin to Cache Slough has a number of crevasses with characteristic sand splays and connecting sloughs (Thompson 1960, Robertson 1987, Hitchcock et al. 2005, Singer et al. 2008). Both Cache Creek and Putah Creek discharge into the Yolo Basin, and their waters do not join the channel of the Sacramento River until Cache Slough near the center of the Delta. Under historical flood conditions, the combined flow through Cache Slough was often greater than the flow in the Sacramento River Channel and under natural conditions created a hydraulic dam at their confluence which backed up the Sacramento River (Thompson 1960, Roos 2006, James and Singer 2008, Singer et al. 2008). The Mokelumne River discharges into the San Joaquin River on the eastern side of the Delta and only became tidally influenced within the last 1,000 years compared to approximately 6,000 years ago for the rest of the Delta (Shelmon 1971, Brown and Pasternack 2005). Marsh Creek, on the southwestern edge of the delta, has migrated back and forth across its broad alkaline clay alluvial plain and has discharged at different points into that area of the Delta (The Natural Heritage Institute 2003, SFEI 2010).

Approximately 21,000 years ago, the last glacial maximum ended and eustatic sea level began to rise from the lowstand of -394 feet (-120 m) in a series of large meltwater pulses interspersed by periods of constant rising elevation until the Laurentide ice sheet had completely melted 6,500 years ago and the rate of sea level rise slowed dramatically (Edwards 2006, Peltier and Fairbanks 2006). The modern Delta formed sometime between 10,000 and 6,000 years ago when rising sea level flooded a broad valley. The inlet elevation to the valley is constrained by river-cut notches in the bedrock under the Carquinez Strait and the east end of Sherman Island at depths of -131 feet (-40 m) and -121 feet (-37 m) below current sea level respectively, which are elevations that would have been flooded by rising sea levels approximately 10,000 years ago (Shelmon 1971, Peltier and Fairbanks 2006, Drexler et al. 2009a). Until approximately 6,700 years ago, sediment deposits in the central and western Delta were primarily composed of mineral alluvium. Since that time, peat has accumulated from depths of approximately -30 feet (-9 m) to the current sea level (Goman and Wells 2000, Drexler et al. 2009a). These deposits could have only accumulated under anaerobic conditions present in a permanently flooded Delta, likely maintained by high sea levels (Drexler et al. 2009a). This hypothesis is supported by fluctuating levels of oceanic-derived salinity as indicated by shifts in the dominance of aquatic plant species that are adapted to either brackish or freshwater conditions (Goman and Wells 2000, Byrne et al. 2001, Malamud-Roam and Ingram 2004, Malamud-Roam et al. 2006, Malamud-Roam et al. 2007, Watson and Byrne 2009).

At Browns Island in the western Delta, the transition to peat was apparently interspersed with periods dominated by fine mineral sediments, whereas peat developed abruptly and continuously in the central Delta (Drexler et al. 2009a). Sea level would have been approximately -13 ft (-4 m) below its current level 6,000 years ago (Peltier and Fairbanks 2006). There is currently no explanation for the approximately 13 ft (4 m) of additional peat in the central Delta, the difference between sea level 6,000 years ago and peat deposits that extend to a depth of approximately -26 ft (-8 m) (Drexler et al. 2009a), although at least a portion of this difference could be attributed to tectonic subsidence as there is a 10-ft high scarp along the Midland Fault in this area (Unruh and Hitchcock 2009).

Although the geomorphology of the Delta has often been described as a typical "bird's foot" delta, this description inaccurately describes the complex system of alluvial fans and flood basins that were converted into multiple deltas when they were drowned by rising sea level and that are visually apparent when viewing historical maps and aerial photographs (Hitchcock et al. 2005, Grossinger et al. 2008). The complex geomorphology of sea level induced deltas is just beginning to be studied and understood (Shelmon 1971, Blum and Tornqvist 2000, Parker et al. 2008). Under these dynamic conditions, deltas can be single thread linear channels, large fans, or complex combinations of different forms (Atwater et al. 1979, Blum and Tornqvist 2000, Hitchcock et al. 2005, Kim et al. 2009, Van Dijk et al. 2009).

Suisun Marsh lies immediately to the west of the Delta in a subsiding basin (Unruh and Hector 1999) between the bedrock notches of Carquinez Strait and Sherman Island, and because the base elevation of Suisun Bay is controlled by the bedrock notches upstream and downstream, it probably was flooded by rising sea level at the same time as the central Delta. Two studies conducted at Rush Ranch, which is at the northern end of the marsh and distant from the main channel that runs from Suisun Bay to the San Francisco Bay, indicate that marsh vegetation at that location established between approximately 3,000 and 2,500 years ago (Byrne et al. 2001, Malamud-Roam and Ingram 2004). Suisun Marsh is unique in that its water is brackish with salinities that have varied from fresh at its eastern end to nearly saline at its western end depending on the combined flow volume of the Sacramento and San Joaquin rivers (Goman and Wells 2000, Byrne et al. 2001, Malamud-Roam and Ingram 2004, Malamud-Roam et al. 2006, Malamud-Roam et al. 2007, Watson and Byrne 2009). Additionally, flows into the north end of the marsh from Green Valley Creek can reach 5,000 cfs and can affect the salinity of the water both in the channels and on the marsh plain (Burau 2004). Increasing salinity levels can shift the species composition from highly productive freshwater-adapted plants to much less productive salt-adapted plants (Byrne et al. 2001, Culberson 2001, Boul and Keeler-Wolf 2008, Watson and Byrne 2009), influencing the rate of peat bed development and the elevation of the marsh surface above sea level (Culberson et al. 2004). Early charts of the marsh display classic tidal channel geomorphology with channels interspersed with ponds and the boundary of the upper margin of the marsh traced with salt pannes (Grossinger 2004). A salinity gradient exists as salt accumulates in areas more distant from channels that are not flushed by the tides during the rainless summer months (Sanderson et al. 2000, Culberson 2001, Culberson et al. 2004, Watson and Byrne 2009). The duration of tidal inundation also affects the distribution of plant species at the upper margin of the marsh (Culberson 2001, Watson and Byrne 2009) and establishes bare mudflats at the lowest areas of the marsh adjacent to Suisun Bay (Cappiella et al. 1999).

The natural geomorphology of the Delta, Yolo Bypass, and Suisun Marsh has been greatly altered by anthropogenic changes in sediment supply, flood control projects including levee building and draining, mosquito ditches in Suisun Marsh, and by large water dam and diversion projects throughout its watershed. The impact of the enormous pulse of sediment produced by hydraulic mining from 1853-1884 has been well-documented (Gilbert 1917, Kelley 1989, Mount 1995, Kimmerer 2004, Shvidchenko et al. 2004, James and Singer 2008, Keller 2009), but it is less well-known that additional mining sediment was produced between 1893-1953, and that large quantities of sediment still remain in reaches below dams (James 1999, 2006, James et al. 2009). The initial pulse of sediment increased flooding along the Sacramento River and built extensive mudflats on the outer margin of Suisun Marsh as the sediment made its way to the San Francisco Bay (Gilbert 1917, Kelley 1989, Mount 1995, Keller 2009). Current sediment supply rates are too low to sustain those mudflats and other features that were created prior to the building of large debris dams and water storage dams, and those features have been eroding for many years (Cappiella et al. 1999, Kimmerer 2004, Wright and Schoellhamer 2004, McKee et al. 2006, Ganju and Schoellhamer 2010). Levee building has affected the Plan Area in diverse ways. Upstream of the Delta along the Sacramento River and in the various flood basins, levee building has both trapped and sped the delivery of sediment to the Delta (James 1999, Singer and Dunne 2001, James 2004a, 2004b, 2006, Mikhailov et al. 2006, James and Singer 2008, Singer 2008, Singer et al. 2008, James et al. 2009, Singer and Aalto 2009). In the Delta proper, levees and various land uses have reduced the depth of peat soils within the confines of the levees to depths of -24 feet (-7.25 m) (Drexler et al. 2009b), which creates an enormous volume of accommodation space that, in the event of a levee break, will bring saline and brackish water from the west further into the Delta (Mount and Twiss 2005).

As noted above, the alluvium underlying the Sacramento-San Joaquin Delta is dominated by Quaternary alluvial deposits in the channels and on the levees and peat beds in the center of the islands (Figure 2-3). The peat beds, combined with historical floodwater alluvial deposits of fine mineral particles, have provided highly fertile and productive soils to support the agriculture industry throughout the Plan Area (Figure 2-4). The smaller extent of mineral soils, including soils in the map units Zamora-Rincon-Capay-Brentwood, Veritas-Tinnin-Delhi, and Willows-Waukena-Pescadero-Fresno, are located primarily along the western and southern edges of the Plan Area (Figure 2-4).

Prior to reclamation for agriculture, much of the vegetation of the Delta (approximately 380,000 acres; 1538 km^2) was dominated by tidal marshes (Atwater 1980, The Bay Institute 1998). By 1930, island reclamation was complete, and by 1980, only about 16,000 acres (65 km^2) of marshes remained (Atwater 1980, The Bay Institute 1998). Today, these areas of former tidal marshes consist primarily of channelized waterways surrounding highly productive row-cropped agricultural islands that are protected from flooding by over 1,300 miles (2,093 km) of levees. Dewatering of the marshes and plowing the peat soils for farming have led to peat oxidation losses, soil compaction, and erosion of the islands, resulting in surface subsidence. The result is that the interiors of many Delta islands have substantially subsided and are now depressions well below the level of the surrounding water, protected only by a ring of levees (Figures 2-5 through 2-9).

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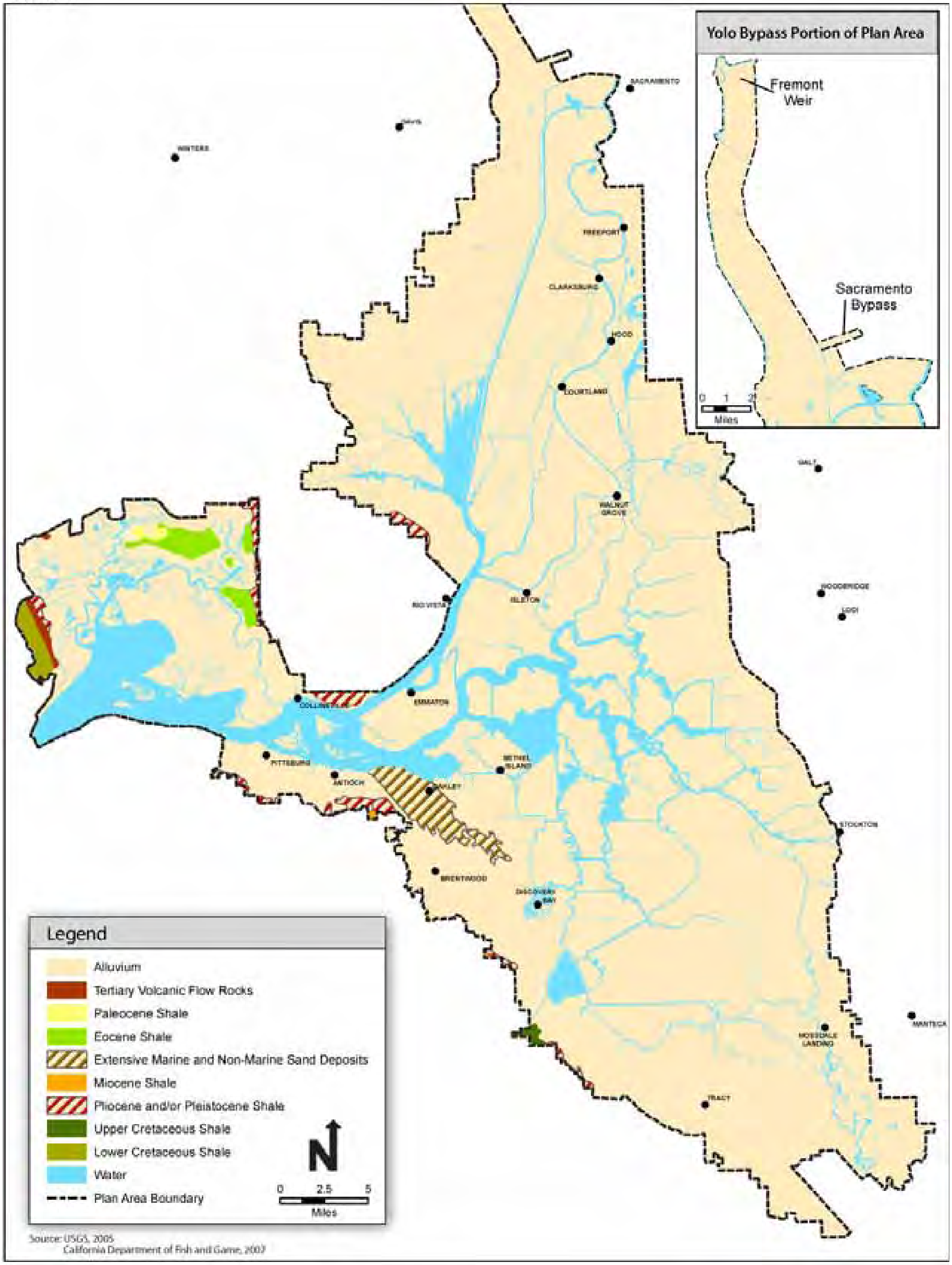

Figure 2-3. Geology of the BDCP Plan Area

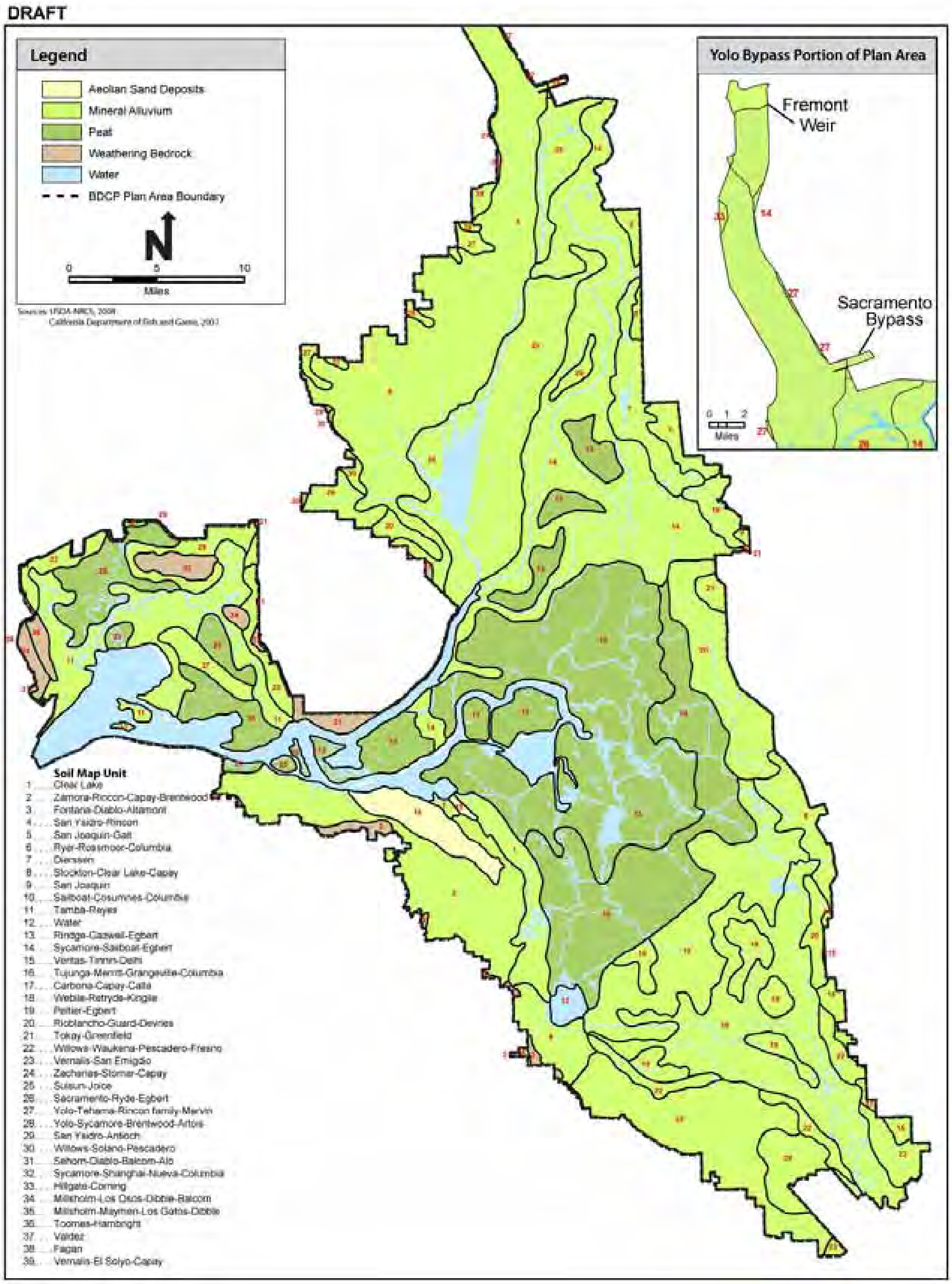

Figure 2-4. Soil Types of the BDCP Plan Area

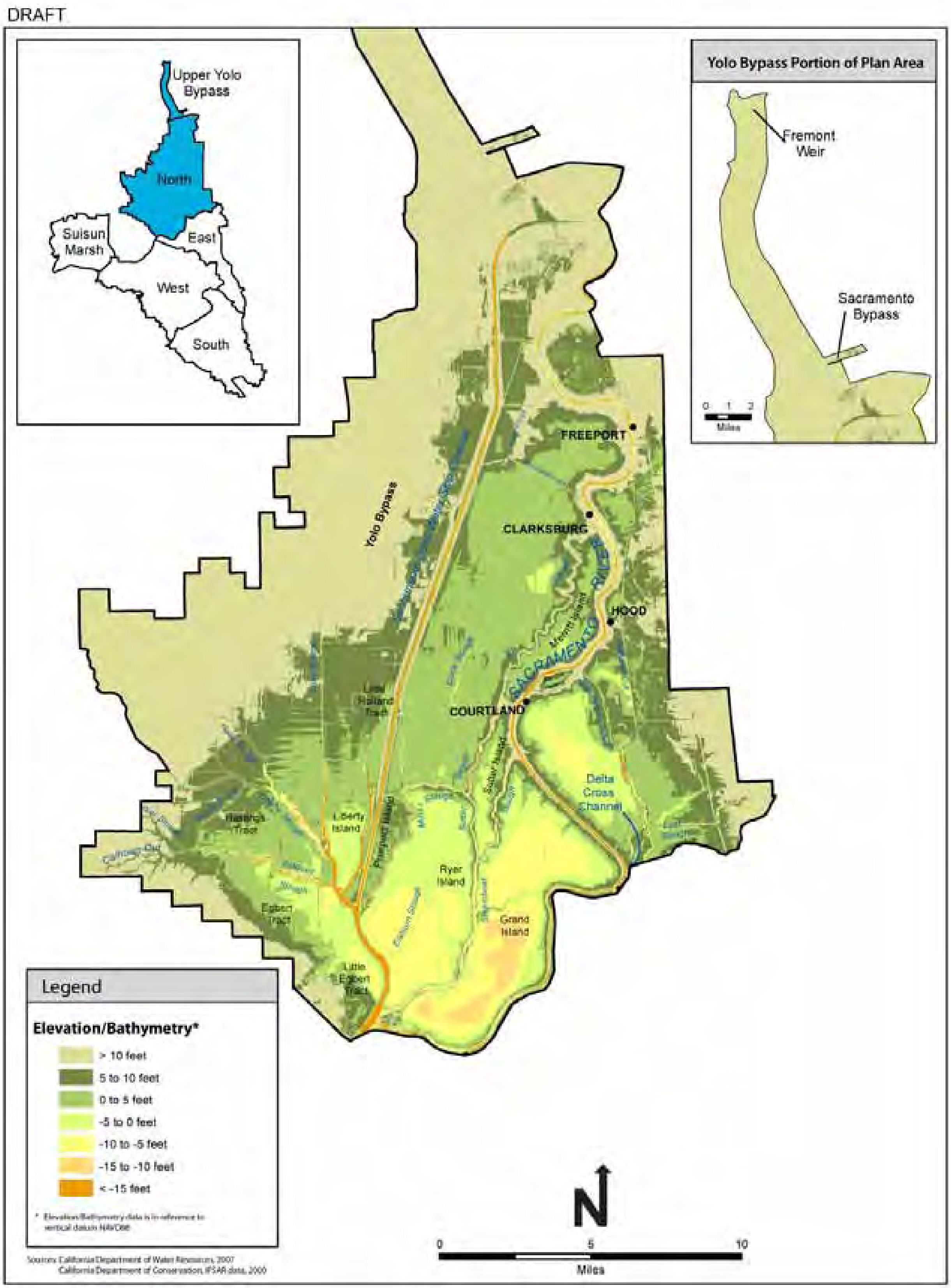

Figure 2-5. Bathymetry and Elevation Data – North Delta and Upper Yolo Bypass

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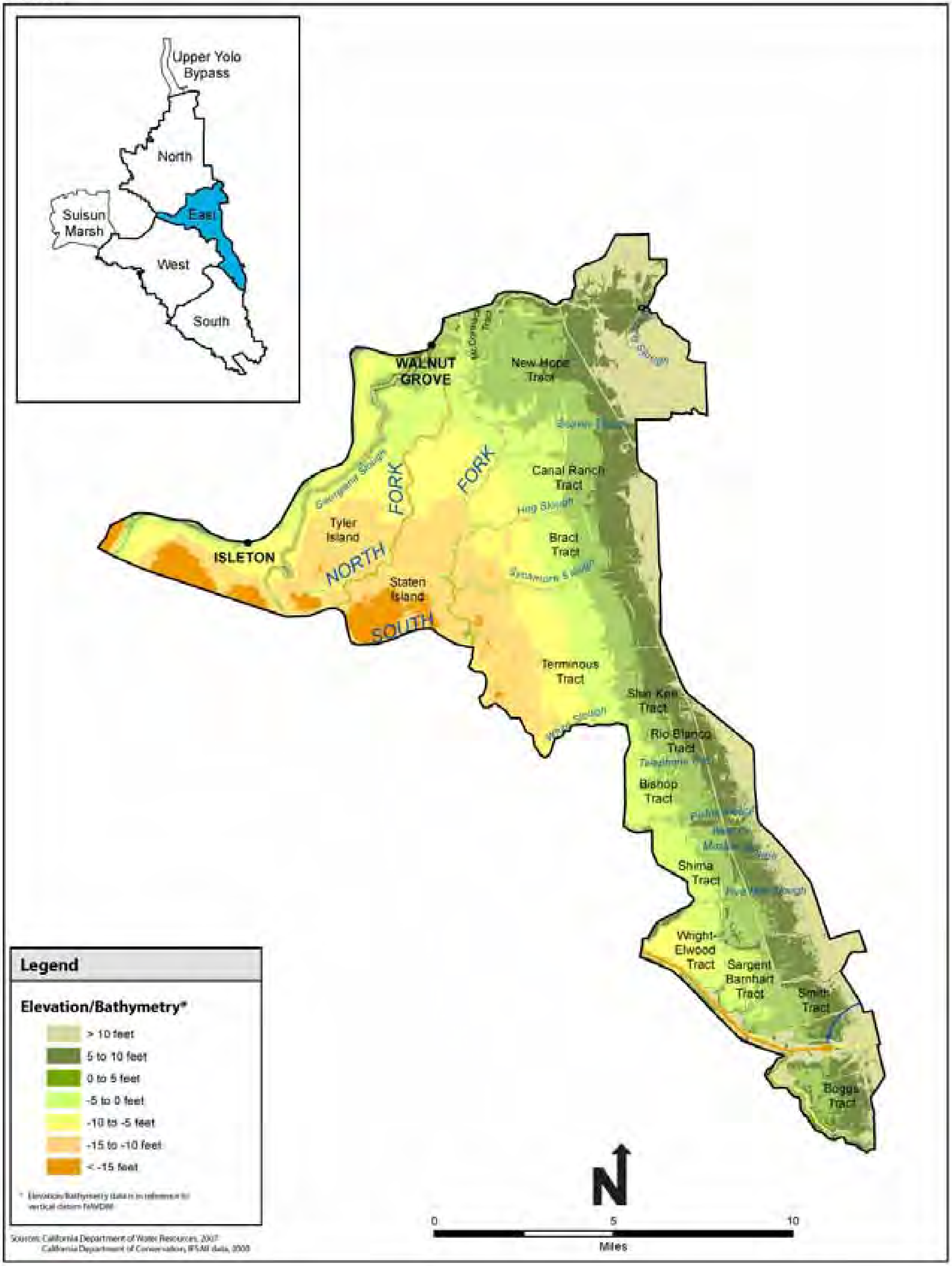

Figure 2-6. Bathymetry and Elevation Data – East Delta

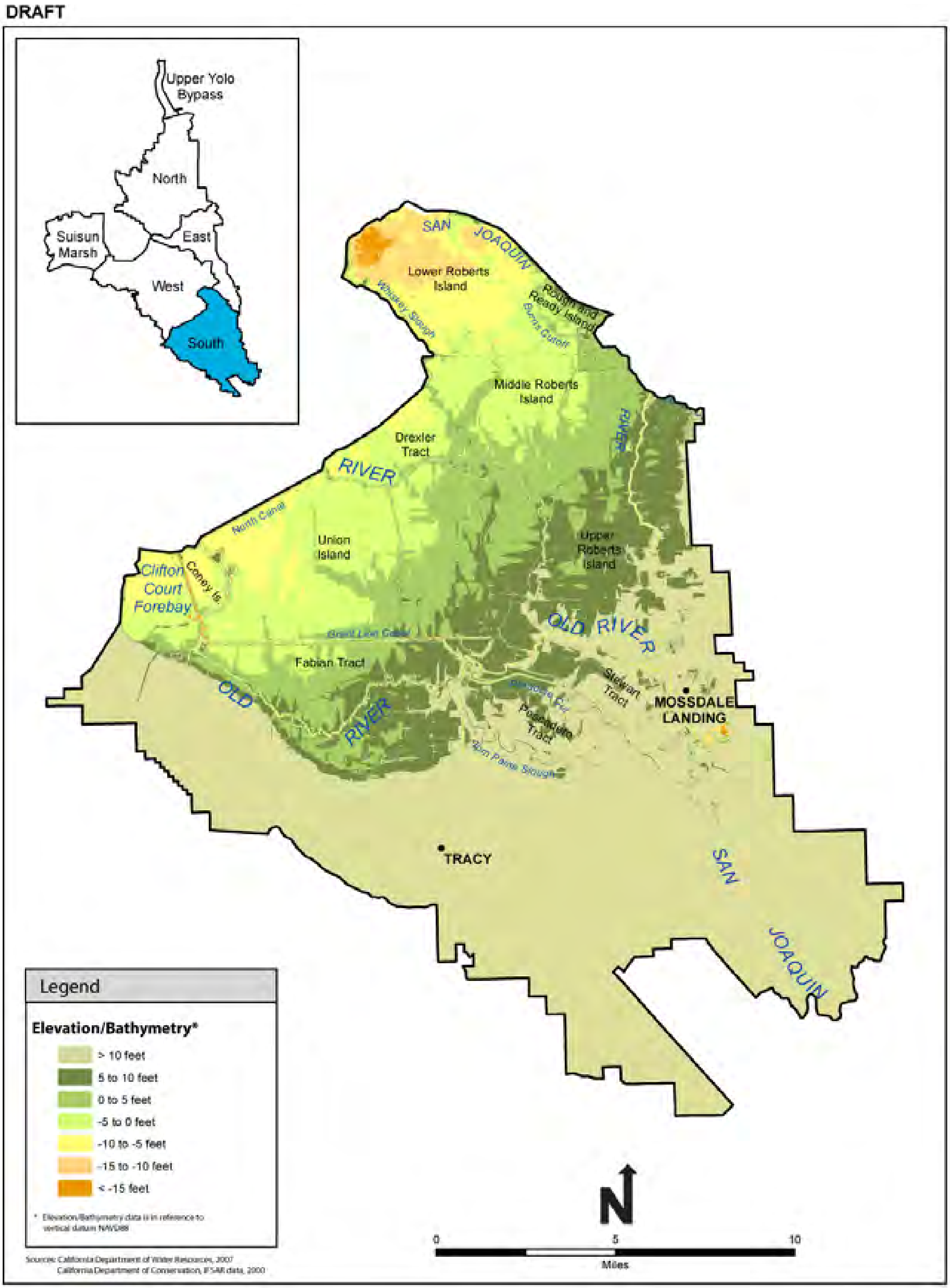

Figure 2-7. Bathymetry and Elevation Data – South Delta

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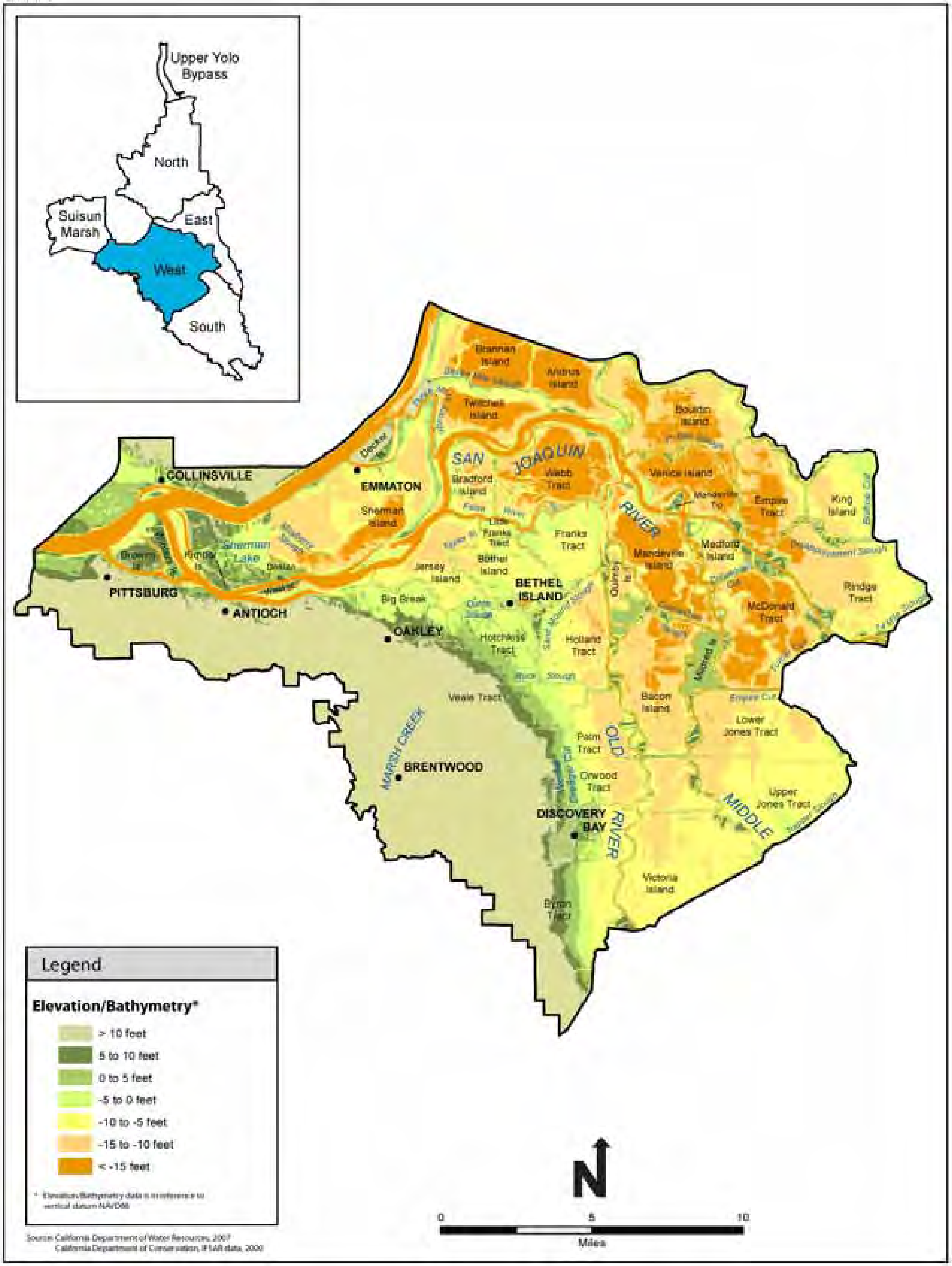

Figure 2-8. Bathymetry and Elevation Data – West Delta

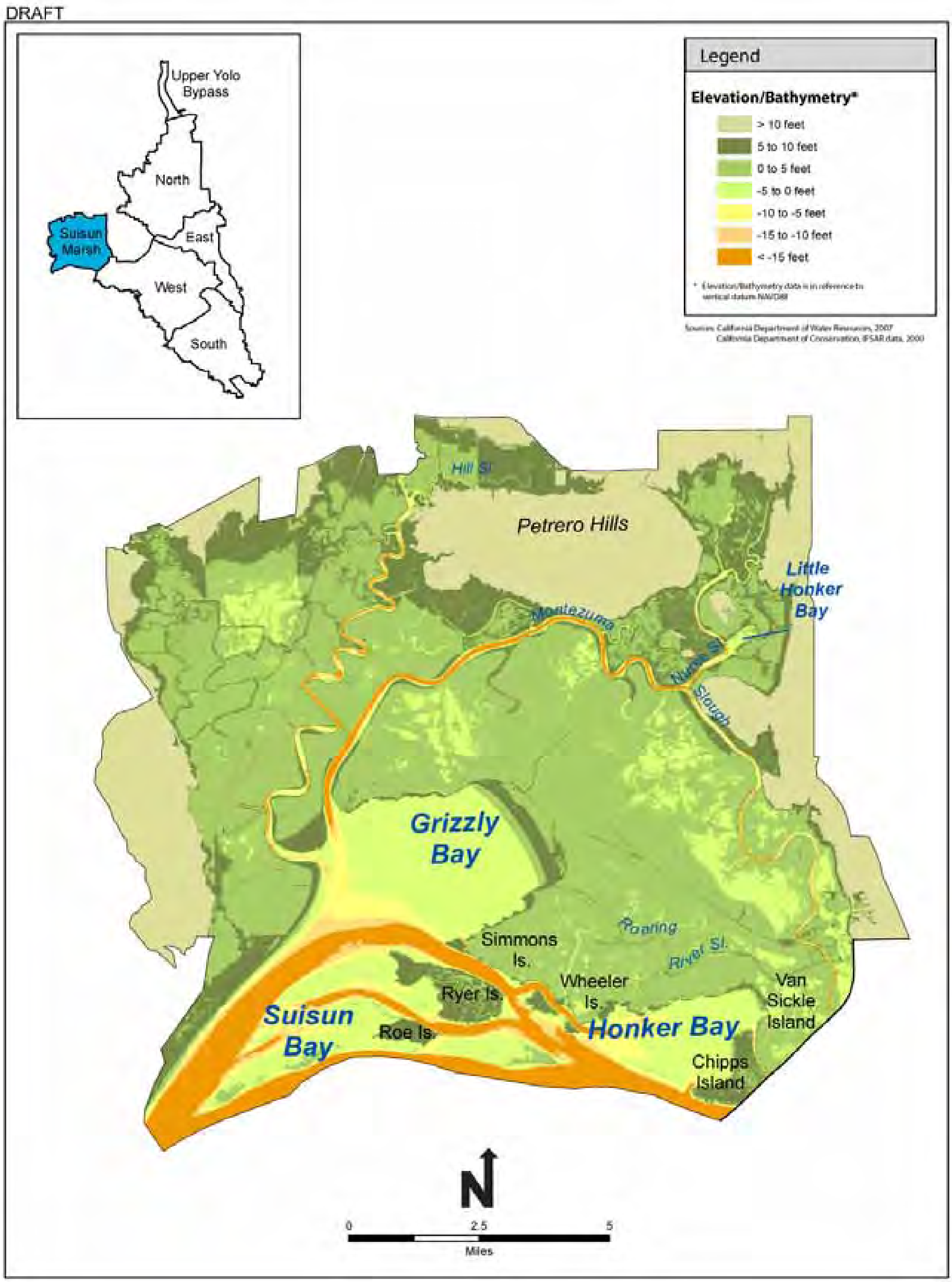

Figure 2-9. Bathymetry and Elevation Data – Suisun Marsh

2.3.3.2 Climate

The climate in the Sacramento-San Joaquin Delta region is spatially variable, but is generally characterized as hot Mediterranean (Köppen climate classification) (McKnight and Hess 2005). The general climate becomes milder from east to west due to marine influence as it is affected by influxes of winds off of the Pacific Ocean.

Summers are hot with average daily highs from June through September in the upper 80s degrees Fahrenheit (°F) to lower 90s °F with very little to no precipitation and low humidity. Heat waves are common in summer months, during which temperatures can reach triple digits for consecutive days. Periodically, a "Delta breeze" of cool and humid air from the ocean moves onshore and cools the Central Valley in the vicinity of the Delta by up to 7°F (3.9 degrees Celsius [°C]) (Pierce and Gaushell 2005). Winters are mild (average daily highs during November through March are in the mid-50s to mid-60s °F) and wet. Approximately 80 percent of annual precipitation occurs between November and March. The primary origin of precipitation is the seasonal arrival of low pressure systems from the Pacific Ocean. Very dense ground fog (tule fog) is common between periods of precipitation in the Plan Area from November through March.

The climate of the Plan Area is predicted to change in complex ways. Although there is high uncertainty, temperatures in the Plan Area are projected to increase at an accelerating pace from 3.6 to 9°F (2 to 5°C) by the end of the century (Cayan et al. 2009). Depending upon the general-circulation model used, there are variable predictions for precipitation change, with most models simulating a slight decrease in average precipitation (Dettinger 2005, California Climate Change Center 2006). The Mediterranean seasonal precipitation experienced in the Plan Area is expected to continue, with most precipitation falling during the winter season and originating from North Pacific storms. Although the amount of precipitation is not expected to change dramatically over the next century, seasonal and interannual variation in precipitation will likely increase as it has over the past century (DWR 2006). This could lead to more intense winter flooding, greater erosion of riparian habitats, and increased sedimentation in wetland habitats (Field et al. 1999, Hayhoe et al. 2004).

Global sea level rise predictions vary. One model predicts that by the end of this century, global sea level will increase by 7 to 23 inches (18 to 59 cm); with an additional 6 inches (15 cm) of sea level rise if the rate of Greenland ice-melt intensifies (Intergovernmental Panel on Climate Change 2007). Another model projection for sea level rise has produced mid-range estimates from 28 to 39 inches (70 to 100 cm) by the end of this century, with a full range of variability from 20 to 55 inches (50 to 140 cm) (Rahmstorf 2007). Recently issued U.S. Army Corps of Engineers guidance on incorporation of sea level rise in civil works projects suggests end of century sea level rise in the range of 20 to 59 inches (50 to 150 cm) (USACE 2009).

Predicted warmer temperatures will affect the rate of snow accumulation and melting in the snowpack of the Sierra Nevada. Some projections predict reductions in the Sierra Nevada spring snowpack of as much as 70-90 percent by the end of the century (California Climate Change Center 2006). Knowles and Cayan (2002) estimated that a projected warming of 3°F (1.6°C) by 2060 would cause the loss of one-third of the watershed's total April snowpack, whereas a 4°F (2.1°C) warming by 2090 would reduce April snowpack by 50 percent. The loss of snowpack is predicted to be greater in the northern Sierra Nevada than in the southern Sierra Nevada because of differences in the relative amounts of low- and mid-elevation snowpack (DWR 2006). Measurements taken to track the water content of snow (snow water equivalent [SWE]) since 1930 show that peak snow mass in the Sierra Nevada has been occurring earlier in the year by 0.6 days per decade (Kapnick and Hall 2009). These predicted changes in the dynamics of the snowpack will influence the timing, duration, and magnitude of inflow from the Sacramento and San Joaquin River watersheds. For example, with more precipitation falling as rain instead of snow and the snowpack melting earlier, greater peak flows will result during the rainy season and lower flows during the dry season. Knowles and Cayan (2004) predict that inflows will increase by 20 percent from October through February and decrease by 20 percent from March through September. Storm surges (tidal and wind-driven) associated with the more intense storms predicted for the future will also exacerbate Delta flooding.

2.3.3.3 Hydrologic Conditions

2.3.3.3.1 River Hydrology

The hydrology of the Plan Area is primarily influenced by freshwater inflows from the Sacramento River from the north and the San Joaquin River from the south. East-side streams, particularly the Mokelumne River, also contribute inflows to the Plan Area. Numerous upstream dams and diversions greatly influence the timing and volume of water flowing into the Delta. There are multiple upstream tributaries to the Sacramento and San Joaquin rivers that influence flow into the Plan Area. The Feather and American rivers and many large creeks drain directly into the Sacramento River while the Cache and Putah creeks drain into the Yolo Bypass which joins the Sacramento River in the Cache Slough area (Figure 2-10). The Yuba and Bear rivers drain into the Feather River before its confluence with the Sacramento River. The Calaveras, Stanislaus, Tuolumne, Merced, and Kings rivers drain into the San Joaquin River upstream of the Delta. The Cosumnes River drains directly into the Mokelumne River, and both drain into the San Joaquin River after entering the Delta. In addition to the Sacramento and San Joaquin deltas, the Mokelumne delta in some ways can be viewed as a third important river delta.

Regardless of water-year type, the large majority of unimpaired upstream flow into the Delta originates from the Sacramento River and its tributaries, and a lesser extent originates from the San Joaquin River and its tributaries (Figure 2-11). The Cosumnes and Mokelumne rivers and other smaller tributaries, collectively called the "Eastside Tributaries" in Figure 2-11, contribute only a small percentage of inflows. Upstream diversions reduce the total inflow from upstream rivers and tributaries. Only a small proportion of water, relative to upstream flows, enters the Plan Area through precipitation. In the 2000 Water Year, an above normal water year, nearly 70 percent of water entering the Delta passed through the system as outflow, 6 percent was consumed within the Delta, less than 1 percent was diverted via the North Bay Aqueduct and

Contra Costa Water Districts, and 24 percent was exported via SWP and CVP facilities (Figure 2-12). Additional water was taken upstream of the Delta in upstream diversions and reservoirs that accounted for an additional 7525 thousand acre feet (TAF) (Governor's Delta Vision Blue Ribbon Task Force 2008). These values vary by water year type and the inflows associated with the water year (Figures 2-12 and 2-13). For example, in the 2001 water year, a dry year, approximately 54 percent of water entering the Delta passed through the system as outflow, 13 percent was consumed within the Delta, and 39 percent was exported via SWP and CVP facilities (Figure 2-13). Because exports and in-Delta use are relatively consistent among years, inflows affect Delta outflow most significantly, with a lower proportion of water exiting the system as outflow during drier years and a higher proportion during wetter years.

The hydrograph of the Delta is highly variable both within and among years (Figure 2-14). Within years, water flow is generally greatest in winter and spring with inputs of wet season precipitation and snowpack melt from the Sierra Nevada and lowest during fall and early winter before significant rainfall. The construction of upstream dams and reservoirs for flood protection and water supply has dampened the seasonal variation in flow rates. Water is released from reservoirs year-round, and flooding is much less common than it was before dam and levee construction. As a result, the frequency of small- to moderate-sized floods has been significantly reduced since major dam construction, although the magnitude and frequency of large floods has not been significantly altered; additionally, because of climatic changes there have been more large floods in the last 50 years than the previous 50 years. Among years, wet and dry periods (defined as periods during which unimpaired runoff was above or below average, respectively, for three or more years) occurred numerous times in the last 100 years; although the duration and magnitude of the wet and dry periods have increased in the last 30 years, including the 6-year drought of 1987 to 1992 and the prolonged periods of wetness in the early- to mid-1980s and the mid- to the late-1990s (Dayflow 2007). The wet and dry periods recorded over the last 150 years, however, are less severe and shorter than the prolonged wet and dry periods of the previous 1,000 years.

The Yolo Bypass is an important physical feature affecting river hydrology during high flow events in the Sacramento River watershed. The bypass is a 59,280-acre engineered floodplain that conveys flood flows from the Sacramento River, Feather River, American River, Sutter Bypass, and western tributaries and drains (Figure 2-15) (Harrell and Sommer 2003). The leveed Bypass protects Sacramento and other nearby communities from flooding during high water events. Most water enters the Yolo Bypass by spilling over the Fremont and Sacramento weirs and returns to the Sacramento River in the Delta approximately 5 miles upstream of Rio Vista. The Yolo Bypass floods seasonally in approximately 60 percent of years (Sommer et al. 2001b) and can convey up to 80 percent of flow from the Sacramento basin during high water events (Sommer et al. 2001a).

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Figure 2-10. Major California Waterways Influencing the BDCP Plan Area

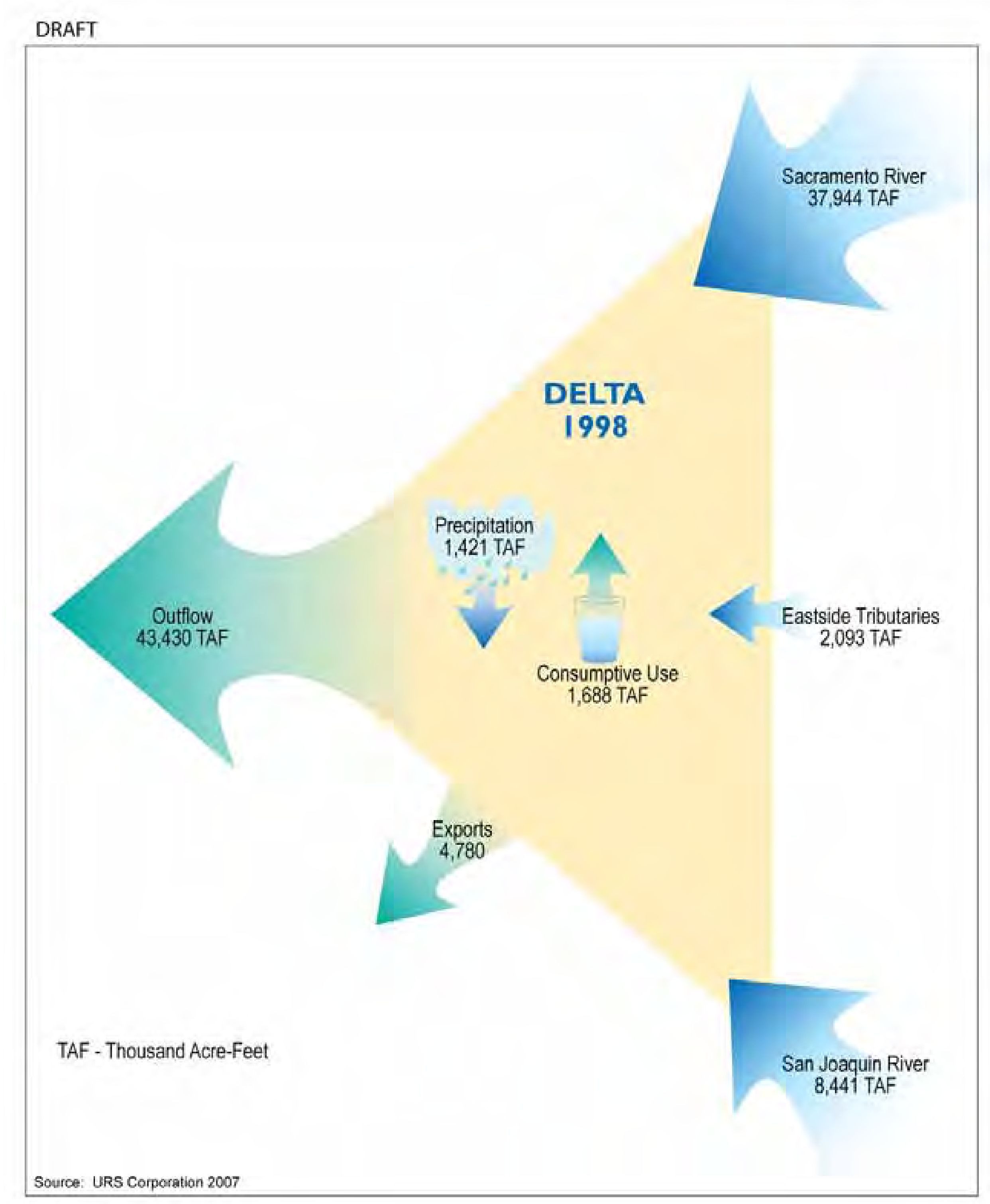

Figure 2-11. Example Delta Water Balance for 1998 Water Year (Wet Water Year)

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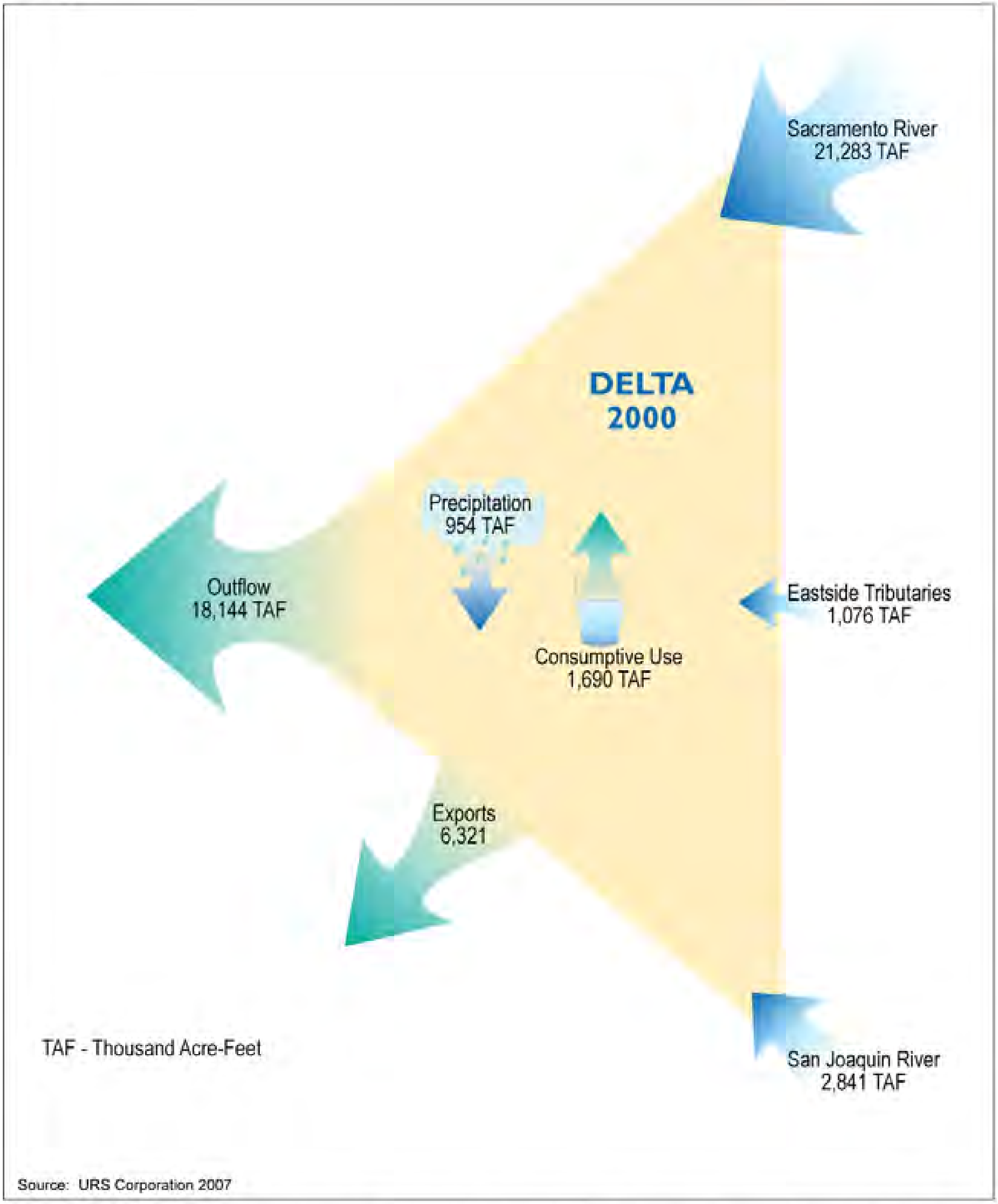

Figure 2-12. Example Delta Water Balance for 2000 Water Year, an Above Normal Water Year

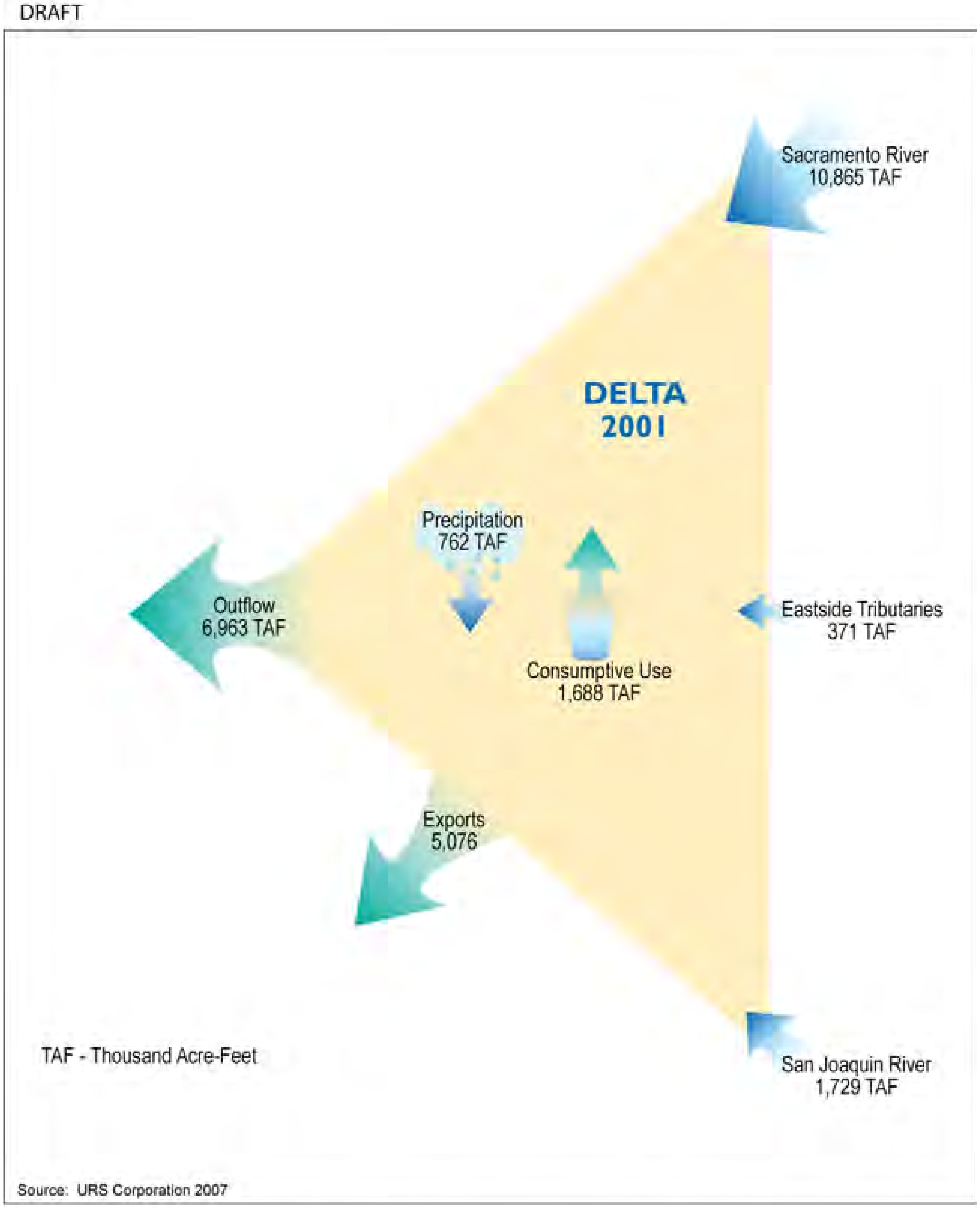

Figure 2-13. Example Delta Water Balance for 2001 Water Year, a Dry Water Year

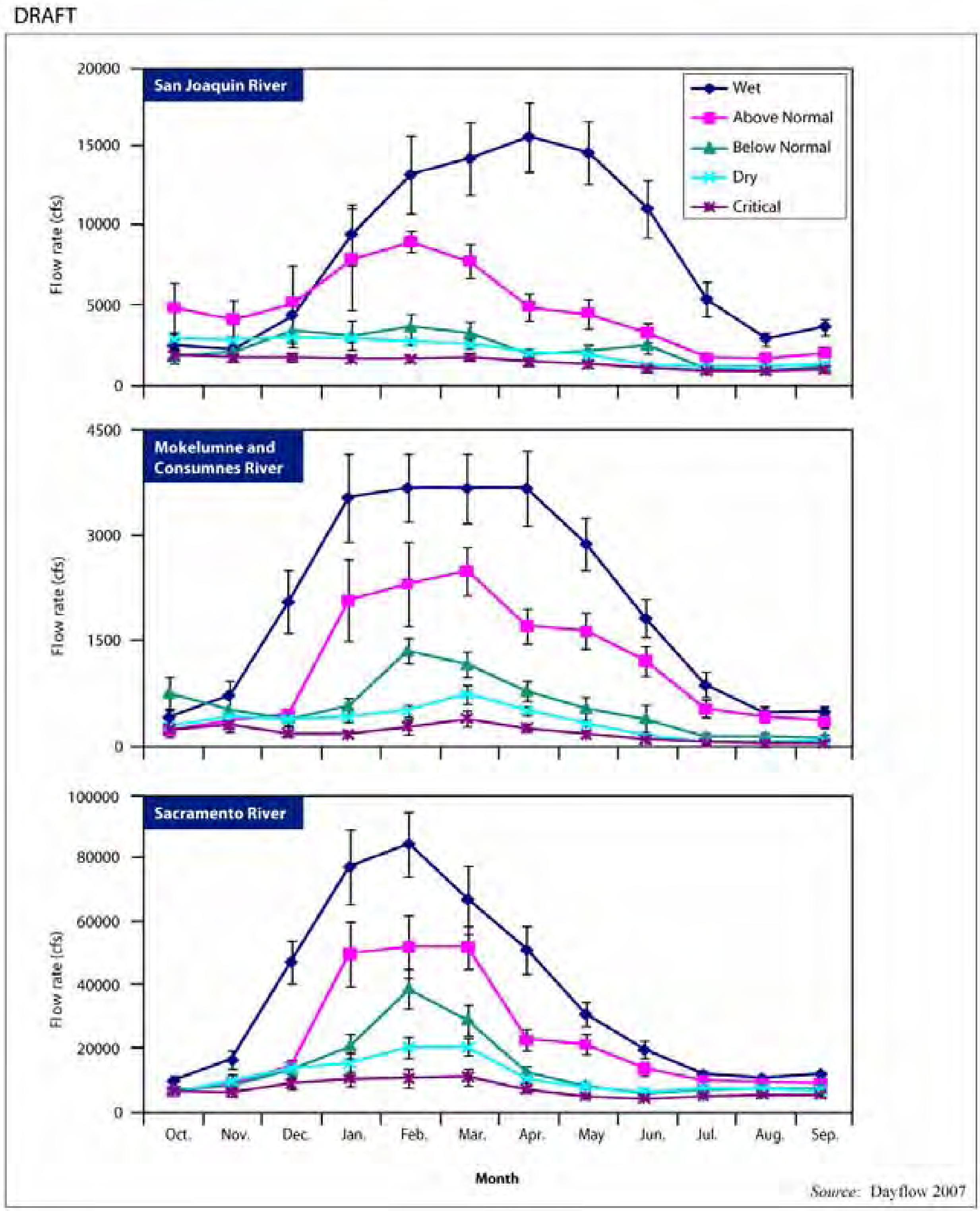

Figure 2-14. Average Monthly Flow Rates in (a) San Joaquin, (b) Mokelumne and Cosumnes, and (c) Sacramento Rivers by Water Year Type between 1956 and 2006

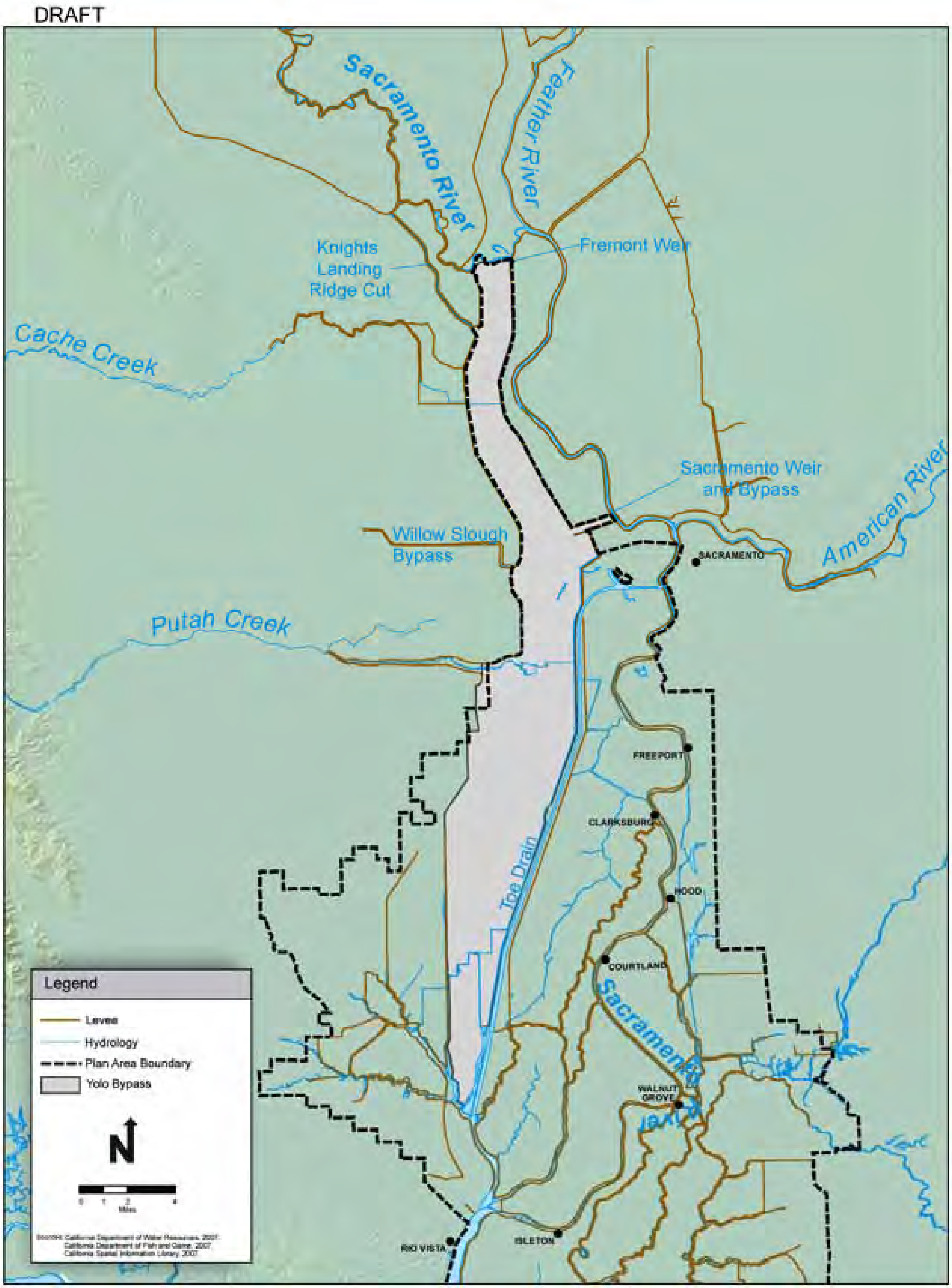

Figure 2-15. Yolo Bypass Intakes and Effluents

2.3.3.4 Tides

The Delta, lower portion of the Yolo Bypass, and Suisun Marsh are tidally influenced by the Pacific Ocean, although tidal range and influence decreases with increasing distance from the San Francisco Bay (Kimmerer 2004, Siegel 2007). Tides are mixed semidiurnal with two highs and two lows each day, one large magnitude high and low, and one lower magnitude high and low. A typical diurnal range is 3.3 to 4.6 feet (1 to 1.4 m) in the western Delta (Orr et al. 2003). The entire tidal cycle is superimposed upon the larger 28-day lunar cycle with more extreme highs and lows during spring tides and depressed highs and lows during the neap tides. In addition, there is an annual cycle in which tidal elevation is greatest in February and August. The multiple temporal scales at which these cycles occur causes significant variation in draining and filling of the Delta, and therefore, in patterns of mixing of the waters (Kimmerer 2004). Additionally, variation in sea level can also be caused by changes in atmospheric pressure and winds.

2.3.3.4.1 Water Supply Facilities and Facility Operations

There are over 3,000 diversions that remove water from upstream and in-Delta waterways for agricultural, municipal, and industrial uses; 722 of these are located in the mainstem San Joaquin and Sacramento rivers and 2,209 diversions are in the Delta (Herren and Kawasaki 2001). In the Delta, the Central Valley Project (CVP) managed by the Bureau of Reclamation and the State Water Project (SWP) managed by DWR use the Sacramento and San Joaquin rivers and other Delta channels to transport water from river flows and reservoir storage to two water export facilities in the south Delta (Figure 2-16). The C.W. “Bill” Jones Pumping Plant (herein referred to as the Jones Pumping Plant) is operated by the CVP and the Harvey O. Banks Delta Pumping Plant (herein referred to as the Banks Pumping Plant) is operated by the SWP. Water from these facilities is exported for urban and agricultural water supply demands throughout the San Joaquin Valley, Southern California, the central coast, and the southern and eastern San Francisco Bay area.

Water enters the Banks Pumping Plant via the Clifton Court Forebay (CCF) (Figure 2-16). Large radial arm gates control inflows to CCF during the tidal cycle to reduce approach velocities, prevent scouring of adjacent channels, and by allowing water to enter the CCF at times other than low tide, reducing water level fluctuation in the south Delta (USFWS 2005). The Banks Pumping Plant operates to move water from CCF into the 440-mile (708-km) California Aqueduct. Water in the California Aqueduct travels to O’Neill Forebay; where a portion of the water is diverted to the joint-use SWP/CVP San Luis Reservoir for storage. The remaining water flows southward via the joint-use San Luis Canal.

Water from Old River in the Delta is pumped by the Jones Pumping Plant into the Delta-Mendota Canal. The Jones Pumping Plant facility does not have an associated forebay. The Delta-Mendota Canal sends water southward, providing irrigation water along the way, towards the O’Neill Forebay where a portion of the water is diverted into the San Luis Reservoir. The remaining water continues in the Delta-Mendota Canal, providing irrigation water along the way, until it reaches the Mendota Pool, where water is returned to the San Joaquin River to replenish downstream flows.

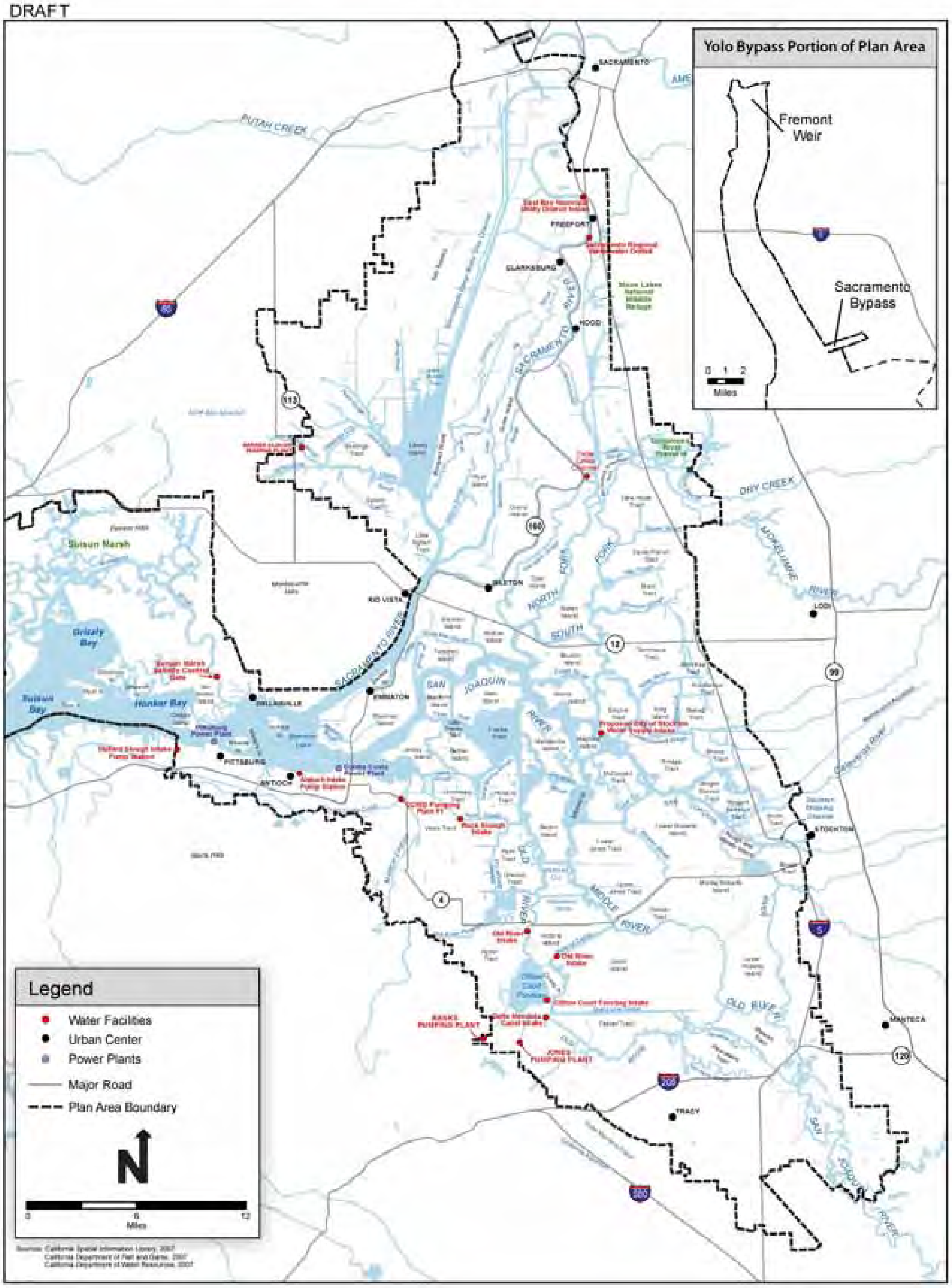

Figure 2-16. Water Facilities in the BDCP Plan Area

The Delta Cross Channel (DCC) is operated by the Bureau of Reclamation to improve through-Delta flows from the Sacramento River towards the pumping facilities in the south Delta (Figure 2-16). Water is diverted into Snodgrass Slough, a tributary of the Mokelumne River, through which it travels into the central Delta. Two large radial gates on the DCC can open or close to control flows into the central Delta. Reasons for closure include reduction in scour in the channels on the downstream side of the DCC, reduction in flood flows into the Mokelumne River, and fish protection.

The Barker Slough Pumping Plant is operated by the SWP and draws water from Barker Slough into the North Bay Aqueduct (Figure 2-16). The intake is located just upstream of where Barker Slough empties into Lindsey Slough, which is approximately 10 miles (16 km) from the mainstem Sacramento River. Water from the Barker Slough Pumping Plant is delivered to Napa and Solano counties for municipal and industrial uses. The North Bay Aqueduct (NBA) is operated by DWR as part of the SWP and delivers wholesale water to the Solano County Water Agency and the Napa County Flood Control and Water Conservation District. The 27.6 mile NBA extends from Barker Slough to the end of the Napa Turnout Reservoir. Water is pumped from the Delta at the Barker Slough Pumping Plant, which is located 7 river miles upstream from the confluence of Barker Slough with the Sacramento River in southeast Solano County. Water is then diverted to the Travis Surge Tank where it flows by gravity through the NBA to the Cordelia Pumping Plant.

The South Delta Temporary Barriers project consists of the installation of four rock barriers each spring in south Delta channels: the head of Old River, Old River at Tracy, Grant Line Canal, and Middle River. The head of Old River barrier is also installed during the fall for dissolved oxygen reasons. The head of Old River barrier is considered a fish barrier because it is installed to keep migrating juvenile Chinook salmon in the San Joaquin River. The other three barriers are agricultural barriers; meaning they are installed to maintain water quality for agricultural uses in the south Delta. The head of Old River barrier was not installed in spring of 2009 or 2010 as the 2008 USFWS Biological Opinion prohibited the installation of the barrier for the protection of delta smelt. The rock barriers are not installed in years when San Joaquin River flows are high, such as during 1998.

The Contra Costa Water District (CCWD) diverts water from the Delta to the Contra Costa Canal and the Los Vaqueros Reservoir using four intake locations: Rock Slough, Old River, Mallard Slough, and Middle River (on Victoria Canal) (Figure 2-16). The Contra Costa Canal and its pumping plants have a capacity of 350 cfs and were built by the U.S. Bureau of Reclamation from 1937 to 1948 as part of the CVP. The Contra Costa Canal is owned by the Bureau of Reclamation but operated and maintained by CCWD. The screened Old River Pump Station (250 cfs capacity) was built in 1997 as part of the Los Vaqueros Project to improve water quality for CCWD. The Old River pump station connects via pipelines to a transfer pump station (200 cfs) used to pump water into Los Vaqueros Reservoir (100,000 af [acre feet] capacity) and from the transfer station via gravity pipeline to the Contra Costa Canal. The screened Mallard Slough intake (39 cfs capacity) was constructed in the 1920s and rebuilt to make it seismically protected in 2001. It is used primarily in winter and spring during wet periods when water quality is sufficiently high. The screened Middle River intake and pump station (250 cfs capacity) were completed in 2010 to provide additional operational flexibility and improved water quality. The Middle River intake connects to the Old River Pump Station via pipe that crosses Victoria Island and tunnels underneath Old River. The Middle River intake is used primarily in late summer and fall to provide better water quality than is obtainable from the other three intakes.

East Contra Costa Irrigation District provides water supplies to the city of Brentwood, portions of Antioch and Oakley, the unincorporated community of Knightsen, and surrounding unincorporated rural areas (Dudek 2007). The East Contra Costa Irrigation District operates a diversion located at Indian Slough on Old River in combination with canals and pumping stations for distribution within the service area. The primary purpose of the diversion is to provide raw water for irrigation of agricultural lands, landscape, and recreational uses (e.g., golf courses). The district has agreements with CCWD and City of Brentwood to make surplus water available for municipal use.

The city of Antioch, located in eastern Contra Costa County, supplies water through diversions directly from the San Joaquin River, raw water purchased from CCWD that is delivered through the Contra Costa Canal, and treated water delivered through CCWD's Multi-Purpose Pipeline (Dudek 2007). Antioch receives approximately 85 percent of its water supplies from CCWD. The majority (76 percent in 2004) of the water is provided for municipal/residential use, with industrial (11 percent) and agricultural (13 percent) uses in the service area.

Byron Bethany Irrigation District provides water for agricultural, industrial, and municipal uses to portions of Alameda, Contra Costa, and San Joaquin counties (San Joaquin County Planning Division 2008). The district maintains two water diversions from the Delta under a pre-1914 appropriative water right and a riparian water right on Old River. Water diversions occur from the SWP intake channel, located between the Skinner Fish Protection Facility and the Banks Pumping Plant. Two diversions serve the Byron Division and the Bethany Division. The District also operates a series of pumping stations and canals for water distribution.

East Bay Municipal Utility District's Mokelumne Aqueduct traverses the Delta, carrying water from Pardee Reservoir on the Mokelumne River to the East Bay (Figure 2-16). East Bay Municipal Utility District, in partnership with Sacramento County, constructed a major new diversion from the Sacramento River at Freeport. This new diversion, sized at 185 million gallons/day capacity, will feed into the Mokelumne Aqueduct and the Vineyard Surface Water Treatment Plant for central Sacramento County use.

There are over 2,200 water diversions in the Delta, most of which are unscreened and used for in-Delta agriculture irrigation (Figure 2-17) (Herren and Kawasaki 2001). Industrial diversions in the Plan Area include the Mirant Power plants at Pittsburg and Antioch. Water from these diversions cools generators producing electric power at the plants.

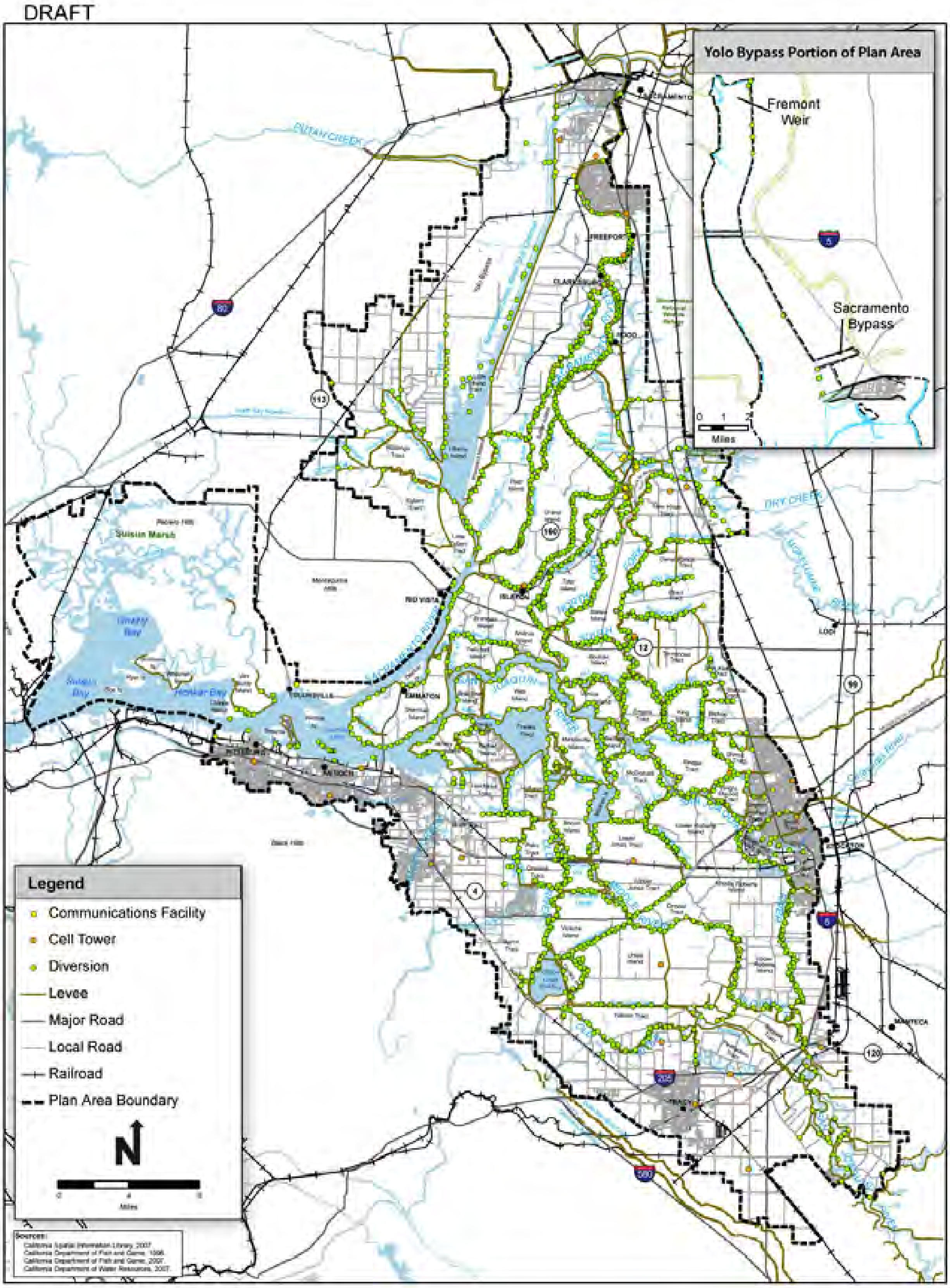

Figure 2-17. Infrastructure within the BDCP Plan Area

Suisun Bay and Suisun Marsh are important ecosystems connected to the Delta, and habitat conditions and facility operations in Suisun Bay and Marsh can affect ecosystem conditions in the Delta (Figure 2-16 and Figure 2-17). A system of levees, canals, gates, and culverts in Suisun Marsh was constructed in 1979-80 and is currently operated by DWR to lower salinity in privately managed wetlands in the marsh. The Suisun Marsh Salinity Control Gates are composed primarily of a set of radial gates that extend across the entire width of Montezuma Slough. The control gates are used to reduce salinity from Collinsville through Montezuma Slough and into the eastern and central parts of Suisun Marsh and to reduce intrusion of saltwater from downstream into the western part of Suisun Marsh. In addition to radial gates, the Suisun Marsh Salinity Control Gates consist of permanent barriers adjacent to the levee on either side of the channel, flashboards, and a boat lock. The gates have been operated historically from September to May and open and close twice a day during full operation to take advantage of tidal flows. The gates are opened during ebb tides to allow freshwater from the Sacramento River to flow into Montezuma Slough and are closed during flood tides to prevent higher salinity water from downstream from entering Montezuma Slough. Gate operations have been curtailed in recent years.

2.3.3.5 Non-Water Supply Plan Area Infrastructure and Uses

The Plan Area supports a substantial amount of infrastructure related to urban development, transportation, agriculture, recreation, energy, and other uses (Figure 2-17). Portions of six counties are included in the legal Delta: Yolo, Sacramento, Solano, Contra Costa, Alameda, and San Joaquin (DWR 2006).

The major land use for the Plan Area is agriculture, which represents approximately two-thirds of all surface area. There is increasing residential, commercial, and industrial land use in the Plan Area, most of which occurs around the periphery of the Delta. Major urban development within the cities of Sacramento, West Sacramento, Stockton, Tracy, Antioch, Brentwood, and Pittsburg are in the Plan Area. Small towns located wholly within the Delta include Clarksburg, Hood, Walnut Grove, Isleton, Collinsville, Courtland, Locke, Ryde, Bethel Island, and Discovery Bay. Much of this development occurs in the secondary zone of the Delta (as defined in *Section 12220* of the Water Code).

Several interstate highways (I-5, I-80, I-205/580, and I-680) and one state highway (State Route [SR] 99) are on the periphery of the Delta, and three state highways (SR 4, SR 12, and SR 160) and multiple county roads cut across the Delta (Figure 2-17). Three major railways cross through the Delta. The Plan Area contains a network of electrical transmission lines (over 500 miles [805 km]) and gas pipelines (over 100 lines). Natural gas extraction and storage is another important Plan Area use. In addition to approximately 95 public and private marinas (Lund et al. 2007), two major ports (Stockton and Sacramento) and their associated maintained ship channels are in the Delta. These ports can handle high tonnage (55,000 ton class) ships to move cargo to and from the Pacific Ocean. Much of the Plan Area, including 635 miles (1022 km) of boating waterways, is used for a variety of recreational purposes including water sports, fishing, hunting, and wildlife viewing (Lund et al. 2007).

2.3.4 Natural Communities

The natural communities in the Plan Area are tidal perennial aquatic, tidal mudflat, tidal brackish emergent wetland, tidal freshwater emergent wetland, nontidal freshwater perennial emergent wetland, nontidal perennial aquatic, valley/foothill riparian, grassland, alkali seasonal wetland complex, vernal pool complex, managed wetland, other natural seasonal wetland, inland dune scrub, and agricultural habitats (Figures 2-18 through 2-22).

The descriptions of the natural communities are generally based on broad community descriptions that were developed for the CALFED Bay-Delta Program's Multi-Species Conservation Strategy (MSCS) (CALFED 2000). These broad community types were further refined and augmented by input from DFG staff participating in the BDCP Terrestrial Resources subgroup in 2009. In addition to the natural communities, a finer scale delineation of vegetation within the Plan Area was used to model the habitat of covered species, based on a more detailed land cover type classification used by DFG to prepare its Vegetation and Land Use Classification map of the Sacramento-San Joaquin River Delta and the 2006 Vegetation Map Update for Suisun Marsh, Solano County, California (Hickson and Keeler-Wolf 2007, Boul and Keeler-Wolf 2008). The methods used to produce maps of the natural communities are described in Section 2.3.1, *Data Sources and Natural Community Classification***.**

A primary focus of the BDCP Conservation Strategy is habitat restoration in the tidal and riparian natural communities of the Plan Area that support covered fish species: tidal perennial aquatic, tidal mudflat, tidal freshwater emergent wetland, tidal brackish emergent wetland, and valley/foothill riparian. The tidal perennial aquatic natural community includes deepwater aquatic (greater than 10 ft [3 m] deep from mean lower low tide), shallow aquatic (less than or equal to 10 ft [3 m] deep from mean lower low tide). It also coexists spatially with unvegetated intertidal zones of estuarine bays, river channels, and sloughs of the Plan Area that characterize the tidal mudflat community. The tidal freshwater emergent wetland natural community consists of intertidal zones of the Plan Area that support emergent wetland plant species that are intolerant of saline or brackish water. Freshwater emergent vegetation is generally found in water shallower than 6 ft (2 m) deep (Cowardin et al. 1979). The tidal brackish emergent wetland natural community supports similar species as the tidal freshwater emergent wetland in and near channels, and shorter stature, salt-tolerant plants on the marsh plains. It is found from the westernmost tip of Sherman Island westward to the tidal areas of Suisun Marsh and Suisun Bay. The valley/foothill riparian natural community includes all successional stages of woody riparian vegetation, commonly dominated in the Plan Area by willows, Fremont cottonwood, alder, and valley oak. The valley/foothill riparian natural community and the tidal communities are spatially intermingled with the tidal mudflat natural community. A generalized schematic of the distribution of natural communities in the Plan Area relative to tidal levels and representative species associated with each of the communities is depicted in Figure 2-23. All of the communities and covered species are discussed in more detail in the following sections and in Appendix A, *Covered Species Accounts*.

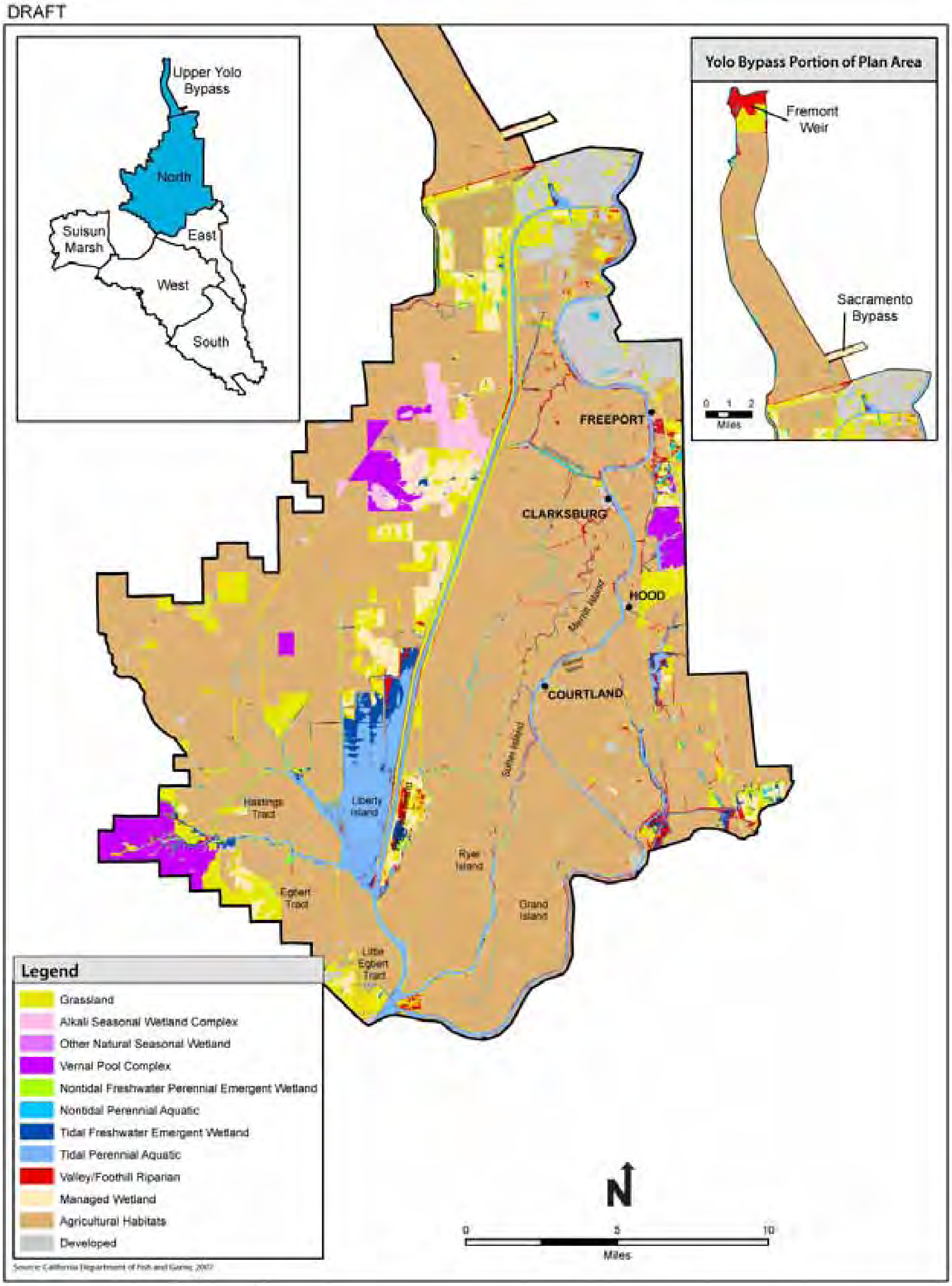

Figure 2-18. Distribution of Natural Communities and Urban Land Cover in the BDCP Plan Area (North Delta and Upper Yolo Bypass)

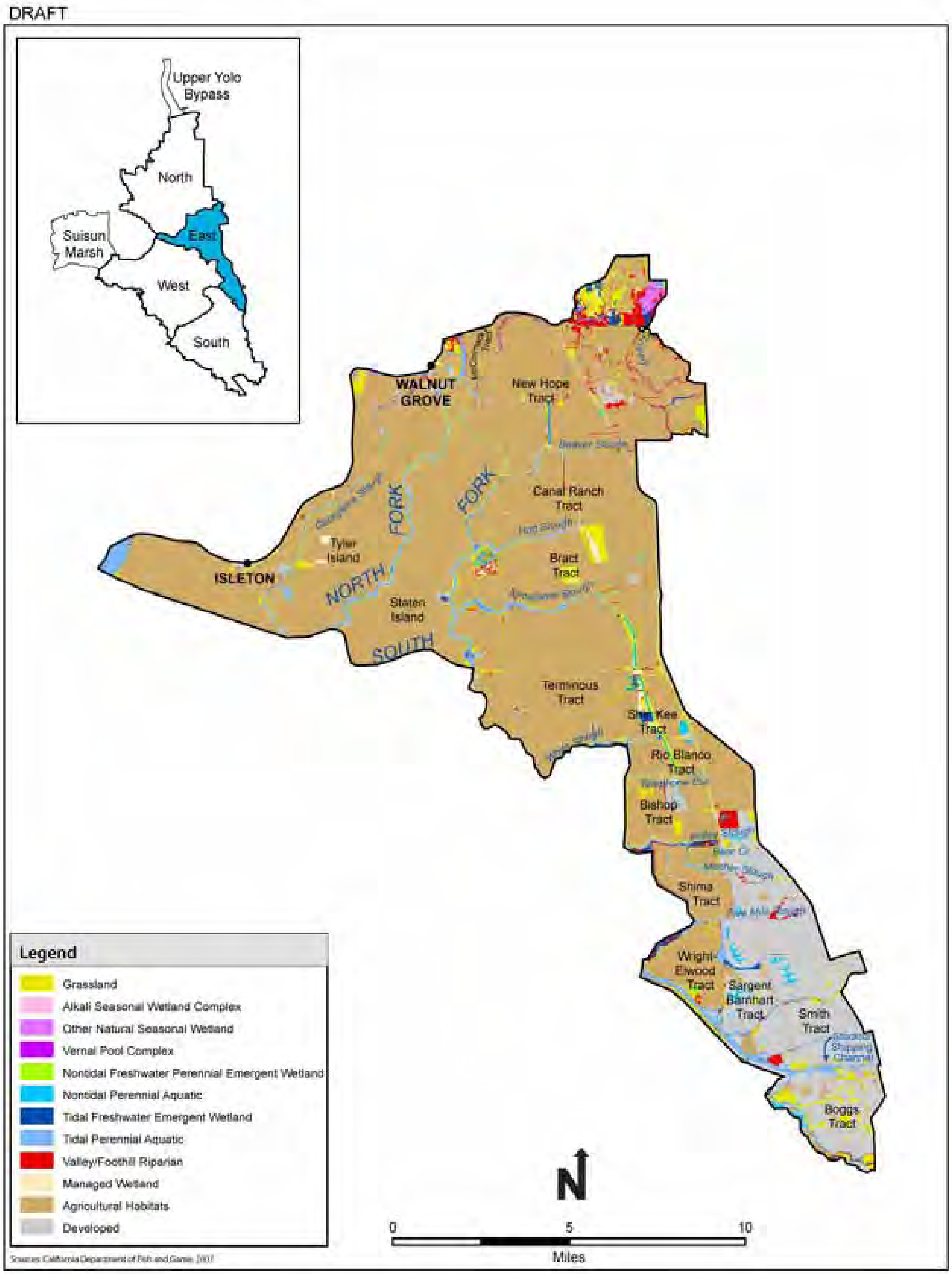

Figure 2-19. Distribution of Natural Communities and Urban Land Cover in the BDCP Plan Area (East Delta)

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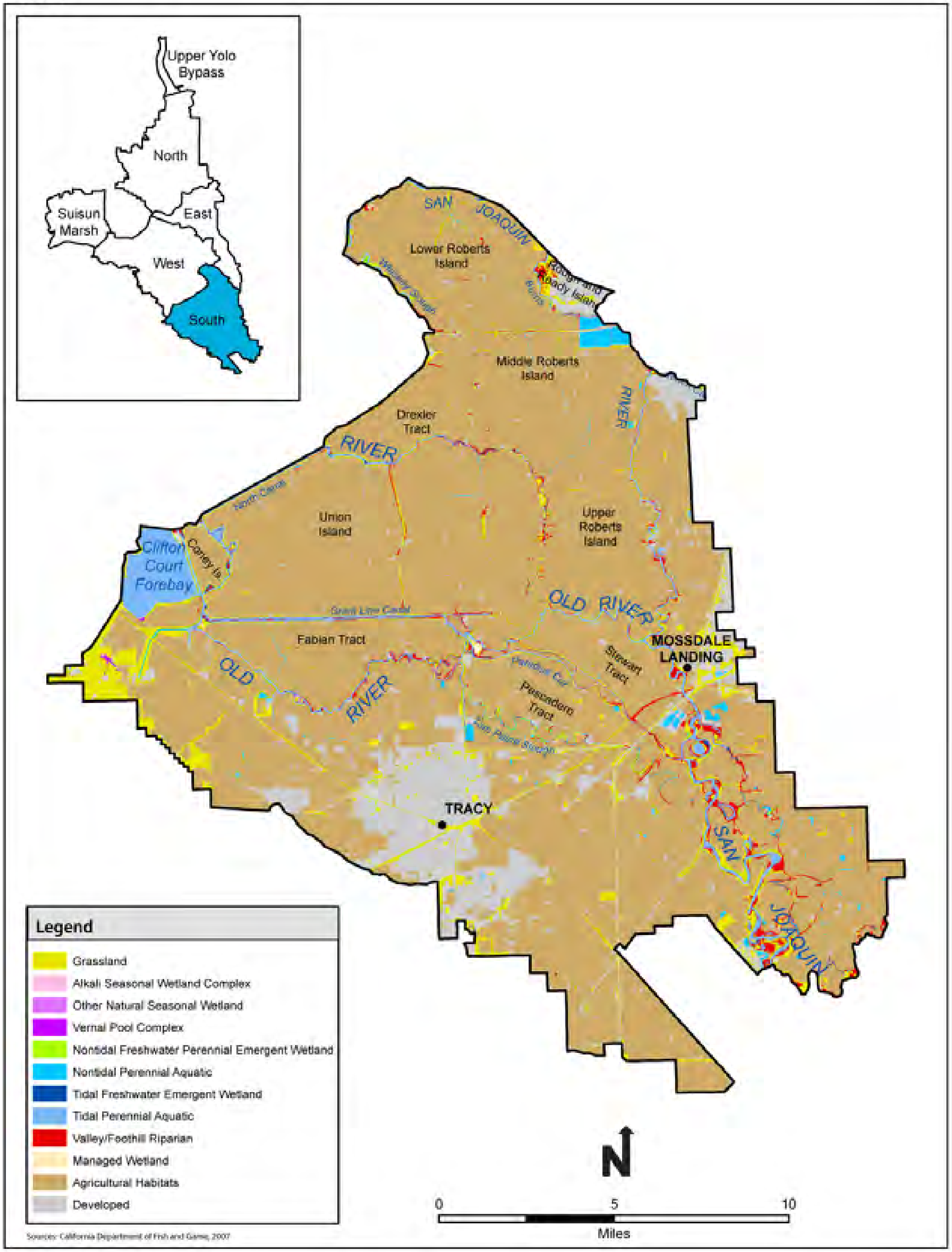

Figure 2-20. Distribution of Natural Communities and Urban Land Cover in the BDCP Plan Area (South Delta)

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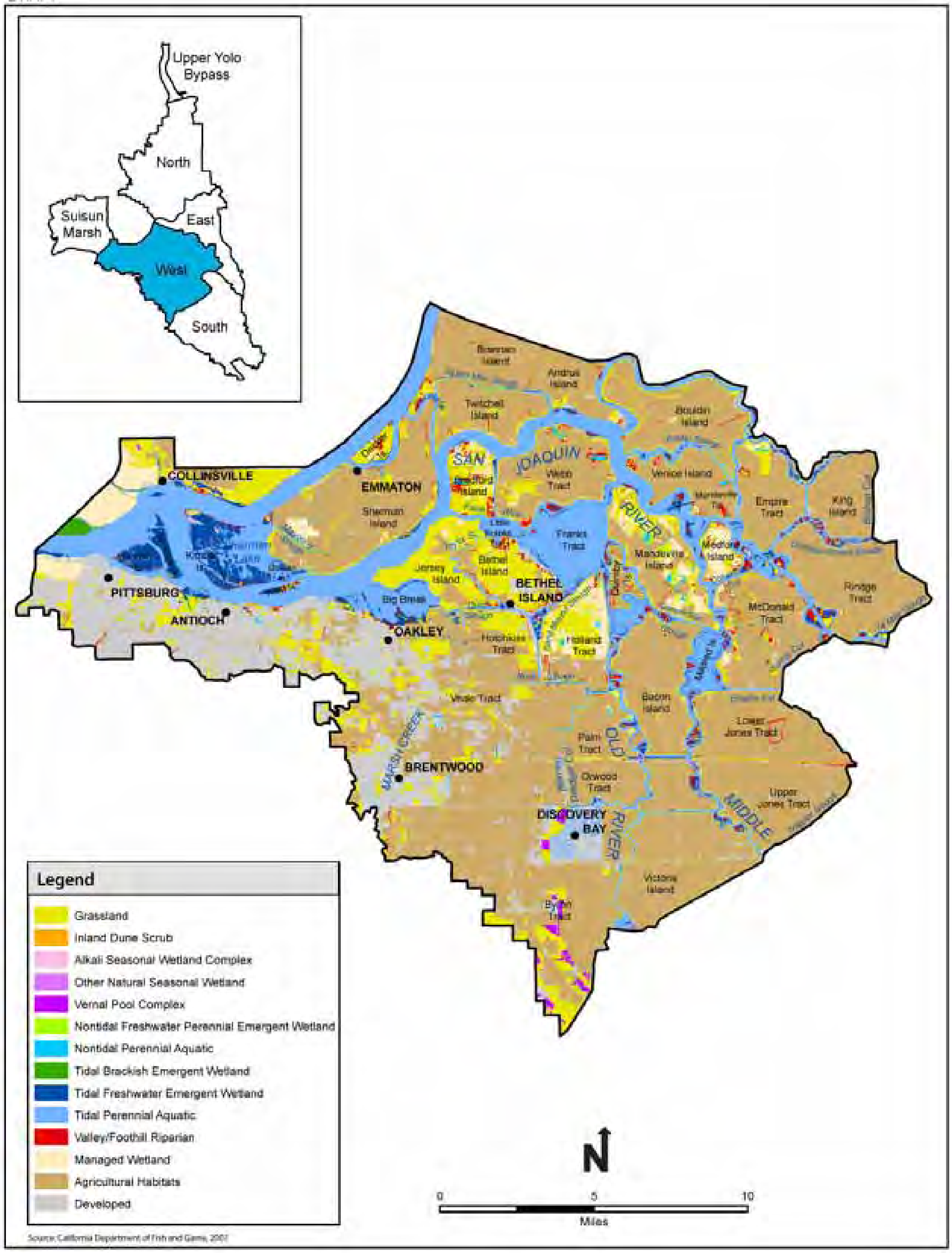

Figure 2-21. Distribution of Natural Communities and Urban Land Cover in the BDCP Plan Area (West Delta)

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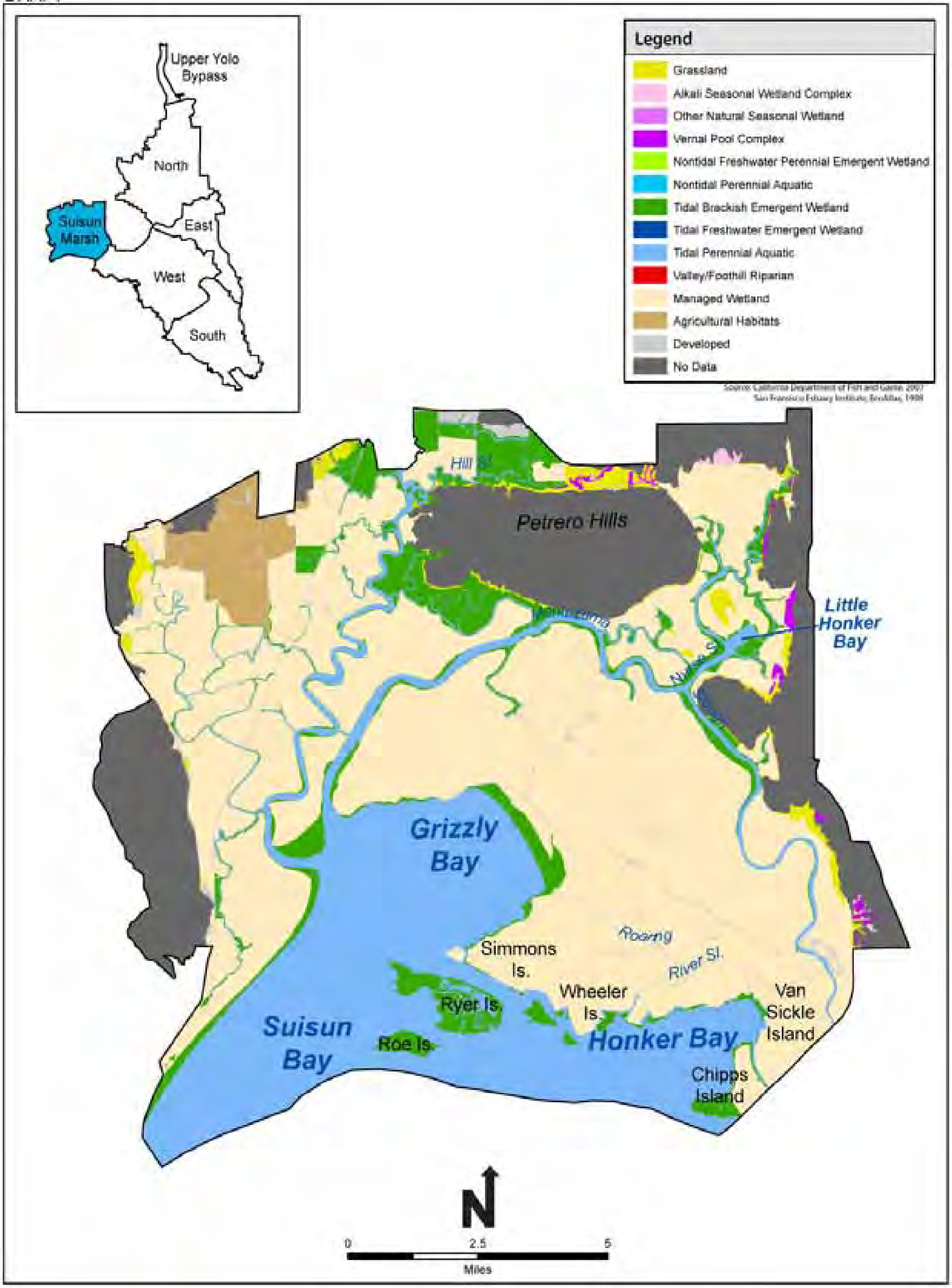

Figure 2-22. Distribution of Natural Communities and Urban Land Cover in the BDCP Plan Area (Suisun Marsh)

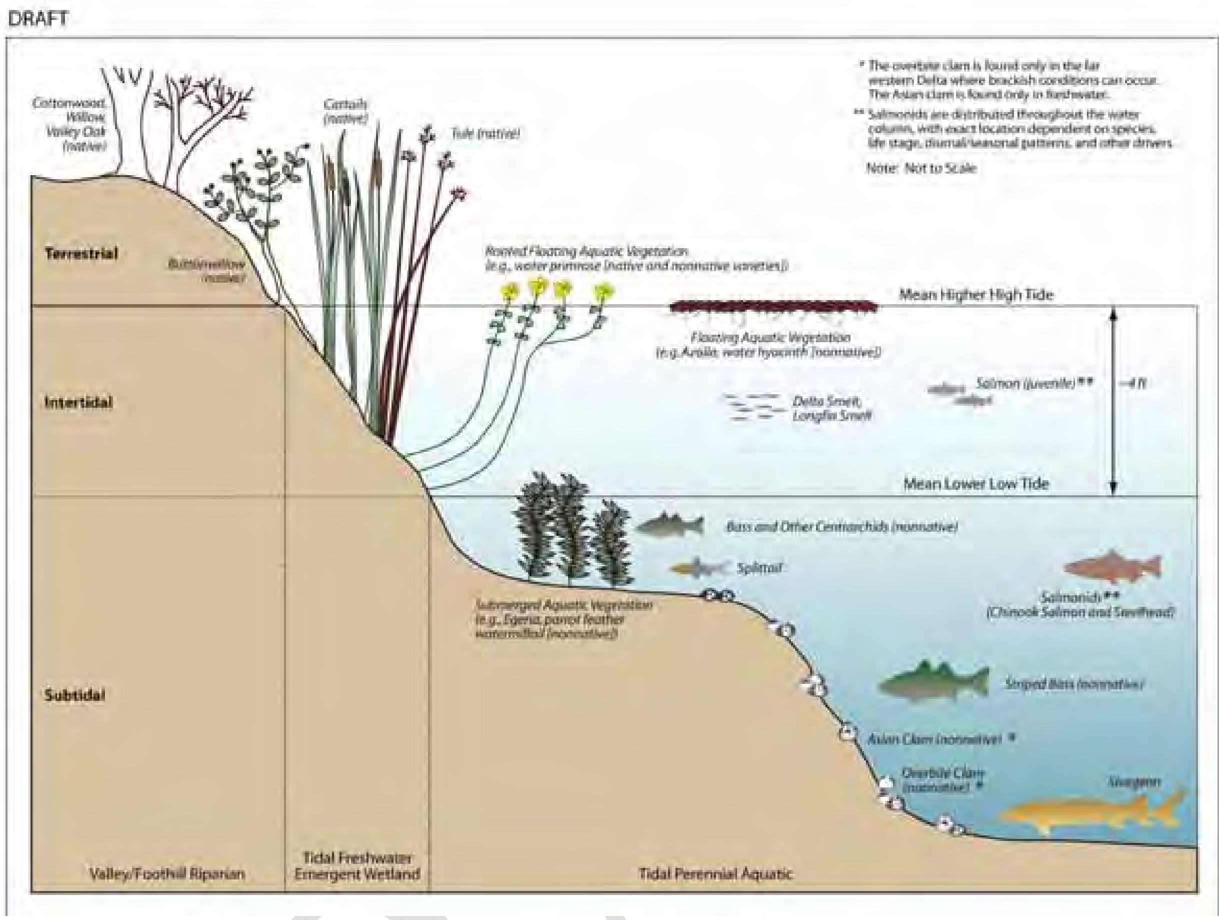

Figure 2-23. Generalized Schematic of Valley/Foothill Riparian, Tidal Freshwater Emergent Wetland, and Tidal Perennial Aquatic Natural Communities

The extent of each natural community within the Plan Area is presented in Table 2-3. The distribution of natural communities in the Plan Area is presented in Figures 2-18 through 2-22.

The following sections describe physical and biological attributes associated with each natural community.

Table 2-3. Extent of Natural Communities in the Plan Area (acres)

Tidal Perennial Aquatic	86,240
Tidal Mudflat	NA[1]
Tidal Brackish Emergent Wetland	8,351
Tidal Freshwater Emergent Wetland	8,947
Valley/Foothill Riparian	17,338
Nontidal Perennial Aquatic	5,341
Nontidal Freshwater Perennial Emergent Wetland	1,134
Alkali Seasonal Wetland Complex	3,722
Vernal Pool Complex	6,959
Managed Wetland	64,844
Other Natural Seasonal Wetland	264
Grassland	62,880
Inland Dune Scrub	20
Agricultural Habitats	503,779
Developed	70,174
No Data[2]	18,379
Total	**858,372**

[1]Tidal mudflats are included in tidal perennial aquatic (upper edge) and tidal freshwater and brackish emergent wetlands.
[2]No data available for upland portions of Suisun Marsh (e.g., Petrero Hills).

These natural communities provide habitat for animals and plants that are covered under the Plan Area. Covered fish, wildlife, and plant species that are present or could be present within these natural communities in the Plan Area are presented in Table 2-4.

Table 2-4. BDCP Covered Species and Natural Communities that Support Covered Species Habitat

Common Name *Scientific Name*	***Natural Communities that Support BDCP Covered Species Habitat***													
	TPA	**TM**	**TBE**	**TFE**	**V/FR**	**NPA**	**NFPE**	**ASW**	**VPC**	**MW**	**ONS**	**G**	**IDS**	**AH**
Fish														
Sacramento splittail *Pogonichthys macrolepidotus*	X	X	X	X										
Delta smelt *Hypomesus transpacificus*	X	X	X	X										
Longfin smelt *Spirinchus thaleichthys*	X	X	X	X										
Steelhead, Central Valley DPS *Oncorhynchus mykiss*	X	X	X	X										
Chinook salmon, Sacramento River winter-run *Oncorhynchus tshawytscha*	X	X	X	X										

Table 2-4. BDCP Covered Species and Natural Communities that Support Covered Species Habitat (continued)

Common Name *Scientific Name*	*Natural Communities that Support BDCP Covered Species Habitat*													
	TPA	**TM**	**TBE**	**TFE**	**V/FR**	**NPA**	**NFPE**	**ASW**	**VPC**	**MW**	**ONS**	**G**	**IDS**	**AH**
Fish														
Chinook salmon, Central Valley spring-run *Oncorhynchus tshawytscha*	X	X	X	X										
Chinook salmon, Central Valley fall- and late fall-run *Oncorhynchus tshawytscha*	X	X	X	X										
Green sturgeon *Acipenser medirostris*	X	X	X	X										
White sturgeon *Acipenser transmontanus*	X	X	X	X										
River lamprey *Lampetra ayresii*	X	X	X	X										
Pacific lamprey *Entosphenus tridentatus (*formerly *Lampetra tridentata)*	X	X	X	X										
Mammals														
San Joaquin kit fox *Vulpes macrotis mutica*												X		X
Riparian (San Joaquin Valley) woodrat *Neotoma fuscipes riparia*					X									
Salt marsh harvest mouse *Reithrodontomys raviventris*			X							X		X		
Riparian brush rabbit *Sylvilagus bachmani riparius*					X									
Townsend's big-eared bat *Corynorhinus townsendii*	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Suisun shrew *Sorex ornatus sinuosus*			X							X				
Birds														
Tricolored blackbird *Agelaius tricolor*			X	X	X		X	X	X	X	X	X		X
Suisun song sparrow *Melospiza melodia maxillaris*			X	X						X				
Yellow-breasted chat *Icteria viriens*					X									
Least Bell's vireo *Vireo bellii pusillus*					X									
Western burrowing owl *Athene cunicularia hypugaea*								X	X	X	X	X		X
Western yellow-billed cuckoo *Coccyzus americanus occidentalis*					X									
California least tern *Sternula antillarum browni*	X													
Greater sandhill crane *Grus canadensis tabida*								X	X	X	X	X		X
California black rail *Laterallus jamaicensis coturniculus*			X	X			X							

Table 2-4. BDCP Covered Species and Natural Communities that Support Covered Species Habitat (continued)

Common Name *Scientific Name*	*Natural Communities that Support BDCP Covered Species Habitat*													
	TPA	**TM**	**TBE**	**TFE**	**V/FR**	**NPA**	**NFPE**	**ASW**	**VPC**	**MW**	**ONS**	**G**	**IDS**	**AH**
Birds														
California clapper rail *Rallus longirostris obsoletus*			X											
Swainson's hawk *Buteo swainsoni*					X			X	X	X	X	X		X
White-tailed kite *Elanus leucurus*					X			X	X	X	X	X		X
Reptiles														
Giant garter snake *Thamnophis gigas*	X			X		X	X	X	X	X	X	X		X
Western pond turtle *Actinemys marmorata*	X		X	X	X	X	X	X	X	X	X	X		X
Amphibians														
California red-legged frog *Rana draytonii*				X	X	X	X	X	X	X	X	X		X
Western spadefoot toad *Spea hammondii*						X		X	X		X	X		
California tiger salamander (Central Valley distinct population segment [DPS]) *Ambystoma californiense*								X	X		X	X		
Invertebrates														
Lange's metalmark *Apodemia mormo langei*													X	
Valley elderberry longhorn beetle *Desmocerus californicus dimorphus*					X							X		
Vernal pool tadpole shrimp *Lepidurus packardi*									X					
Conservancy fairy shrimp *Branchinecta conservatio*									X					
Longhorn fairy shrimp *Branchinecta longiantenna*									X					
Vernal pool fairy shrimp *Branchinecta lynchi*									X					
Midvalley fairy shrimp *Branchinecta mesovallensis*									X					
California linderiella *Linderiella occidentalis*									X					
Plants														
Alkali milk-vetch *Astragalus tener* var. *tener*									X					
Heartscale *Atriplex cordulata*								X	X			X		
Brittlescale *Atriplex depressa*								X	X			X		
San Joaquin spearscale *Atriplex joaquiniana*								X	X			X		
Slough thistle *Cirsium crassicaule*					X									
Suisun thistle *Cirsium hydrophilum* var. *Hydrophilum*			X											
Soft bird's-beak *Cordylanthus mollis ssp. mollis*			X											

Table 2-4. BDCP Covered Species and Natural Communities that Support Covered Species Habitat (continued)

Common Name *Scientific Name*	*Natural Communities that Support BDCP Covered Species Habitat*													
	TPA	TM	TBE	TFE	V/FR	NPA	NFPE	ASW	VPC	MW	ONS	G	IDS	AH
Plants														
Dwarf downingia *Downingia pusilla*									X					
Delta button-celery *Eryngium racemosum*					X			X	X			X		
Contra Costa wallflower *Erysimum capitatum* var. *angustatum*													X	
Boggs Lake hedge-hyssop *Gratiola heterosepala*									X					
Carquinez goldenbush *Isocoma arguta*								X				X		
Delta tule pea *Lathyrus jepsonii* var.*jepsonii*			X	X	X									
Legenere *Legenere limosa*									X					
Heckard's pepper-grass *Lepidium latipes* var. *heckardii*									X					
Mason's lilaeopsis *Lilaeopsis masonii*		X	X	X	X									
Delta mudwort *Limosella subulata*		X	X	X	X									
Antioch Dunes evening-primrose *Oenothera deltoides ssp. howellii*													X	
Side-flowering skullcap *Scutellaria lateriflora*					X									
Suisun Marsh Aster *Symphyotrichum lentum*			X	X	X									
Caper-fruited tropidocarpum *Tropidocarpum capparideum*												X		

Natural community codes:
TPA = Tidal perennial aquatic
TM = Tidal mudflat
TBE = Tidal brackish emergent wetland
TFE = Tidal freshwater emergent wetland
V/FR = Valley/foothill riparian
NPA = Nontidal perennial aquatic
NFPE = Nontidal freshwater perennial emergent wetland
ASW = Alkali seasonal wetland complex
VPC = Vernal pool complex
MW = Managed wetland
ONS = Other natural seasonal wetland
G = Grassland
IDS = Inland dune scrub
AL = Agricultural habitats

2.3.4.1 Tidal Perennial Aquatic

The tidal perennial aquatic natural community includes deep water aquatic (greater than 10 ft [3 m] deep from mean low low tide (lowest of the low tide in a day), shallow aquatic (less than or equal to 10 ft [3 m] deep from mean low low tide), and unvegetated intertidal (i.e. mudflat) zones of estuarine bays, river channels, and sloughs (CALFED 2000). Under present water operation conditions in the Plan Area, tidal perennial aquatic is mainly freshwater, with brackish and saline conditions occurring in Suisun Bay at times of high tides and low flows. The distribution of the tidal perennial aquatic natural community in the Plan Area is shown in Figure 2-24.

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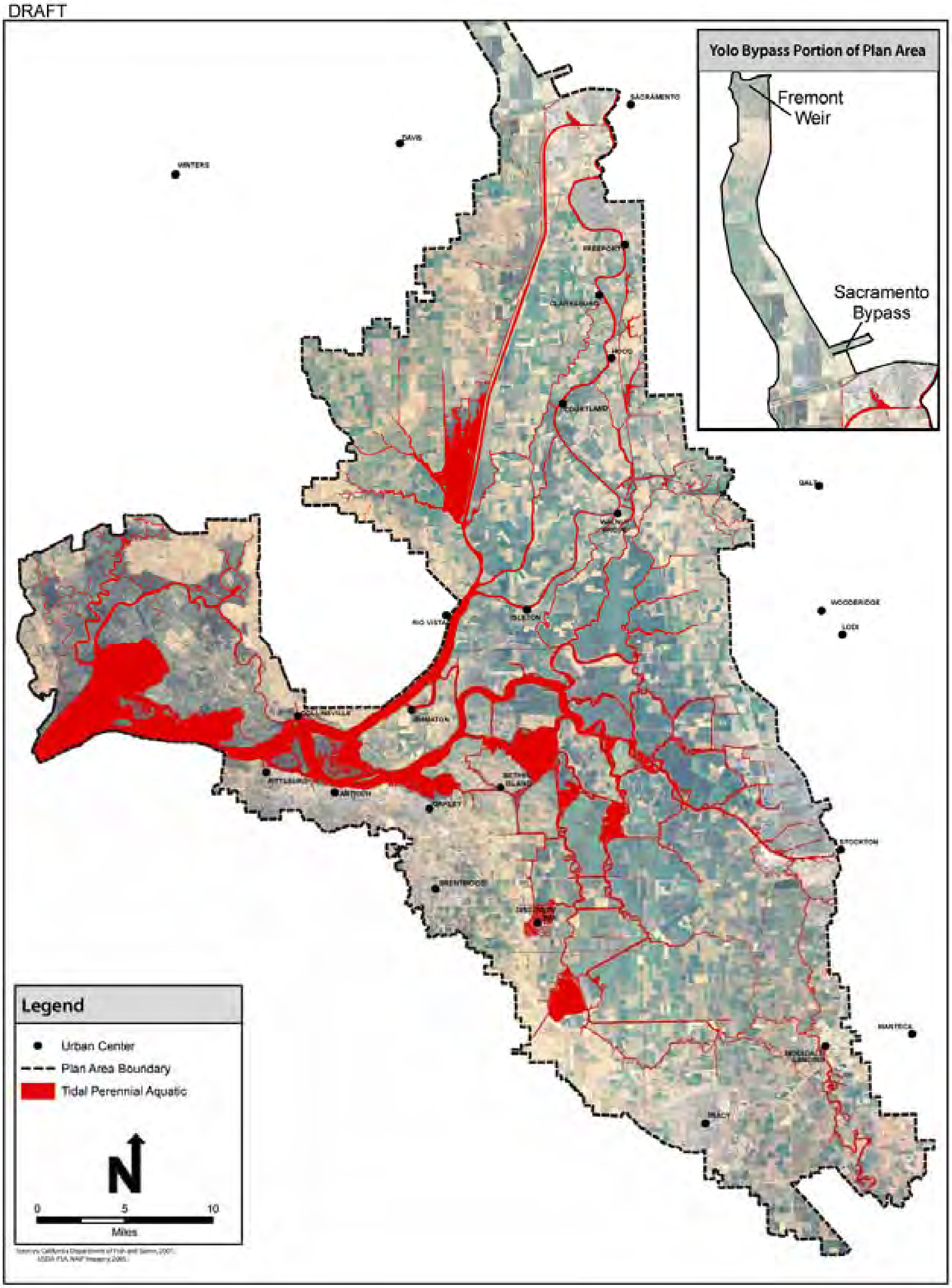

Figure 2-24. Distribution of Tidal Perennial Aquatic Natural Community in the BDCP Plan Area

2.3.4.1.1 Vegetation

The tidal perennial aquatic natural community is largely unvegetated. Where vegetation exists, it can be separated into two categories: submerged aquatic vegetation and floating vegetation (both rooted and unrooted) (Cowardin et al. 1979). The plant associations present and their extent within the tidal perennial aquatic natural community are shown in Table 2-5. The geographic extent of this vegetation is highly dynamic through time and space because it is largely dependent on physical factors that are highly variable, such as depth, turbidity, water flow, salinity, substrate, and nutrient availability.

Table 2-5. Plant Alliances within the Tidal Perennial Aquatic Natural Community in the Plan Area

Mapping Unit[1]	***Plant Alliance (Sawyer and Keeler-Wolf 1995)***	***Acreage in the Plan Area***
Undetermined	Undetermined	22,248
-	Algae	328
Annual Grasses[2]	-	*2*
-	*Atriplex triangular*	0
-	Bare Ground	0
-	Brazilian Waterweed *(Egeria - Myriophyllum)* Submerged	2,883
-	*Calystegia/Euthamia*	2
-	*Conium maculatum*	0
-	*Cotula coronopifolia*	0
Distichlis[2]	-	4
Ditches and Sloughs[2]	-	3,495
-	*Eucalyptus globules*	4
-	Floating Primrose (*Ludwigia peploides)*	133
-	*Foeniculum vulgare*	1
-	Flooded Managed Wetland	2
-	Generic Floating Aquatics	239
-	*Hydrocotyle ranunculoides*	7
	Landscape Trees	0
	Lepidium (generic)	2
	Ludwigia peploides	53
-	Medium Wetland Graminoids	0
Wetland Herbs[2]	-	6
-	Milfoil - Waterweed (generic submerged aquatics)	65
Phragmites[2]	-	5
-	Pondweed (*Potamogeton* spp.)	5
		0
	Potentilla anserina (generic)	0
	Raphanus sativus (generic)	2
	Rosa californica	1
	Rosa/Baccharis	3
	Rubus discolor	1
	Salicornia/Annual Grasses	0
Scirpus[2]	-	115
-	Structure	2
-	Tall Wetland Graminoids	1
Tidal Mudflats[2]	-	354
Typha[2]	-	69
-	Water	56,079
-	Water Hyacinth (*Eichhornia crassipes*)	128
Total		**86,240**

[1]Some of the mapping units provided here are newly described associations or alliances. For more detailed information concerning these mapping units and plant associations/alliances, as well as on methods of classification used, see Hickson and Keeler-Wolf (2007) and Boul and Keeler Wolf (2008).
[2]DFG vegetation types were combined to form this mapping unit in order to condense the list.

Submerged aquatic vegetation consists of aquatic plants that cannot tolerate drying, and as a result, maintain leaves at or below the water surface. Submerged vascular plant species in the tidal perennial aquatic natural community include native water primrose and the highly abundant and invasive nonnative Brazilian waterweed. The introduction of Brazilian waterweed has been detrimental to native fishes in the Plan Area (Section 2.3.4.1.3, *Nonnative Species*). Another common submerged nonnative invasive plant is the Eurasian watermilfoil. In addition to plants, algae and cyanobacteria can be common during summer and fall months in areas with clear water and little shade. Blooms of the nonnative floating toxic cyanobacteria, *Microcystis*, were first documented in the Delta in 2003, and its distribution has subsequently expanded eastward (Lehman et al. 2005). Periphyton, a thin layer of organisms (mostly diatoms and bacteria) and their exudates, forms on substrates throughout this community. The ecologically important eel grass grows in soft sediment in the subtidal estuarine habitat, primarily in the far western Suisun Bay where salinities are sufficiently high for this brackish/saltwater species. Dense eel grass beds can provide suitable habitat for young fish and other aquatic organisms and are an important food source for waterfowl, although their occurrence in the Plan Area is very limited.

Floating aquatic vegetation in this habitat generally consists of free-floating beds of plants at the surface or in the water column. Wind and water movement can be important factors in determining its distribution. Species in this group include native duckweed, native floating water fern, and nonnative invasive water hyacinth. Reddish carpets of native floating water fern occur in calm waters of sloughs supporting tidal perennial aquatic. This water fern has a symbiotic relationship with a nitrogen fixing bacteria that lives within its tissues (Armstrong 1979). Water hyacinth grows in dense mats that can have harmful effects on native fish species (Section 2.3.4.1.3, *Nonnative Species*).

2.3.4.1.2 Fish and Wildlife

Zooplankton are one of the primary consumers of phytoplankton in the food web of the tidal perennial aquatic natural community and are important both as prey to consumers, such as fish and macroinvertebrates, and as consumers of phytoplankton and detritus. Water salinity is a major factor that influences the distribution of zooplankton species in the tidal perennial aquatic natural community. In the brackish portions of the Plan Area, calanoid copepods (*Eurytemora*, *Pseudodiaptomus*) and cyclopoid copepods (*Limnoithona*) are the primary zooplankton species, and mysid shrimp (*Neomysis*) is the dominant macrozooplankton. In freshwater regions, cladocerans (*Daphnia*) and calanoid copepods (*Diaptomus*, *Limnocalanus*) are the dominant zooplankton present (Kimmerer & Orsi 1996, Kimmerer 2004, Gewant & Bollens 2005, Winder & Jassby in press).

The tidal perennial aquatic natural community supports over 50 species of fish, approximately one-half of which are native (Table 2-6). It is used as habitat by fish for foraging, spawning, egg incubation and larval development, juvenile nursery areas, and migratory corridors. Most species spend their entire lives in the community while others may spend certain seasons or part of their lives in habitats outside of the tidal perennial aquatic natural community depending on the state of physical factors such as salinity, turbidity, dissolved oxygen, flow rates, and water temperature.

Table 2-6. Native and Nonnative Fish Species Found in the Plan Area

Family	*Common name*	*Scientific name*
Native Species		
Acipenseridae	Green Sturgeon	*Acipenser medirostris*
	White Sturgeon	*Acipenser transmontanus*
Atherinopsidae	Topsmelt	*Atherinops affinis*
Catostomidae	Sacramento Sucker	*Catostomus occidentalis*
Clupeidae	Pacific Herring	*Clupea pallasii*
Cottidae	Prickly Sculpin	*Cottus asper*
	Pacific Staghorn Sculpin	*Leptocottus armatus*
Cyprinidae	California Roach	*Hesperoleucus symmetricus*
	Hitch	*Lavinia exilicauda*
	Hardhead	*Mylopharodon conocephalus*
	Sacramento Blackfish	*Orthodon microlepidotus*
	Sacramento Splittail	*Pogonichthys macrolepidotus*
	Sacramento Pikeminnow	*Ptychocheilus grandis*
Embiotocidae	Tule Perch	*Hysterocarpus traskii*
Engraulidae	Northern Anchovy	*Engraulis mordax*
Gasterosteidae	Threespine Stickleback	*Gasterosteus aculeatus*
Gobiidae	Chameleon Goby	*Tridentiger trigonocephalus*
Osmeridae	Delta Smelt	*Hypomesus transpacificus*
	Longfin Smelt	*Spirinchus thaleichthys*
Petromyzontidae	River Lamprey	*Lampetra ayresii*
	Pacific Lamprey	*Entosphenus tridentatus* (formerly *Lampetra tridentata)*
Pleuronectidae	Starry Flounder	*Platichthys stellatus*
Salmonidae	Rainbow / Steelhead Trout	*Oncorhynchus mykiss*
	Chinook Salmon	*Oncorhynchus tshawytscha*
Nonnative Species		
Atherinopsidae	Inland Silverside	*Menidia beryllina*
Centrarchidae	Pumpkinseed	*Lepomis gibbosus*
	Warmouth	*Lepomis gulosus*
	Green Sunfish	*Lepomis cyanellus*
	Redear Sunfish	*Lepomis microlophus*
	Bluegill	*Lepomis macrochirus*
	Redeye Bass	*Micropterus coosae*
	Smallmouth Bass	*Micropterus dolomieu*
	Spotted Bass	*Micropterus punctulatus*
	Largemouth Bass	*Micropterus salmoides*
	Black Crappie	*Pomoxis nigromaculatus*
	White Crappie	*Pomoxis annularis*
Clupeidae	American Shad	*Alosa sapidissima*
	Threadfin Shad	*Dorosoma petenense*
Cyprinidae	Goldfish	*Carassius auratus auratus*
	Red Shiner	*Cyprinella lutrensis*
	Common Carp	*Cyprinus carpio*
	Golden Shiner	*Notemigonus crysoleucas*
	Fathead Minnow	*Pimephales promelas*
Fundulidae	Rainwater Killifish	*Lucania parva*
Gobiidae	Yellowfin Goby	*Acanthogobius flavimanus*
	Shokihaze Goby	*Tridentiger barbatus*
	Shimofuri Goby	*Tridentiger bifasciatus*
Ictaluridae	Brown Bullhead	*Ameiurus nebulosus*
	Black Bullhead	*Ameiurus melas*
	White Catfish	*Ameiurus catus*
	Channel Catfish	*Ictalurus punctatus*
Moronidae	Striped Bass	*Morone saxatilis*
Osmeridae	Wakasagi	*Hypomesus nipponensis*
Percidae	Bigscale Logperch	*Percina macrolepida*
Poeciliidae	Western Mosquitofish	*Gambusia affinis*

Source: USFWS, Stockton Office, unpublished data

In addition to its value as habitat for fish, the tidal perennial aquatic natural community provides reproduction, feeding, and resting habitat for many species of mammals and birds. Open water areas supply habitat for rest and foraging by water birds, especially during heavy winter storms when open coastal waters become rough. Bird species that use open water include loons, pelicans, gulls, cormorants, and diving ducks (CALFED 2000). A number of state and federally listed birds feed on fish in the tidal perennial aquatic natural community, including bald eagle, California brown pelican, and California least tern.

2.3.4.1.3 Nonnative Species

The tidal perennial aquatic natural community has been heavily impacted on nearly every trophic level by the introductions of a number of nonnative species. These nonnative species have had substantial adverse effects on the physical habitat and the food web, ultimately impacting the growth and survival of the species covered under the BDCP. Successful nonnatives tend to be better suited than natives to anthropogenic changes to the tidal perennial aquatic natural community. Successful nonnatives generally do not experience the same population controls (i.e., competition, predation, parasitism, and disease) that were present in their place of native origin, resulting in rapid population expansion where they are introduced.

The introduction of two nonnative invasive aquatic plants, water hyacinth and Brazilian waterweed, has reduced habitat quantity and quality for many native fishes in the Plan Area. Under ideal conditions, water hyacinth is capable of extremely rapid growth and can tolerate wide ranges in nutrient concentration, pH, and temperature (Batcher 2000). The species grows as dense floating mats that can greatly reduce primary productivity within the water column (NMFS 2004). Brazilian waterweed grows along the margins of channels and in shallow bays as dense stands that restrict the access of juvenile fish to shallow water habitat within the community. In addition, the thick vegetation of these two invasive species provides excellent habitat for nonnative ambush predators, such as bass and sunfish. Brazilian waterweed is also thought to reduce turbidity through a reduction in water velocity, resulting in higher local precipitation of suspended matter from the water column which results in better hunting conditions for nonnative ambush predators (Brown and Michniuk 2007).

The nonnative copepod, *Pseudodiaptomus*, established after the decline in the abundance of the native copepod, *Eurytemora*, resulted from the introduction of the highly efficient filter-feeding overbite clam (Kimmerer and Orsi 1996). *Eurytemora* can still be abundant during spring, but its populations are replaced by *Pseudodiaptomus* in late spring. Although native fishes, including delta smelt and larval longfin smelt, can switch between these two copepod prey species, because *Pseudodiaptomus* is more elusive than *Eurytemora*, a decrease in the abundance of *Eurytemora* can lead to lower fish foraging efficiency leading to reduced growth rates and the starvation of native fishes (Moyle 2002). More recently, the cyclopoid copepod, *Limnoithona*, has rapidly become the most abundant copepod in the Delta after its introduction in 1993 (Hennessey and Hieb 2007). This species is hypothesized to be a low quality food source and intraguild predator of calanoid copepods such as *Eurytemora* and *Pseudodiaptomus* (Resources Agency et al. 2007).

A variety of macroinvertebrates have been introduced into the tidal perennial aquatic natural community with varying impacts. The Chinese mitten crab experienced a population bloom in 1997 that overwhelmed the fish screening facilities associated with the Jones and Banks pumping plants, but has been uncommon since then. Other potential adverse effects of Chinese mitten crab include: physical impacts, because the crabs burrow into soft sediment and reduce levee stability; ecological impacts, because the crabs are omnivorous, voracious, and experience population blooms; and economic impacts, because the crabs are known to eat rice shoots. The introductions of two clams from Asia, the overbite clam and the Asian clam, have led to major alterations in the food web in the Delta. The overbite clam is most abundant in brackish and saline water while the Asian clam is most abundant in freshwater; therefore, the overbite clam is most abundant in Suisun Bay and the western Delta, and the Asian clam is most abundant in the central Delta. These species are highly efficient filter feeders that significantly reduce phytoplankton and zooplankton concentrations in the water column, which results in reduced food availability for native fishes, such as delta smelt and young Chinook salmon (Kimmerer and Orsi 1996, NMFS 2004, Center for Biological Diversity 2007). In addition to its adverse effects on *Eurytemora*, the overbite clam has been implicated in the reduction of the native opossum shrimp, *Neomysis*, a preferred food of Delta native fishes such as Sacramento splittail and longfin smelt (Feyrer 1999, Moyle 2002).

A large number of nonnative fishes have been introduced into the tidal perennial aquatic natural community of the Delta. Many of the species were introduced for sportfish (striped bass, largemouth bass, smallmouth bass, bluegill, and sunfish); as forage for sportfish (threadfin shad, golden shiner, and fathead minnow); for human food use (common carp, brown bullhead, and white catfish); and from either deliberate or indeliberate release from the aquarium trade or from ballast water release (yellowfin goby, shimofuri goby, and shokihaze goby) (Moyle 2002). Although no introduction of a nonnative fish has unambiguously caused the extinction of a native species in the Bay-Delta (Cohen and Carlton 1995), it is suspected that nonnative introductions have significantly contributed to the decline of some native species due to predation and competition for shared resources. For example, smallmouth bass have been associated with the decline in hardhead, a native minnow found in the Delta, and introductions of several centrarchid species (sunfish and black basses) have been associated with the extirpation of the native Sacramento perch from the Delta.

2.3.4.1.4 Ecosystem Functions

The physical habitat provided by the tidal perennial aquatic natural community supports much of the aquatic Delta food web. This is an extremely complex system, and many details are provided in the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) Food Web Model (Durand 2008). Use of the habitat by individual species is often determined by multiple physical factors (e.g. flow, water salinity, wind, tide, and temperature), many of which vary at multiple temporal scales (Kimmerer 2004). Phytoplankton and zooplankton spend their entire lives in the water medium. As described above, resident and migratory fish use tidal perennial aquatic habitat for spawning, rearing, foraging, and escape cover (CALFED 2000). Young steelhead and Chinook salmon forage in these productive waters as fry and juveniles to put on critical weight before entering the ocean. Changes in physical attributes of the water column, such as flow and water temperature, provide environmental cues for some species to trigger the timing of biological events, such as migration and spawning.

The tidal perennial aquatic natural community is used for foraging, resting, and escape cover by shorebirds, wading birds, and waterfowl. River otters and beavers use this habitat for much of their semi-aquatic lives. The tidal perennial aquatic natural community supports a soft sediment community consisting primarily of invertebrates, including mollusks, crustaceans, and worms.

The tidal perennial aquatic natural community plays a primary role in the formation and maintenance of tidal wetlands (Culberson et al. 2004). As sediments accumulate in the tidal aquatic bed, areas of shallow water increase, and the opportunity for establishment of emergent vegetation increases. Over time, this vegetation may give rise to wetland and riparian communities.

2.3.4.1.5 Environmental Gradients

The tidal perennial aquatic natural community includes an ecologically-important water depth gradient. Many species of phytoplankton, zooplankton, macroinvertebrates, and fish occupy different depths along this gradient depending on their individual physical needs (e.g., light level, temperature, and water velocity). The tidal perennial aquatic natural community also serves as an important link between upstream and downstream ecosystems. Much of the productivity, organic matter, and inorganic sediment from upstream waterways and marshes eventually move into this community and moves downstream to the Pacific Ocean. In the Plan Area, saline water from coastal oceanic water is diluted by flowing freshwater of rivers (Ellison 1983). This mixture of fresh and oceanic water forms a salinity gradient that varies by area and location with seasonal variations in freshwater outflow and tidal action. This gradient drives the location of species that depend on a specific salinity level. The location of this gradient varies on multiple time scales: daily tides, monthly lunar cycle, intra-annual (seasonal) flow patterns, interannual flow variation from interannual rainfall variation, and long-term global climate change (see *Future Conditions with Climate Change* section below) (Kimmerer 2004). Historically, the salinity gradient was generally farther downstream than it now occurs under similar precipitation and unimpaired flow conditions (CCWD 2010).

The tidal perennial aquatic natural community extends shoreward to shallower subtidal zone habitat where light penetrates to the bottom under normal conditions. In this habitat, a distinct benthic flora and fauna exist that rely on light for energy.

2.3.4.1.6 Future Conditions with Climate Change

As described in Section 2.3.3.2, *Climate*, temperatures are projected to increase at an accelerating pace from 3.6 to 9°F (2 to 5°C) by the end of the century (Cayan et al. 2009). Depending upon the general-circulation model used, there are variable predictions for precipitation change, with most models simulating a slight decrease in average precipitation (Dettinger 2005, California Climate Change Center 2006). The Mediterranean-type climate seasonal precipitation experienced in the Plan Area is expected to continue, with most precipitation falling during the winter season and originating from North Pacific storms. Although the amount of precipitation is not expected to change dramatically over the next century, seasonal and interannual variations in precipitation will likely increase as it has over the past century (DWR 2006). With more precipitation falling as rain instead of snow and the snowpack melting earlier, greater peak flows will result during the rainy season and lower flows during the dry season. Knowles and Cayan (2004) predict that inflows will increase by 20 percent from October through February and decrease by 20 percent from March through September. This change in the annual hydrograph could affect species in the tidal perennial aquatic natural community in a number of ways. Many species that inhabit the tidal perennial aquatic natural community have evolved to use environmental cues, such as changes in flows and temperature, to trigger the timing of biological events, such as migration and spawning. Changes in these factors due to global climate change may lead to confusion by these species as to the timing of these natural events and may affect their growth, production, and survival. Reduced outflow from the Delta during the dry season and rising sea level would increase the extent of saltwater intrusion into the Delta (Knowles and Cayan 2002, 2004). Such changes could relocate the extent of tidal influence and the low salinity zone (LSZ) farther upstream. This relocation of the LSZ could influence the amount of rearing habitat available to native estuarine species (USFWS 2004). Reduced flow into the Delta during summer and fall could also lead to increased residence time during these seasons, likely exacerbating high water temperature and low dissolved oxygen problems that already occur in localized areas of the Delta. Toxic substances may also accumulate during the summer and fall as the flow-driven flushing action decreases.

Sea level rise could have negative effects on fish that rely on shallow water habitat by deepening preferred shallow water areas of the Delta and changing them to non-preferred deep water zones. However, sea level rise may create more shallow water and floodplain areas that inundate more readily, thus providing a benefit to species that use floodplains as rearing habitat.

Sea level rise is predicted to be an especially significant factor in the Plan Area, where much of the land has subsided to below sea level and is currently protected from flooding by levees. The current subsided island condition, combined with higher sea level, increased winter river flooding, and more intense winter storms, will significantly increase the hydraulic forces on the levees. With sea level rise exacerbating current conditions, a powerful earthquake in the region could collapse levees, leading to major seawater intrusion and flooding throughout the reclaimed lands of the Delta, altering the tidal prism, and causing substantial changes to the tidal perennial aquatic natural community (Mount and Twiss 2005).

Warmer water temperatures from future climate change would be detrimental to temperature-dependent native fish species in the tidal perennial aquatic natural community by altering the timing of optimal temperature regimes needed for fish spawning, rearing, and migration (Bennett 2005, Lindley et al. 2007). High temperatures can also cause sublethal (e.g., heat shock proteins) and lethal effects to specific life stages of some fish and other organisms in the community. Warmer temperatures could promote the success of nonnative species, such as centrarchids (e.g., black basses, sunfish) and cyprinids (e.g., carp), that spawn during periods with warmer water temperatures (Moyle 2002).

2.3.4.2 Tidal Mudflat

The tidal mudflat natural community typically occurs as mostly unvegetated sediment deposits in the intertidal zone between the mean higher high tide and the mean lower low water (MLLW). The community is typically associated with the tidal freshwater and tidal brackish emergent wetland communities at its upper edge and the tidal perennial aquatic community at its lower edge. The tidal mudflat natural community is ephemeral and owes its physical existence to sediment erosion and deposition processes that differ throughout the Delta and Suisn Marsh, and its biological characteristics to plant succession (Golden and Fiedler 1991, Fiedler and Zebell 1993, Witham and Kareofelas 1994, Zebell and Fiedler 1996, Cappiella et al. 1999, Meisler 2002, Ruhl and Schoellhamer 2004, McKee et al. 2006, Witham 2006). Inflows to the Delta import suspended sediment, and the resuspension and deposition of that sediment are critical accretion factors. Wave energy dissipation and levee maintenance are typical erosion factors. The rate of plant succession on the sediments will vary depending on the supply of plant propagules and the distance to plants that can colonize the sediment by extending their root systems.

The tidal mudflat natural community was not mapped separately in the GIS datasets used for the BDCP. Instead, it was subsumed within the mapped areas of tidal freshwater emergent wetland, tidal brackish emergent wetland, and tidal perennial aquatic natural communities. GIS models were used to estimate the extent of habitat for species that use mudflats (Appendix A, *Covered Species Accounts*).

2.3.4.2.1 Vegetation

The tidal mudflat natural community is generally not vegetated when considered at fine scales, but patches of two small BDCP covered plant species, Mason’s lilaeopsis and Delta mudwort, are found in this community type with the former being more abundant in brackish areas and the latter more abundant in freshwater areas (Golden and Fiedler 1991, Fiedler and Zebell 1993, Zebell and Fiedler 1996, Meisler 2002, Fiedler et al. 2007).

2.3.4.2.2 Fish and Wildlife

An important wildlife habitat function of the tidal mudflat natural community is as foraging habitat for probing shorebirds, including godwits, willets, and sandpipers. This habitat function only exists for shorebirds when the area of mudflat is exposed by the tides. This community supports an extensive invertebrate community that consists of benthic and interstitial species (crustaceans, bivalves, gastropods, aquatic insects, and polychaetes) that provide forage to shorebirds. Other wildlife may access the tidal mudflat natural community occasionally, but there is little habitat value for these species.

When the tidal mudflat natural community is inundated, it serves as shallow open water habitat for several pelagic fish species, including splittail, salmonids, and sturgeon. These species can use tidal mudflat habitat as a shallow water refugia from predators and also forage on benthic invertebrates. Smaller benthic fish species, such as gobies, flatfish, and sculpin inhabit the tidal mudflat natural community at low tide if depressions in the mud support pooled water.

2.3.4.2.3 Nonnative Species

There are no available data regarding the impacts of nonnative invasive species on this community. Where tidal mudflat exists within the valley/foothill riparian natural community, problematic plant species are likely to include giant reed (*Arundo donax*) and perennial pepperweed (*Lepidium latifolium*).

2.3.4.2.4 Ecosystem Functions

At lower intertidal elevations, the tidal mudflat natural community functions as foraging area for waterfowl and shorebirds; and at higher intertidal elevations, it also functions as unoccupied sediment that can be colonized by small stature plant species such as Mason's lilaeopsis and Delta mudwort which are covered species.

2.3.4.2.5 Environmental Gradients

The tidal mudflat natural community occupies a narrow transition zone between tidal perennial aquatic and tidal brackish emergent wetland, tidal freshwater emergent wetland, or valley/foothill riparian. In general, it provides habitat in the lower portion of the tidal range between the mean low tide and extreme low tide where emergent plants typically cannot establish. However, in disturbed sediment depositional areas along natural and artificial levees it provides ephemeral microhabitats within other natural communities when vegetation is removed.

2.3.4.2.6 Future Conditions with Climate Change

Sea level rise is expected to shift the tidal mudflat natural community to higher elevations in areas where the topography rises gradually; however, where steep levee sides are present, it would diminish in areal extent. The tidal mudflat natural community is sensitive to sedimentation and erosion processes (Ruhl and Schoellhamer 2004). If sediment delivery rates do not match sediment export rates, the extent of the tidal mudflat natural community will change until a steady state between supply and export is reached. It is unclear how climate change will affect these processes, but a lack of sediment supply to the Delta and Suisun Marsh will likely decrease the extent of this community (Cappiella et al. 1999, Ganju and Schoellhamer 2010).

2.3.4.3 Tidal Brackish Emergent Wetland

The tidal brackish emergent wetland natural community is a transitional community between the tidal perennial aquatic and terrestrial upland communities. In the Plan Area, tidal brackish emergent wetland exists from near Collinsville westward to the Carquinez Strait. While it is also present on the south side of Suisun Bay and on islands in mid-channel, most of its extent is within Suisun Marsh. The distribution of the tidal brackish emergent wetland natural community in the Plan Area is shown in Figure 2-25 and the constituent plant associations are provided in Table 2-7.

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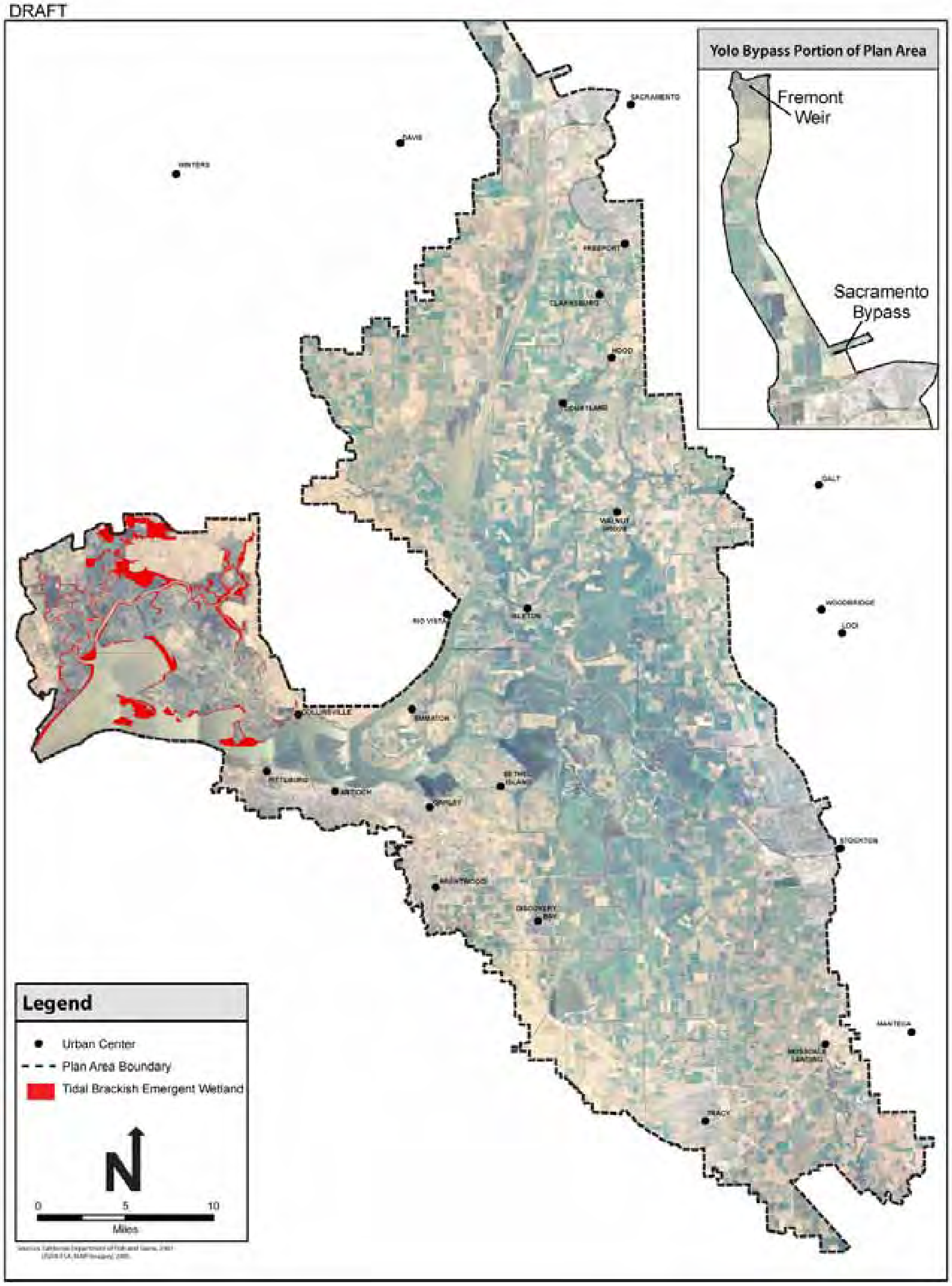

Figure 2-25. Distribution of Tidal Brackish Emergent Wetland Natural Community in the BDCP Plan Area

Table 2-7. Plant Alliances within Tidal Brackish Emergent Wetland Natural Community in the Plan Area

Mapping Unit[1]	*Plant Alliance (Sawyer and Keeler-Wolf 1995)*	*Acreage*
Delta		
Schoenoplectus[2] - *Typha* - *Phragmites*	-	304
Distichlis – Juncus - Sarcocornia[3]	-	2
Other	-	37
Suisun Marsh		
Schoenoplectus - Typha - Phragmites	-	6,048
Distichlis – Juncus – Sarcocornia - Atriplex	-	688
Annual grasses	-	341
Lepidium latifolium	-	181
Other	-	750
Total		**8,351**[3]

[1]Due to the large number of very fine scale mapping units the units shown here are the totals based on the dominant species. Additionally, for Suisun Marsh SFEI (2005) tidal data were used and intersected with the Boul and Keeler-Wolf (2008) vegetation data. For detailed information on these mapping units and plant associations/alliances, as well as on methods of classification used, see Hickson and Keeler-Wolf (2007) and Boul and Keeler-Wolf (2008).
[2]Formerly known as *Scirpus*.
[3]Formerly known as *Salicornia*.

The tidal brackish emergent wetland natural community in the Plan Area is found in undiked areas of Suisun Marsh such as Rush Ranch and Hill Slough, along undiked shorelines on the south shore of Suisun Bay, and on undiked in-channel islands such as Brown's Island. Prior to anthropogenic hydrological modifications, the tidal brackish emergent wetland natural community comprised an estimated 69,000 acres of Suisun Marsh (Boul and Keeler-Wolf 2008) but only 12 percent, or 8,351 acres, remain. At any particular place within this community, the composition of the dominant plant species are controlled by salinity in the channel water and in soil pore water (Culberson 2001, Culberson et al. 2004). Salinity levels in the channels are controlled by local sources of freshwater, seasonal outflow through the Delta and long term climatic variations, semidiurnal tides, and through the operation of a number of water control structures (Byrne et al. 2001, Culberson 2001, Suisun Ecological Workgroup 2001, Brown 2004, Culberson et al. 2004, Malamud-Roam and Ingram 2004, Malamud-Roam et al. 2006, Malamud-Roam et al. 2007, Watson and Byrne 2009).

The effects of channel water salinity are attenuated with distance away from the channel as evapotranspiration through the dry season drives increases in soil pore water salinity that is not flushed away by tidal influences (Culberson 2001, Culberson et al. 2004, Watson and Byrne 2009). This results in higher salinity in the soil pore water of the channel/marsh transition zone and highest salinity levels in the marsh plain (Culberson 2001, Culberson et al. 2004). Additionally, within the marsh plain, depressions and small ponds may support vegetation adapted to less saline conditions (Suisun Ecological Workgroup 2001). Because soil pore water salinity and distance from channel, and not elevation, are the primary drivers of vegetation composition in these brackish marshes, the distributions of saltgrass and pickleweed in the marsh plain proper are driven by subtle differences in inundation duration (Culberson 2001, Culberson et al. 2004, Watson and Byrne 2009). Because the extent of the community is determined by dynamic salinity gradients, the vegetation is also naturally spatially and temporally variable and this variability leads to high plant diversity compared to tidal saline marshes (Watson and Byrne 2009).

Soils underlying the tidal brackish emergent wetland natural community are heavily influenced by suspended sediment along the channels and by the formation of peat beds away from the channels (Culberson 2001, Culberson et al. 2004). The rate of peat accumulation in the marsh plain is slow due to the low productivity of the small stature dominant plants, but has been sufficiently rapid to maintain its surface with increases in sea level (Culberson et al. 2004).

2.3.4.3.1 Vegetation

The tidal brackish emergent wetland natural community in the Plan Area is characterized by tall herbaceous hydrophytes that line the channels down to approximately 18 inches below mean lower low water (MLLW) with species that include hard-stem bulrush (*Schoenoplectus acutus*), California bulrush (*Schoenoplectus californicus*), common reed (*Phragmites australis*), and cattail (*Typha* spp.) (Culberson 2001, Suisun Ecological Workgroup 2001, Watson and Byrne 2009). The borders of first order channels and mosquito ditches, which mimic small channels, are also habitat for Suisun thistle (*Cirsium hydrophilum* var. *hydrophilum*), a BDCP covered species (USFWS 2009a). These same large species occur as clumps in the channel to marsh transition zone and share the zone with many other species such as saltgrass (*Distichlis spicata*), Baltic rush (*Juncus balticus*), and seaside arrow grass (*Triglochin maritima*). The boundary between the distant edge of the transition zone and marsh plain is gradual, and this is where the soft bird's-beak (*Cordylanthus mollis* ssp. *mollis*), a BDCP covered species, occurs with pickleweed (*Sarcocornia pacifica,* formerly *Salicornia virginica*), saltgrass, salt marsh dodder (*Cuscuta salina*), and spearscale (*Atriplex triangularis*) (Grewell 2005, USFWS 2009b). The marsh plain proper is dominated by a variable mixture of pickleweed and saltgrass.

2.3.4.3.2 Fish and Wildlife

The tidal brackish emergent wetland natural community in the Plan Area is productive wildlife habitat. The vegetation and associated waterways provide food and cover for numerous species of birds (e.g., waterfowl, wading birds), mammals, reptiles, and emergent aquatic insects. Many species rely on these emergent wetlands for their entire life cycle. Covered species that depend on the tidal brackish emergent wetland natural community include California black rail, California clapper rail, Suisun song sparrow, salt marsh harvest mouse, and Suisun shrew (Table 2-4).

When inundated, the tidal brackish emergent wetland natural community provides high quality fry and juvenile rearing habitat for a variety of fish species adapted to low salinities, such as splittail, salmonids, and sturgeon. In addition, organic material is exported from the community to provide food to nearby pelagic species, such as delta and longfin smelt.

2.3.4.3.3 Nonnative Species

The tidal brackish emergent wetland natural community and native plant and wildlife species present in the community have been, and continue to be, significantly impacted by invasive nonnative taxa. Invading plant species can potentially alter the species composition of the vegetation, its structure, and its chemical characteristics. Invasions of perennial pepperweed, which are often accompanied by fennel (*Foeniculum vulgare*), are one of the most serious threats to this community (Brown 2004, Vaghti and Keeler-Wolf 2004, Grewell 2005, SFEI 2006, ESA 2007, Fiedler et al. 2007, Hickson and Keeler-Wolf 2007, Boul and Keeler-Wolf 2008, Andrew and Ustin 2009, USFWS 2009a, USFWS2009b). This tall species commonly forms dense patches that exclude native species including BDCP covered species such as soft bird's-beak and Suisun thistle (Grewell 2005, Fiedler et al. 2007, USFWS 2009a, USFWS2009b). Other large stature invasive plant species that are problematic include pampas grass (*Cortaderia selloana*), giant reed (*Arundo donax*), and the nonnative genotype of common reed (*Phragmites australis*). These species commonly establish and spread along channels, in the marsh plain transition zone, and along the upland/marsh transition zone. Additionally, small nonnative annual grasses, particularly barbgrass (*Hainardia cylindrical*) and rabbitsfoot grass (*Polypogon monspeliensis*), have significantly impacted BDCP covered soft bird's-beak by functioning as ineffective host plants to this hemiparasite (Grewell 2005).

A number of nonnative animals are serious predators of native wildlife and have been shown to significantly reduce populations of salt marsh harvest mouse, California black rail, and California clapper rail which are covered species (Suisun Ecological Workgroup 2001, Brown 2004). These invasive and high impact nonnative wildlife species include red fox (*Vulpes vulpes*), feral cats (*Felis domesticus*), and rats (*Rattus* spp.) (Brown 2004, Takekawa et al. 2006). Additionally, ground disturbances caused by foraging by feral pigs (*Sus scrofa*) are significantly impacting the covered Suisun thistle (Fiedler et al. 2007, USFWS 2009a).

2.3.4.3.4 Ecosystem Functions

Because it is connected to the Plan Area through the semi-diurnal tidal cycle, the tidal brackish emergent wetland natural community has both local ecosystem characteristics and is also part of other ecosystems through its contribution to the shared food web. Local effects are dominated by vegetation productivity and decomposition rates which affect tidal channel morphology and tidal plain elevation (Culberson 2001, Culberson et al. 2004, Pearce 2004). Because the soil away from the immediate channel margins is primarily peat, a dynamic equilibrium exists between sea level changes, underground biomass production, and decomposition rates that controls the extent of emergent vegetation (Culberson 2001, Culberson et al. 2004). Additionally, the structure of the vegetation provides cover for aquatic species in the channels and over the transition zone and marsh plain when high tides flood the marsh (Brown 2004). Organic carbon and invertebrates produced within this community are transported to the channels and then to the Delta where they contribute significantly to the greater food web (Brown 2004).

2.3.4.3.5 Environmental Gradients

The tidal brackish emergent wetland natural community exists at the intersection of many gradients that are spatially and temporally variable. The gradients are primarily determined by tidal flows which range from 300,000-600,000 cfs between Chipps Island and Carquinez Strait and 6,500-50,000 cfs in Montezuma Slough (Brown 2004). These large flows create fast currents in the smaller channels, but the transport of materials into and out of the community depends on complex flow dynamics (Brown 2004). The tidal surges create a large scale salinity gradient that is manifested by brackish water conditions that exist because of the mixing of freshwater from the Delta and local creeks with oceanic water from San Francisco Bay. The longitudinal boundary between fresh and brackish water is not discrete but generally occurs over a distance of several miles from Sherman Island to the Carquinez Strait with smaller local boundaries where tributaries enter the northern portion of Suisun Marsh. There is no clear definition of brackish water, but a salinity range of 5-15 ppt generally describes the channel water salinity in the areas where the tidal brackish emergent wetland natural community is found (Conomos et al. 1985, Goman and Wells 2000, Culberson 2001, Kimmerer 2004). The amount of freshwater available to dilute oceanic water is generally determined by water management operations, sewage effluent discharge, and by winter creek and Sacramento River flows. Within this community, a secondary soil pore water salinity gradient develops between the channels and the marsh plain during the dry season as salts accumulate away from the channels through evapotranspiration (Culberson 2001). An elevational gradient also exists between the channels and the marsh plain with the dividing elevation at mean higher high water (MHHW) (Goman and Wells 2000). Below MHHW, large clonal species dominate, while above MHHW are mixtures of various large and small species. The combination of the salinity and elevational gradients creates a wide range of physical habitats that lead to a high diversity of species compared to salt and freshwater marshes (Watson and Byrne 2009).

2.3.4.3.6 Future Conditions with Climate Change

As with all intertidal communities, the tidal brackish emergent wetland natural community is by definition directly linked to sea level as well as the ratio of salt to freshwater. As a result, it is particularly sensitive to long-term sea level rise associated with global climate change and changes in Delta discharge. In order to persist, the tidal brackish emergent wetland natural community must be able to accrete sediments at high enough rates to keep their surfaces intertidal (Watson and Byrne 2009); that rate will depend upon how changing salinity and inundation duration affects the species composition of the wetland (Culberson et al. 2004, Watson and Byrne 2009).

2.3.4.4 Tidal Freshwater Emergent Wetland

The tidal freshwater emergent wetland natural community is typically a transitional community between the tidal perennial aquatic, and valley/foothill riparian and various terrestrial upland communities across a range of hydrologic and edaphic conditions. In the Plan Area, the tidal freshwater emergent wetland natural community often occurs at the shallow, slow-moving or stagnant edges of freshwater waterways in the intertidal zone and is subject to frequent long duration flooding. The distribution of the tidal freshwater emergent wetland natural community in the Plan Area is shown in Figure 2-26, and the constituent plant associations are provided in Table 2-8.

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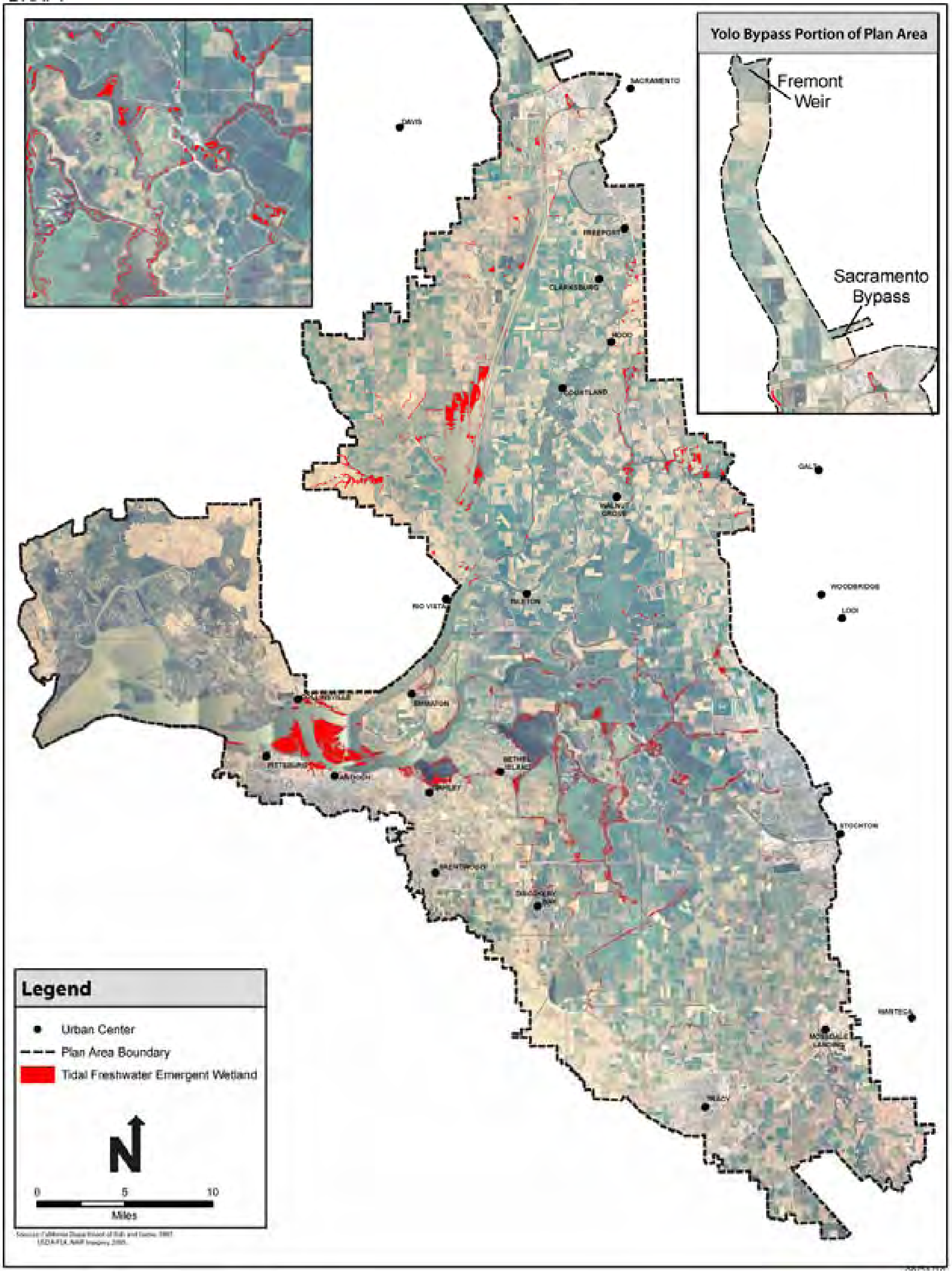

Figure 2-26. Distribution of Tidal Freshwater Emergent Wetland Natural Community in the BDCP Plan Area

Table 2-8. Plant Alliances within the Tidal Freshwater Emergent Wetland Natural Community in the Plan Area

Mapping Unit[1]	*Plant Alliance (Sawyer and Keeler-Wolf 1995)*	*Acreage in Plan Area*
Schoenoplectus (formerly *Scirpus) californicus - Schoenoplectus acutus*	Mixed Scirpus Mapping Unit	340
-	Mixed Scirpus / Floating Aquatics (*Hydrocotyle - Eichhornia*) Complex	323
-	Mixed Scirpus / Submerged Aquatics (*Egeria-Cabomba-Myriophyllum* spp.) complex	378
Schoenoplectus acutus - (Schoenoplectus tabernaemontani)	Hard-stem Bulrush (*Scirpus acutus*)	170
Schoenoplectus acutus	*Scirpus acutus* Pure	1,386
Schoenoplectus acutus-Typha angustifolia	*Scirpus acutus - Typha angustifolia*	768
Schoenoplectus acutus-Typha latifolia	*Scirpus acutus -Typha latifolia*	2,214
Schoenoplectus acutus-Phragmites australis	*Scirpus acutus* - (*Typha latifolia*) - *Phragmites australis*	1,581
Schoenoplectus californicus	California Bulrush (*Scirpus californicus*)	420
Schoenoplectus californicus-Eichhornia crassipes	*Scirpus californicus - Eichhornia crassipes*	14
Schoenoplectus californicus-Schoenoplectus acutus	*Scirpus californicus – Scirpus acutus*	676
Schoenoplectus americanus	American Bulrush (*Scirpus americanus*)	142
Typha angustifolia, T. domingensis Tidal Herbaceous	Narrow-leaf Cattail (*Typha angustifolia*)	98
Typha angustifolia-Distichlis spicata	*Typha angustifolia - Distichlis spicata*	3
Deschampsia caespitosa Tidal Herbaceous	California Hair-grass (*Deschampsia caespitosa*)	1
Deschampsia caespitosa-Lilaeopsis masonii	*Deschampsia caespitosa - Lilaeopsis masonii*	1
Phragmites australis	Common Reed (*Phragmites australis*)	357
Undetermined[2]	Undetermined[2]	78
Total		**8,947**

[1]Some of the mapping units provided here are newly described associations or alliances. For more detailed information concerning these mapping units and plant associations/alliances, as well as on methods of classification used, see Hickson and Keeler-Wolf (2007) and Boul and Keeler-Wolf (2008).

[2]Extent of this natural community present in the Plan Area for which DFG did not delineate plant alliances. As described in Section 2.3.1, *Data Sources and Natural Community Classification*, these areas were delineated as this natural community type from aerial photography interpretation.

Note: Acreage total accommodates for rounding.

The tidal freshwater emergent wetland natural community is distributed in narrow, fragmented bands along island levees, in-channel islands, shorelines, sloughs, and shoals. Prior to the 1860s, it comprised an estimated 87 percent of the Delta, with extensive marshes forming dense stands of vegetation bisected by meandering channels (The Bay Institute 1998, Grossinger et al. 2008). Today, remnant patches of this community are found in the western portion of the Delta near the confluence of the Sacramento and San Joaquin rivers, along Lindsey Slough and the Yolo Bypass, along the mainstem and several channels of the San Joaquin, Old, and Middle rivers, Lost Slough, and the area where the Cosumnes and Mokelumne rivers join the Delta. The loss and degradation of its historical extent is due to its conversion to agriculture as well industrial and urban development; and those losses have led to dramatic reductions in habitat that is available for associated fish and wildlife species (The Bay Institute 1998, CALFED 2000). Channelization, levee-building, removal of vegetation to stabilize levees, and upstream flood control have also reduced the extent of this community and altered its ecological function through changes to flooding frequency, inundation duration, and quantity of alluvial material deposition.

The tidal freshwater emergent wetland natural community occurs along a hydrologic gradient in the transition zone between open water and riparian vegetation or upland terrestrial vegetation such as grasslands or woodlands. In the Plan Area, there are often abrupt transitions to agricultural habitats and managed wetland natural communities and also along the boundaries formed by levees and other artificial landforms. The environmental conditions that support the tidal freshwater emergent wetland natural community are dynamic with frequent flooding disturbances and geomorphologic changes (i.e., alluvial deposition and scouring). Its constituent species composition and ecosystem functions are consequently variable in space and time (The Bay Institute 1998). As a result of the different sources of variability and the anthropogenically restricted area in which it can occur, the community vegetation may be distributed in small patches or in occasional large areas.

Soils underlying the tidal freshwater emergent wetland natural community are heavily influenced by inundation period, water flow, and alluvial deposition. They are hydric soils and when mineral-based, their texture can vary from clay to sand; and when based on organic material, can form peat beds (Goman and Wells 2000, Hitchcock et al. 2005, Drexler et al. 2009a). The soils are typically anaerobic due to frequent or permanent saturation with slow decomposition rates resulting in the accumulation of organic debris in various stages of decomposition. The composition of the vegetation is limited to relatively few dominant species that are tolerant of inundation and anaerobic soil conditions and typically are not tolerant of saline or brackish conditions (Holland and Keil 1995).

The natural topography of the Plan Area that supports this community is virtually flat, draining gradually toward the center of the Delta and then westward toward Suisun Bay. Under natural hydrological conditions, deposits of alluvial material sometimes shifted due to scouring and redeposition, and elevational differences of the vegetation from place to place were a function of alluvium elevation and tidal inundation levels (Grossinger et al. 2008). Today, artificial levees provide topographic barriers adjacent to waterways, and the inboard areas of many of the leveed islands that historically supported this community have subsided below sea level (CALFED 2000). In some cases, where levees have been breached and not repaired, portions of the islands that have not significantly subsided support tidal freshwater emergent wetland (e.g., northern Liberty Island); however, other deeply subsided islands that have flooded and have not been reclaimed support the tidal perennial aquatic natural community due to deeper inundation by floodwaters (e.g., Franks Tract, southern Liberty Island).

2.3.4.4.1 Vegetation

The tidal freshwater emergent wetland natural community is characterized by erect herbaceous hydrophytes (Holland and Keil 1995). There are 17 plant community alliances (i.e., unique species assemblages) mapped in the Plan Area that fall within the tidal freshwater emergent wetland natural community (Table 2-8) (Sawyer and Keeler-Wolf 1995, Hickson and Keeler-

Wolf 2007). The typical vegetation of this type, as mapped by DFG and adopted for vegetation mapping purposes, is dominated by tall, perennial monocots that reproduce by seed as well as vegetatively through rhizomes. However, the DFG vegetation classification was based on vegetation structure and species composition and did not consider ecosystem functions such as location within or above the intertidal region along drainages. In many areas of what is functionally tidal freshwater emergent wetland, woody species, especially willows (*Salix* spp.), occur in the intertidal region and co-dominate the vegetation (Atwater 1980, Watson 2006, EDAW 2007b, Watson and Byrne 2009). These intertidal areas with woody vegetation were not distinguishable in the DFG data set.

Cattails (*Typha* spp.) dominate the vegetation of this community along the Sacramento River; while throughout the San Joaquin River area, bulrushes (*Schoenoplectus americanus* and *Bolboschoenus maritimus*), tules (*Schoenoplectus californicus* and *S. acutus*), and common reed (*Phragmites australis*) are more often the dominant species (Atwater 1980, Watson 2006, EDAW 2007, Hickson and Keeler-Wolf 2007, Watson and Byrne 2009). In the far western portion of the Delta, where tidal waters are generally fresh but may be brackish during periods of low outflow, saltgrass becomes common (Boul and Keeler-Wolf 2008). Numerous native and nonnative dicots and rooted aquatics also commonly occur in the tidal freshwater emergent wetland natural community. Covered plant species associated with the tidal freshwater emergent wetland natural community are presented in Table 2-4.

2.3.4.4.2 Fish and Wildlife

The tidal freshwater emergent wetland natural community provides productive habitat for wildlife. Its vegetation and associated waterways provide food and cover for numerous species of birds (e.g., waterfowl, wading birds), mammals, reptiles, emergent aquatic insects, and amphibians. BDCP covered wildlife species associated with the tidal freshwater emergent wetland natural community are presented in Table 2-4.

Although the remaining areas of tidal freshwater emergent wetlands in the Plan Area are highly altered, they remain critical wintering grounds for migratory birds. A small number of wetland-associated species, such as waterfowl and egrets, have successfully adapted to foraging on some types of croplands that were converted from historical wetland areas (DFG 2005).

Many of the species of fish that use the tidal perennial aquatic natural community for habitat will also use the tidal freshwater emergent wetland natural community as habitat when it is inundated. Younger stages (e.g., larvae and fry) of some species rear in shallow waters that support emergent vegetation. Further, many fish species use emergent vegetation as refuge from predation and high flows (The Bay Institute 1998).

2.3.4.4.3 Nonnative Species

One important invasive nonnative species that has become established in the tidal freshwater emergent wetland natural community is giant reed (*Arundo donax*). This species grows as dense monocultures which shade and crowd out native plant species in this community (Dudley 2000).

Giant reed is found growing along natural and artificial watercourses throughout the Plan Area, but the acreage of the invasion is unknown (Hickson and Keeler-Wolf 2007). By eliminating native plants, giant reed reduces food and habitat for a number of birds, insects, and other wildlife.

2.3.4.4.4 Ecosystem Functions

The tidal freshwater emergent wetland communities provide critical biogeochemical, hydrologic, and geomorphic functions, as well as habitat for a variety of fish and wildlife; however, island reclamation throughout the Delta, channelization, and anthropogenic changes to flow patterns have dramatically altered the ecosystem function and habitat value of these wetlands in the Plan Area (DFG 2005). The tidal freshwater emergent wetland natural community in the Delta provides habitat for microorganisms, macroinvertebrates, and insects that form the base of the aquatic food chain. The vegetation also releases organic debris ("drift") into the waterways that is a source of nutrients and cover. The warm, shallow water and dense vegetation that is often present in this community provides cover for some species and can be a key source of aquatic food or prey for birds and larger wildlife (The Bay Institute 1998). Additionally, it provides allochthonous sources of food and prey for fish and other aquatic species.

The tidal freshwater emergent wetland natural community also naturally absorbs or processes influxes of nutrients that find their way into the aquatic system ("nutrient transformation"), thereby acting as a biogeochemical buffer and contributing to the aquatic food web.

2.3.4.4.5 Environmental Gradients

The tidal freshwater emergent wetland natural community provides habitat on virtually all exposures and slopes provided the surface is saturated or at least periodically flooded by tidal action. However, level topography dominates in the Plan Area, and on the water-side of levees from a depth of approximately 18 inches below mean lower low water (MLLW), the community occurs as a distinct transition to the levee bank upland vegetation. The upland limit of the habitat is generally the boundary between hydric soils supporting predominantly hydrophytic vegetation and non-hydric soils on the levees with primarily non-aquatic vegetation (Cowardin et al. 1979). The boundary between habitat associated with the tidal freshwater emergent wetland natural community and deep water habitats is approximately 18 inches below MLLW (Atwater et al. 1979, Simenstad et al. 2000).

Where brackish conditions occur at the western edge of the Delta, Suisun Bay, and Suisun Marsh, the tidal freshwater emergent wetland natural community merges into the tidal brackish emergent wetland natural community that supports plant and wildlife that are tolerant of brackish water or saline soil conditions. Physical factors that drive the location of gradients between community types include elevation, salinity, and flow patterns at multiple temporal scales (e.g., daily tidal, lunar, seasonal, inter-annual) (Culberson 2001, Watson 2006, Watson and Byrne 2009).

2.3.4.4.6 Future Conditions with Climate Change

As with all intertidal communities, the tidal freshwater emergent wetland natural community is by definition directly linked to sea level. As a result, it is particularly sensitive to long-term sea level rise associated with global climate change (Nicholls et al. 1999). Higher sea level will relocate the natural community to higher elevations in the Delta. Further, tidally influenced waterways would be relocated upstream, thus shifting the tidal freshwater emergent wetland natural community farther upstream. Because much of the Delta is armored with levees, the sea level driven relocation of the intertidal zone would be primarily vertical and not horizontal, likely resulting in a reduction in the extent of the tidal freshwater emergent wetland natural community as it is replaced by deep water habitat (i.e., tidal perennial aquatic natural community) adjacent to steep-sided levees. The greatest increase in the extent of this natural community will primarily occur along the periphery of the Delta where there are gently sloping areas of upland (Knowles 2006).

In order for its extent to remain constant the tidal freshwater emergent wetland natural community must accrete sediments, both influxes of mineral soil as well as local accumulations of peat, at a rate high enough to keep its lowest surface above an elevation of 18 inches below MLLW (Atwater et al. 1979, Simenstad et al. 2000, Kimmerer 2004). Given the reductions in sediment loads over the past half century (Section 2.3.2, *Ecosystem Processes*) (Cappiella et al. 1999, Wright and Schoellhamer 2004, Ganju and Schoellhamer 2010), and the likely inability of peat accumulation to keep pace with accelerating sea level rise (Orr unpublished data) it is likely that the extent of this community will be reduced where its vegetation cannot colonize newly inundated uplands.

2.3.4.5 Valley/Foothill Riparian

Broadly defined, the valley/foothill riparian natural community is often found as a transition zone between aquatic and terrestrial habitats and often expresses a wide range of environmental conditions (e.g., variable light and nutrient availability) (Holland and Keil 1995, The Bay Institute 1998, Vaghti and Greco 2007). In the Plan Area, the valley/foothill riparian natural community occurs along the margins of low-gradient perennial and intermittent waterways, floodplains, tidal areas, or where the water table is sufficiently high to provide water to plants year-round (e.g., oxbows) (CALFED 2000, Vaghti and Greco 2007). The distribution of the valley/foothill riparian natural community is shown in Figure 2-27, and the extent of its constituent vegetation associations is presented in Table 2-9.

The valley/foothill riparian natural community usually occurs in the Plan Area as long, linear patches separating other terrestrial biological communities and agricultural or urban land, or in low-lying, flood-prone patches near river bends, canals, or breached levees (Figures 2-18 through 2-22). Such areas are located along many of the major and minor waterways, oxbows, and levees in the Plan Area, including the Sacramento River, Deep Water Ship Channel, Yolo Bypass, and channels of the San Joaquin River and the Delta. Patches of riparian vegetation are also found on the interior of leveed Delta islands, along drainage channels and pond margins, and in abandoned low-lying fields.

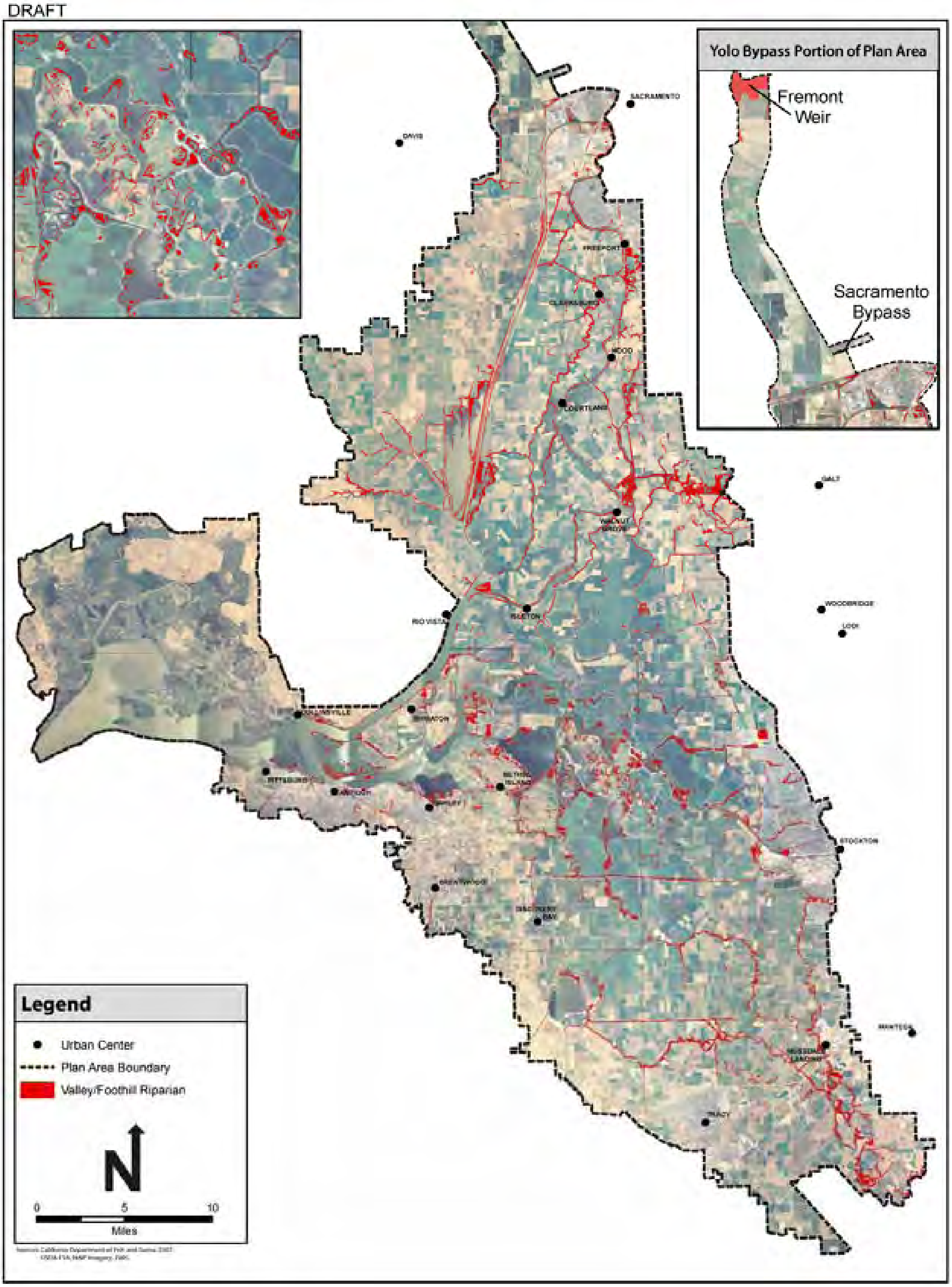

Figure 2-27. Distribution of Valley/Foothill Riparian Natural Community in the BDCP Plan Area

The current extent of the valley/foothill riparian natural community represents only a small proportion of its historical extent in the Plan Area (Thompson 1961, The Bay Institute 1998). Historically, valley oak (*Quercus lobata*) and cottonwood (*Populus fremontii*) occurred on coarser textured soils along natural levees and ranged from scraggy trees in the vicinity of Brannan Island to larger trees upriver (Thompson 1957). Similarly, in mineral soil areas of the south Delta, valley oak occurred sporadically as scraggy trees near drainage channels (Norris 1851). In contrast to historical conditions, these species occur on man-made levees sporadically throughout the Delta where vegetation control has not been a constant practice. In contrast to valley oak, under both historical and current conditions, extensive stands of willows occur throughout the Delta with box elder (*Acer negundo*), red alder (*Alnus rubus*), Redosier dogwood (*Cornus sericea*) and Oregon ash (*Fraxinus latifolia*), becoming increasingly common upstream from the Lower Sherman Island (Atwater 1980, EDAW 2007, Hickson and Keeler-Wolf 2007). The loss of riparian vegetation throughout California is estimated to be between 85-95 percent, and was caused by human activities such as river and stream channelization, levee building, removal of vegetation to stabilize levees, and extensive agricultural and urban development (Riparian Habitat Joint Venture 2004).

2.3.4.5.1 Vegetation

DFG identified 41 plant community alliances (i.e., unique species assemblages) in the Delta that fall within the valley/foothill riparian natural community (Table 2-9) (Sawyer and Keeler-Wolf 1995, Hickson and Keeler-Wolf 2007). The most common riparian plant associations in the Plan Area are dominated by valley oak, Fremont cottonwood, and Gooding’s black willow in the overstory and Himalayan blackberry, narrow-leaf willow, arroyo willow, and California wild rose in the understory or as riparian scrub. A recent Delta DFG survey discovered areas of valley/foothill riparian vegetation dominated by Redosier dogwood (*Cornus sericea*). Other native trees and shrubs that may be locally-dominant or important include white alder, California sycamore, buttonbush, California dogwood, Oregon ash, red willow, Pacific willow, box elder, Mexican elderberry, and Hinds’ walnut. California wild grape is a vine commonly found climbing upon other riparian vegetation.

Due to the wide range of abiotic environmental conditions in which the valley/foothill riparian natural community is found (e.g., substrate, flood frequency and duration, groundwater level, salinity), species composition and vegetation density and structure varies widely, from tall-canopied riparian forests dominated by deciduous, broad-leaved trees, to riparian scrub dominated by shorter stature trees, shrubs, and brambles. Species composition overlaps among the various riparian vegetation associations, and the structure and density of vegetation may vary even at relatively small spatial scales. The vegetation alliances, which make up the valley/foothill riparian natural community as identified by DFG in the Plan Area, can be placed into riparian forest, woodland, and scrub categories, based largely on the canopy height and the structure of the dominant plant taxa (Holland and Keil 1995). Riparian forest is dominated by broad-leaved, winter deciduous trees, such as valley oak and Fremont cottonwood, that form closed canopies up to 115 feet (35 m) tall (Griggs et al. 1993, Tu 2000, Griggs and Golet 2002, Trowbridge 2002, Trowbridge et al. 2005). This type of riparian vegetation is typically found along perennial or intermittent streams and tends to consist of relatively even-aged trees that reproduce episodically after flood events (Trowbridge 2005, Vaghti and Greco 2007). Riparian woodland may have similar species composition to the forests and are also typically dominated by tall, broad-leaved, winter deciduous trees. However, woodland canopies tend to be more open, likely due to hydrologic conditions and the species adaptations to the flooding regime. These conditions are found in few areas in the Delta today. Thickets dominated by one or more shorter stature willows (typically narrow leaf willow or arroyo willow) are categorized as riparian scrub, and are common along newly or frequently flooded waterways. Riparian scrub may contain saplings of riparian trees, other fast-growing shrubs, and vines that recolonize quickly following flood disturbance.

Table 2-9. Plant Alliances within the Valley/Foothill Riparian Natural Community in the Plan Area

Mapping Unit[1]	***Plant Association (Sawyer and Keeler-Wolf 1995)***	***Acreage in Plan Area***
Acacia-Robinia	*Robinia pseudoacacia*	86
Acer negundo-Salix gooddingii	*Acer negundo-Salix gooddingii*	32
Alnus rhombifolia/Cornus sericea	*Alnus rhombifolia/Cornus sericea*	32
Alnus rhombifolia/Salix exigua (Rosa californica)	*Alnus rhombifolia/Salix exigua* (*Rosa californica*)	419
Arroyo Willow *(Salix lasiolepis)*	*Salix lasiolepis* Great Valley	461
*Baccharis pilularis/*Annual Grasses & Herbs	*Baccharis pilularis/*Annual Grass-Herb	53
Black Willow *(Salix gooddingii)*	*Salix gooddingii*	635
Black Willow *(Salix gooddingii)*-Valley Oak *(Quercus lobata)* restoration	-	93
Blackberry *(Rubus discolor)*	*Rubus discolor*	1204
Blackberry NFD Super Alliance	-	2
Box Elder *(Acer negundo)*	*Acer negundo*	44
Buttonbush *(Cephalanthus occidentalis)*	*Cephalanthus occidentalis*	7
California Dogwood *(Cornus sericea)*	*Cornus sericea*	117
California Wild Rose *(Rosa californica)*	*Rosa californica*	98
Coast Live Oak *(Quercus agrifolia)*	*Quercus agrifolia*	84
Cornus sericea-Salix exigua	*Cornus sericea-Salix exigua*	122
Cornus sericea-Salix lasiolepis/(Phragmites australis)	*Cornus sericea-Salix lasiolepis*	823
Coyotebush *(Baccharis pilularis)*	*Baccharis pilularis*	28
Fremont Cottonwood *(Populus fremontii)*	*Populus fremontii*	642
Fremont Cottonwood-Valley Oak-Willow (Ash-Sycamore) Riparian Forest NFD Association	-	414
Giant Reed *(Arundo donax)*	*Arundo donax*	61
Hinds' walnut *(Juglans hindsii)*	*Juglans X hindsii*	21
Horsetail *(Equisetum spp.)*	*Equisetum (arvense, variegatum, hyemale)*	83
Intermittently Flooded to Saturated Deciduous Shrubland	Intermittently flooded cold-deciduous shrubland	141
Intermittently or Temporarily Flooded Deciduous Shrublands	Intermittently flooded cold-deciduous shrubland	536
Mexican Elderberry *(Sambucus mexicana)*	*Sambucus mexicana*	17

Table 2-9. Plant Alliances within the Valley/Foothill Riparian Natural Community in the Plan Area (continued)

Mapping Unit[1]	*Plant Association (Sawyer and Keeler-Wolf 1995)*	*Acreage in Plan Area*
Microphyllous Shrubland	-	1
Mixed Fremont Cottonwood-Willow spp. NFD Alliance	-	421
Mixed Willow Super Alliance	-	88
Narrow-leaf Willow *(Salix exigua)*	*Salix exigua*	294
Oregon Ash *(Fraxinus latifolia)*	*Fraxinus latifolia*	1
Pampas Grass *(Cortaderia selloana-C. jubata)*	*Cortaderia (selloana, jubata)*	16
Quercus lobata-Acer negundo	*Quercus lobata-Acer negundo*	68
Quercus lobata-Alnus rhombifolia (Salix lasiolepis-Populus fremontii-Quercus agrifolia)	*Quercus lobata-Alnus rhombifolia*	368
Quercus lobata-Fraxinus latifolia	*Quercus lobata-Fraxinus latifolia/Vitis californica*	304
Quercus lobata/Rosa californica (Rubus discolor-Salix lasiolepis/Carex spp.*)*	-	802
Restoration Sites	-	31
Rubus discolor	*Salix exigua*	4
Salix exigua-(Salix lasiolepis-Rubus discolor-Rosa californica)	*Salix exigua-(Salix lasiolepis)-Rubus discolor*	1089
Salix gooddingii-Populus fremontii-(Quercus lobata-Salix exigua-Rubus discolor)	*Salix gooddingii-Populus fremontii*	1733
*Salix gooddingii-Quercus lobata/*Wetland Herbs	*Salix gooddingii-Quercus lobata*/wetland herb	429
Salix gooddingii/Rubus discolor	-	143
*Salix gooddingii/*Wetland Herbs	*Salix gooddingii*/wetland herb	651
Salix lasiolepis-(Cornus sericea)/Scirpus spp.-*(Phragmites australis-Typha* spp.*)* complex unit	-	488
Salix lasiolepis-Mixed brambles *(Rosa californica-Vitis californica-Rubus discolor)*	-	1535
Shining Willow *(Salix lucida)*	*Salix lucida*	78
Temporarily or Seasonally Flooded - Deciduous Forests	Temporarily flooded cold-deciduous forest	140
Tobacco brush *(Nicotiana glauca)* mapping unit	-	2
Valley Oak *(Quercus lobata)*	*Quercus lobata*	2019
Valley Oak *(Quercus lobata)* restoration	-	96
Valley Oak Alliance-Riparian	-	8
White Alder *(Alnus rhombifolia)*	*Alnus rhombifolia*	150
White Alder *(Alnus rhombifolia)*-Arroyo willow *(Salix lasiolepis)* restoration	-	8
-	Undetermined[2]	115
Total		**17,338**

[1]Some of the mapping units provided here are newly described associations or alliances. For more detailed information concerning these mapping units and plant associations/alliances, as well as on methods of classification used, see Hickson and Keeler-Wolf (2007) and Boul and Keeler-Wolf (2008).

[2]Extent of this natural community present in the Plan Area for which DFG did not delineate plant alliances. As described in Section 2.3.1, *Data Sources and Natural Community Classification*, these areas were delineated as this natural community type from aerial photography interpretation.

Note: Acreage total accommodates for rounding.

The understory in riparian forest and woodland may contain immature canopy species and species commonly found in the riparian scrub community. All three structural types of the valley/foothill riparian natural community typically contain diverse mixtures of herbaceous plant species in the understory, often including graminoids such as rushes, bulrushes, sedges, flat-sedges, and grasses, as well as forbs such as monkeyflowers, stinging nettle, and watercress. Woody vines or lianas are also common and may form a dense understory composed of species such as honeysuckles, poison oak, and California wild grape (Holland and Keil 1995, Vaghti and Greco 2007).

BDCP covered plant species found or likely to be found in the valley/foothill riparian natural community in the Plan Area are listed in Table 2-4.

2.3.4.5.2 Wildlife

Although significantly altered and reduced in extent since initial European settlement (Katibah 1984), riparian habitats continue to support the greatest diversity of wildlife species of any habitat in California. The rich and complex vegetation composition and structure present in the valley/foothill riparian natural community provides habitat for over 225 bird, mammal, and reptile species (Riparian Habitat Joint Venture 2004). Over 80 percent of all wildlife species in the Sacramento Valley use riparian areas during a part of their life cycle for nesting, movement, cover, or forage (Riparian Habitat Joint Venture 2004). BDCP covered wildlife species associated with the valley/foothill riparian natural community are listed in Table 2-4.

Mammals that use the valley/foothill riparian natural community as habitat or movement corridors include ringtails, muskrats, raccoons, deer, coyotes, mountain lions, bobcats, woodrats, and mice. Two covered mammal species, riparian brush rabbit and riparian woodrat, are dependent upon the valley/foothill riparian natural community in the Plan Area. Riparian brush rabbit, a federally-listed endangered species, relies on the community for its entire lifecycle. The riparian woodrat (aka San Joaquin Valley woodrat), federally-listed as endangered and a state species of concern, inhabits riparian areas in the Plan Area. Bats are also found in greater densities near riparian areas feeding on the abundant swarms of aquatic insects and also use riparian areas for roosting habitat.

Abundant micro- and macro-invertebrate wildlife inhabit both the belowground and aboveground portions of the valley/foothill riparian natural community, contribute to ecosystem function and food web diversity. Soil invertebrates are a critical factor controlling decomposition and nutrient cycling (Power and Rainey 2000).

Riparian habitat is considered the most important habitat to landbird species in California (Manly and Davidson 1993, Davidson 1995). Migratory birds use riparian areas as stopover points. Major direct and indirect anthropogenic and non-anthropogenic impacts on this community in the Plan Area that affect avian species include degradation and fragmentation of habitat, nest parasitism, disruption of hydrologic processes by levees, clearing for agricultural and urban development, and biological invasions. Special-status bird species that are riparian habitat specialists include Swainson’s hawk, bank swallow, yellow warbler, common yellowthroat, Wilson’s warbler, yellow-breasted chat, and tricolored blackbird.

2.3.4.5.3 Nonnative Species

Riparian environments, with their high edge-to-area ratios and frequent disturbance regime, are prone to biological invasions (Planty-Tabacchi et al. 1996). In the valley/foothill riparian systems, introduced nonnative woody and herbaceous plant species may replace native species, and once established, can be extremely difficult to control or eradicate. Problematic nonnative invasive plant species in riparian areas include tree-of-heaven, *Sesbania*, Chinese tallowtree, black locust, tamarisk, Russian olive, bluegum eucalyptus, Himalayan blackberry, palm trees (multiple genera), giant reed, and perennial pepperweed. For example, the introduction of giant reed has negatively impacted the valley/foothill riparian natural community because the species grows in very dense monocultures, displacing natives and changing hydrological regimes (Dudley 2000). By eliminating native plants, giant reed removes food and habitat for a number of birds, insects, and other wildlife.

Many nonnative invasive wildlife species such as red-eared sliders and black rats have also impacted the valley/foothill riparian natural community. Feral domestic cats are another important nonnative species that can impact many native bird species in this community.

2.3.4.5.4 Ecosystem Function

The valley/foothill riparian natural community provides disproportionately higher ecosystem services and wildlife habitat compared to other terrestrial communities (National Research Council 2002). Riparian areas serve as the hydrologic connection between terrestrial uplands and aquatic ecosystems, receiving water from precipitation, overland runoff, groundwater discharge, and flow from an adjacent water body or alluvial aquifer (Vaghti and Greco 2007). They provide benefits to water quality by processing and filtering runoff, retaining and recycling nutrients, and trapping sediments (National Research Council 2002). Within the Plan Area, these ecosystem functions have been substantially negatively impacted due to the destruction and fragmentation of the community.

Although the covered fish species do not rely primarily on riparian habitat because they are aquatic species, they are directly and indirectly supported by the habitat services and food sources provided by the highly productive riparian ecosystem, particularly during flood flows when riparian habitats are inundated. Riparian vegetation is a source for organic material (e.g., falling leaves), insect food, and woody debris in waterways and can influence the course of water flows and structure of in-stream habitat. This debris is an important habitat and food source for fish, amphibians, and aquatic insects (Opperman 2005).

2.3.4.5.5 Environmental Gradients

Due to its location in the transition zone between aquatic and terrestrial ecosystems, the valley/foothill riparian natural community is characterized by biotic (e.g., species composition) and abiotic (e.g., hydrologic) gradients (Vaghti and Greco 2007). These gradients interact to form highly diverse and complex communities, both structurally and functionally. They also interact strongly with and influence the aquatic, emergent, and upland habitats along their edges.

The valley/foothill riparian natural community is associated with active and remnant hydrologic features in the Plan Area, as well as areas with a high water table that are periodically inundated. Plant community composition and structure is tightly coupled with fluvial processes (Strahan 1984). Vegetation density is inversely related to frequency of flooding; low-stature annual and perennial species on frequently-inundated sandbars and low-elevation ground give way to taller, longer-lived species further upland. In the Plan Area, there are abrupt transitions to agricultural cover, managed wetlands, or boundaries formed by levees and other man-made landforms.

Although the valley/foothill riparian vegetation is found on a range of soil types, the vast majority are primarily mineral or intermixed with peat in the Plan Area (Figure 2-4) (Hitchcock et al. 2005, Unruh and Hitchcock 2009). Soil conditions associated with this vegetation type are also typically influenced by current and past hydrologic conditions (Figure 2-10).

2.3.4.5.6 Future Conditions with Climate Change

Future climate change (Section 2.3.3.2, *Climate*) is expected to alter the valley/foothill riparian natural community in a variety of ways. Rising sea level will affect the location, extent, and composition of the valley/foothill riparian natural community as a result of increased water elevation and increased salt water intrusion. As water levels rise, riparian vegetation at the water's edge will become more frequently flooded, and many species intolerant of this longer inundation will migrate upslope if suitable habitat and hydrologic regimes are present. The ability to colonize new ground by shifting away from water's edge will depend on the availability of space in adjacent higher elevation areas and the ability of individual riparian species to colonize any new spaces (e.g., via seed dispersal or clonal growth).

Future vegetation composition and extent of the valley/foothill riparian natural community will also depend on the tolerance levels of individual plant species to the higher salinity associated with saltwater intrusion. Changes in channel water salinity may cause species shifts in the lower Delta by eliminating non-willow tree species, but the effect will be difficult to determine even qualitatively due to the inherent variability of the system.

Changes to the timing, duration, and magnitude of Delta inflows associated with future climate change are anticipated to result in more intense winter flooding and greater erosion of riparian habitats (Field et al. 1999, Hayhoe et al. 2004). The hydrodynamics of stream channels and the width of riparian corridors will be altered, resulting in losses or shifts in species composition of riparian vegetation.

Increased variability in precipitation is expected to produce prolonged droughts that make riparian vegetation more prone to fires. Thus, the frequency of wildfires in the valley/foothill riparian natural community is expected to increase in the future.

2.3.4.6 Nontidal Perennial Aquatic

The nontidal perennial aquatic natural community in the Delta can range in size from small ponds in upland areas to small lakes, such as the North and South Stone Lakes. The nontidal perennial aquatic natural community can be found in association with any terrestrial habitat and often transitions into nontidal freshwater perennial emergent wetland and valley/foothill riparian. The distribution of nontidal perennial aquatic is shown in Figure 2-28. The littoral zone of the nontidal perennial aquatic community is defined as the portion of the water column penetrable by light and that occurs at the edges of lakes and throughout most ponds (Moss 1998, Scheffer 2004). The limnetic zone extends below the littoral zone to the deepest part of the water body. Light penetration is inversely related to turbidity. Water temperature varies with depth; colder water generally occurs deeper due to the inverse relationship between water temperature and density. The oxygen concentration in nontidal perennial aquatic waters is low relative to that of flowing water. Only a small portion of water is in direct contact with air at the surface, where gas exchange with the atmosphere occurs. Dead organic material typically sinks to the bottom and decomposes, increasing biological oxygen demand near the bottom of some water bodies. Because of the stratification of these physical variables, there is a distinct zonation in plants and animals living in the nontidal perennial aquatic natural community (DFG 2005).

2.3.4.6.1 Vegetation

The plant associations present and their extent within the nontidal perennial aquatic natural community are described in Hickson and Keeler-Wolf (2007) (Table 2-10). Non-plant primary producers such as diatoms, desmids, and filamentous green algae often form the base of the food web where they dominate open water habitat. Plant species found in this community vary with inundation depth and distance from shore, from submerged aquatics (e.g., pondweed and Brazilian waterweed) to floating aquatic vegetation (e.g., duckweed and water hyacinth) that are found closer to shore and which may increase the rates of sediment and organic matter accumulation (DFG 2005).

Table 2-10. Plant Alliances within the Nontidal Perennial Aquatic Natural Community in the Plan Area

Mapping Unit[1]	*Plant Alliance (Sawyer and Keeler-Wolf 1995)*	*Acreage in Plan Area*
Ludwigia peploides	Floating primrose (*Ludwigia peploides*)	53
Ludwigia peploides	*Ludwigia peploides*	34
Eichhornia crassipes	Water hyacinth (*Eichornia crassipes*)	96
Egeria-Cabomba-Myriophyllum spp.	Brazilian waterweed (*Egeria- Myriophyllum*) Submerged	112
-	Algae	69
-	Generic floating aquatics	216
-	Milfoil-waterweed (generic submerged aquatics)	6
Undetermined[2]	Undetermined[2]	8
Water	-	4,747
Total		**5,341**

[1]Some of the mapping units provided here are newly described associations or alliances. For more detailed information concerning these mapping units and plant associations/alliances, as well as on methods of classification used, see Hickson and Keeler-Wolf (2007), Boul and Keeler-Wolf (2008), and TAIC (2008).
[2]Extent of this natural community present in the Plan Area for which DFG did not delineate plant alliances. As described in Section 2.3.1, *Data Sources and Natural Community Classification*, these areas were delineated as this natural community type from aerial photography interpretation.

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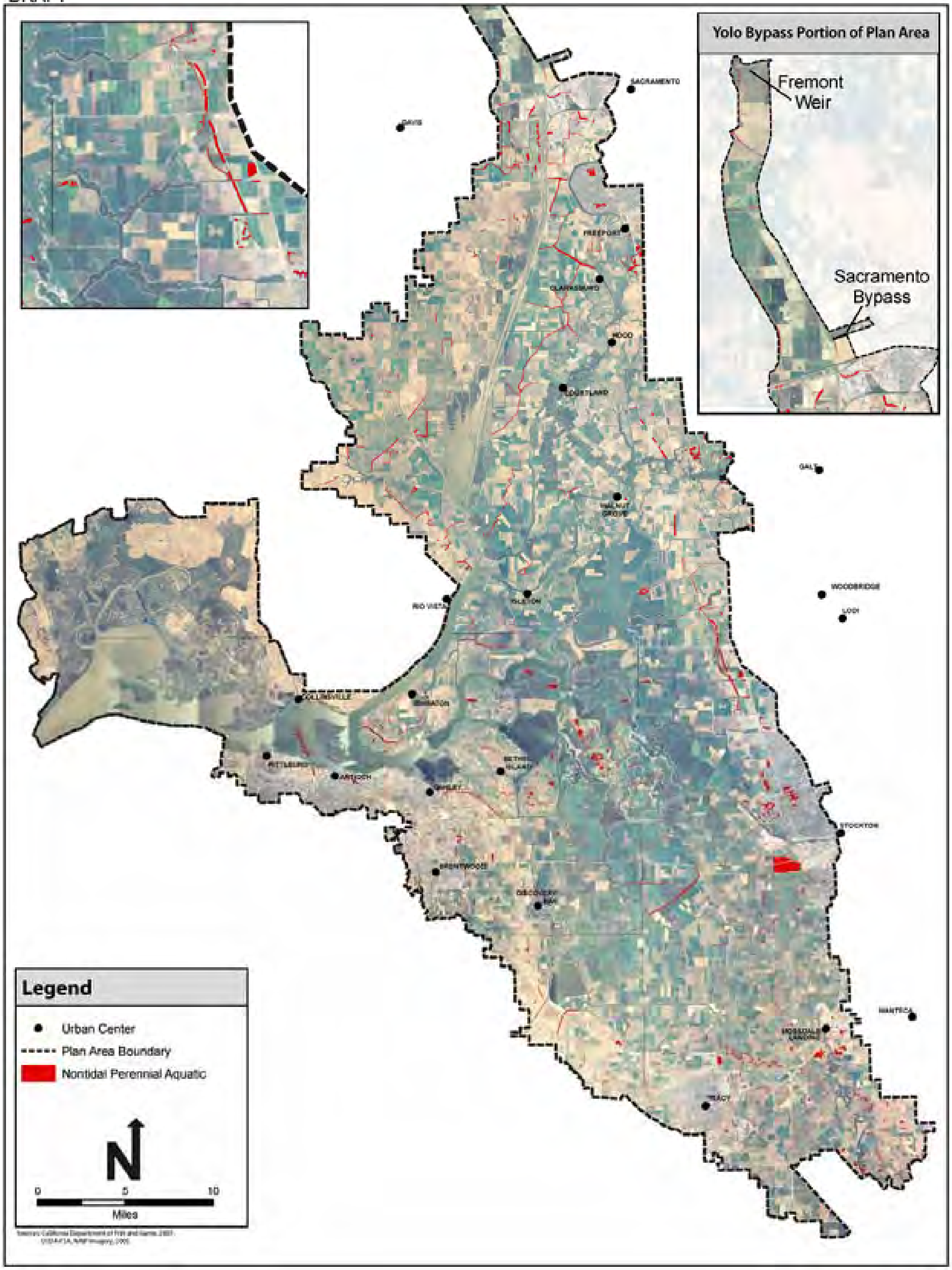

Figure 2-28. Distribution of Nontidal Perennial Aquatic Natural Community in the BDCP Plan Area

Shallow bodies of water, such as ponds and small lakes, generally are found in either a clear-water state with rooted and floating aquatic plants or in a turbid-water state dominated by algae with very few aquatic plants (Moss 1998, Scheffer 2004). These states can be stable or can oscillate between each other depending on a large number of factors that primarily affect the density of *Daphnia* zooplankton populations (Moss 1998, Scheffer 2004). The submerged portions of the plants provide a substrate for smaller algae and cover for smaller aquatic animals, including fish. Floating aquatics provide food and support for herbivorous crustaceans and mollusks (Smith 1974). Vegetation cover in the nontidal perennial aquatic natural community ranges from continuous to open (CALFED 2000). Covered plant species associated with the nontidal perennial aquatic natural community are presented in Table 2-4.

2.3.4.6.2 Fish and Wildlife

A thin layer of floating duckweed often covers the surface of shallow nontidal perennial aquatic waters. Desmids, diatoms, protozoans, crustaceans, hydras, and snails live on the under-surface of the layer, whereas mosquitoes and other aquatic insect larvae may live in between the plants.

Zooplankton, such as rotifers, copepods, and cladocerans, live suspended in the water column and graze on phytoplankton (Smith 1974). Together with phytoplankton, these organisms compose the base of the nontidal perennial aquatic food web. A variety of aquatic insects (e.g., dipterans, coleopterans, chironomids, trichopterans, plecopterans, and ephemeropterans) and collembolans use the nontidal perennial aquatic habitat for their larval stage. Native fish that can (or could in the past) be found in some nontidal perennial aquatic communities include the Sacramento perch, hitch, and tule perch (Moyle 2002).

A variety of wildlife species use the nontidal perennial aquatic natural community for resting and foraging, including waterfowl, shorebirds, semi-aquatic mammals (e.g., beaver, muskrat, and river otter), piscivorous birds (e.g., bald eagles and osprey), and insectivorous birds and bats that prey on insects that gather over open water. Ponds and other small bodies of open water also serve as important brooding habitat for ducks nesting in nearby upland habitats. Many water-dependent species (e.g., western pond turtle) require adjacent upland, riparian woodlands, or emergent wetlands for cover or nesting habitat. BDCP covered fish and wildlife species associated with the nontidal perennial aquatic natural community are presented in Table 2-4.

2.3.4.6.3 Nonnative Species

Many nonnative species have invaded the nontidal perennial aquatic community. Common invasive plants found in this habitat include Brazilian waterweed, Eurasian watermilfoil, and water hyacinth (DBW 2006, 2008). These plants form thick mats that exclude native vegetation and associated wildlife (SFEI 2003).

The nontidal perennial aquatic natural community in the Plan Area supports many nonnative freshwater fish species, including centrarchids, common carp, inland silverside, fathead minnow, and western mosquitofish. Additionally, the nonnative bullfrog is frequently present. These nonnative species prey on or compete with native fish and amphibian species both directly and indirectly for resources, including the BDCP covered California red-legged frog and California tiger salamander.

2.3.4.6.4 Ecosystem Functions

The nontidal perennial aquatic natural community is embedded in other communities, and generally the most significant ecosystem functions include providing an alternative source of primary productivity through its aquatic food web and an aquatic habitat for native fish, amphibians, and reptiles such as giant garter snake, a BDCP covered species. As described above, the source of primary productivity can either be algal phytoplankton or aquatic plants depending on whether the body of water is in a turbid- or clear-water state. The identity of the primary consumers and their feedback effects on the ecosystem depend in complex ways on many factors and cause impacts on the secondary consumers such as planktivorous or benthivorous (cyprinids) fish (Scheffer 2004).

2.3.4.6.5 Environmental Gradients

Within the water column of the nontidal perennial aquatic natural community there are gradients of light, oxygen and other chemicals, pH, and temperature which combine in various ways and result in a range of micro-habitat types (Moss 1998, Scheffer 2004). External gradients to terrestrial ecosystems always exist at the boundary of this community and vary from direct transitions to riparian forest, grassland, or agricultural lands in the Plan Area.

2.3.4.6.6 Future Conditions with Climate Change

Ongoing and future climate change (Section 2.3.3.2, *Climate*) is expected to alter the nontidal perennial aquatic natural community. Where this community exists at elevations at or below current sea level, rising sea level will alter its location, extent, and composition and potentially result in increased saltwater intrusion through an altered tidal hydrological regime. Also, where this community exists in flooded depressions in upland areas, which presumably already support the nontidal perennial aquatic community, it is not likely that natural processes could replace the area that will be lost.

2.3.4.7 Nontidal Freshwater Perennial Emergent Wetland

The nontidal freshwater perennial emergent wetland natural community is composed of perennially saturated wetlands, including meadows, dominated by emergent plant species that do not tolerate perennial saline or brackish conditions (CALFED 2000). Nontidal freshwater perennial emergent wetland communities in the Plan Area occur in small fragments along the edges of the nontidal perennial aquatic and valley/foothill riparian natural communities (Figure 2-29). Soils are predominantly silt and clay, although coarser sediments and organic material may be intermixed (Cowardin et al. 1979). In some areas, organic soils (peat) may constitute the primary growth medium (USACE 1978).

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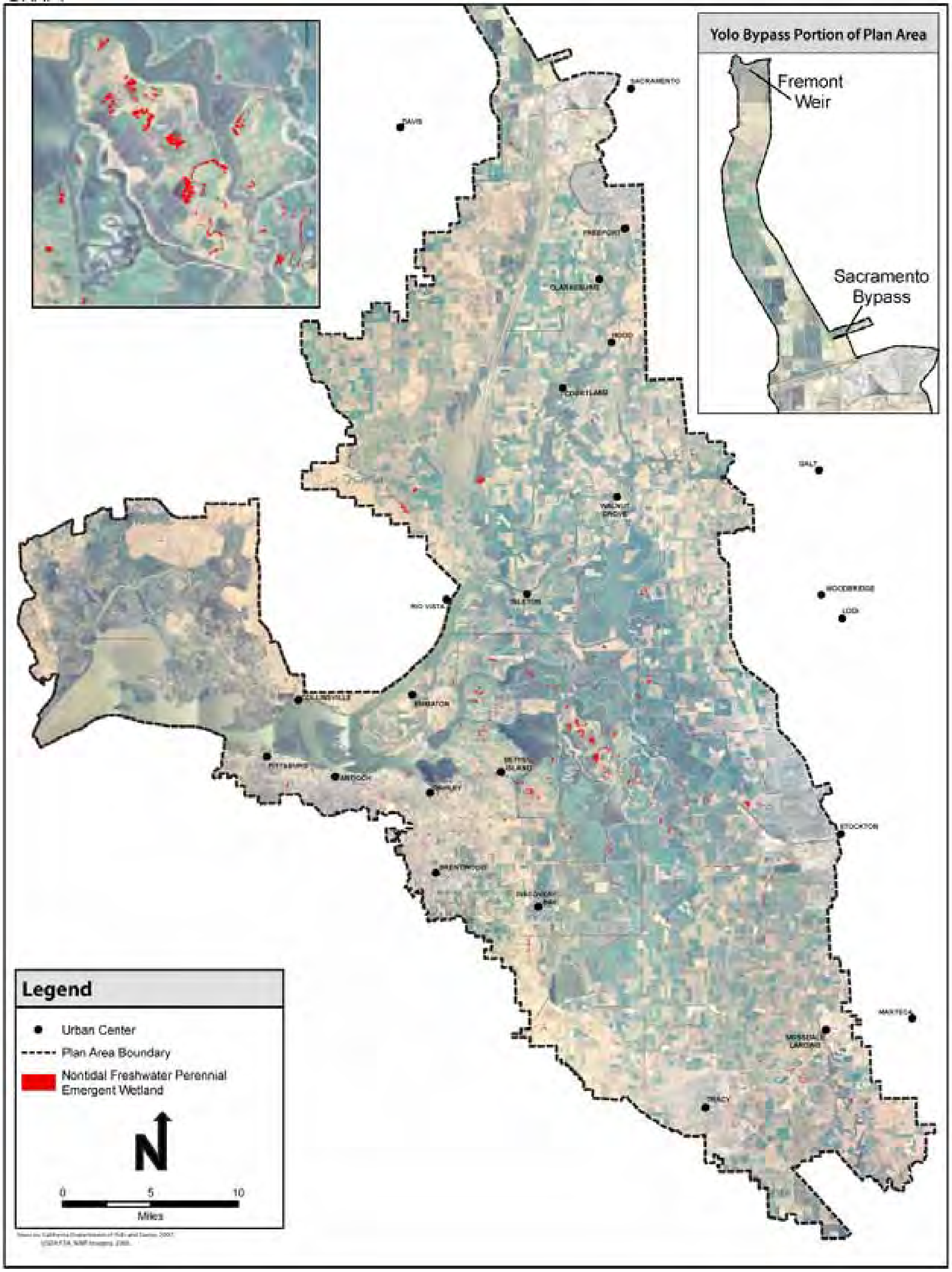

Figure 2-29. Distribution of Nontidal Freshwater Perennial Emergent Wetland Natural Community in the BDCP Plan Area

The extent of nontidal freshwater perennial emergent wetland in California, including the Delta, has declined dramatically over the past century due to reclamation and conversion of the habitat to other uses, primarily agriculture (Gilmer et al. 1982, The Bay Institute 1998). Only 1,134 acres of this natural community remain within the Plan Area. The extent of this natural community in the Delta has been dramatically reduced in the past century, with a corresponding reduction in its function as habitat for associated fish and wildlife species (The Bay Institute 1998).

2.3.4.7.1 Vegetation

The nontidal freshwater perennial emergent wetland natural community is distinguished by environmental conditions that support erect, rooted herbaceous plant species that can tolerate long inundation periods. All patches of these wetlands mapped in the Plan Area are dominated by broad-leaf cattail (Table 2-11) (Hickson and Keeler-Wolf 2007). This plant community frequently includes tules, bulrushes, sedges, rushes, and other emergent plant species. BDCP covered plant species associated with nontidal freshwater perennial emergent wetlands are presented in Table 2-4.

Table 2-11. Plant Alliances within the Nontidal Freshwater Perennial Emergent Wetland Natural Community in the Plan Area

Mapping Unit[1]	***Plant Alliance (Sawyer and Keeler-Wolf 1995)***	***Acreage in Plan Area***
Undetermined[2]	Undetermined[2]	14
	American Bulrush (*Scirpus americanus*)	5
	Broad-leaf Cattail (*Typha latifolia*)	362
	Common Reed (*Phragmites australis*)	15
	Flooded Managed Wetland	1
Mixed *Scirpus*[3]	-	157
	Narrow-leaf Cattail (*Typha angustifolia*)	1
	Perennial Pepperweed (*Lepidium latifolium*)	0
	Salicornia[4]/Annual Grasses	1
Scirpus acutus-Typha/*Scirpus acutus*[3]	-	577
Total		**1,134**

[1]Some of the mapping units provided here are newly described associations or alliances. For more detailed information concerning these mapping units and plant associations/alliances, as well as on methods of classification used, see Hickson and Keeler-Wolf (2007) and Boul and Keeler-Wolf (2008).
[2]Extent of this natural community present in the Plan Area for which DFG did not delineate plant alliances. As described in Section 2.3.1, *Data Sources and Natural Community Classification*, these areas were delineated as this natural community type from aerial photography interpretation.
[3]DFG vegetation types were combined to form this mapping unit in order to condense the list.
[4]The genus of pickleweed is now *Sarcocornia* instead of *Salicornia*.
Note: Acreage total accommodates for rounding.

2.3.4.7.2 Wildlife

The nontidal freshwater perennial emergent wetland natural community is among the most productive wildlife habitat in California (DFG 2005). It provides food, cover, and water for numerous mammals, reptiles, amphibians, and birds. Many species rely on fresh emergent wetlands for their entire life cycle (e.g., giant garter snake). Others use the habitat primarily for breeding (e.g., California red-legged frog), feeding and hunting (e.g., bald eagle), or foraging and loafing habitat (e.g., migrating waterfowl). Within the Plan Area, the ecological functions provided by nontidal freshwater perennial emergent wetlands in support of wildlife are very limited because this community is highly fragmented and occurs in small patches (e.g., the 1,134 acres of this natural community are distributed among 159 mapped polygons). BDCP covered wildlife species that may use nontidal freshwater perennial emergent wetlands are presented in Table 2-4.

2.3.4.7.3 Nonnative Species

Many nonnative species have invaded the nontidal freshwater perennial emergent wetland natural community. Common invasive plants found in this habitat include Brazilian waterweed, Eurasian watermilfoil, and water hyacinth (DBW 2006, 2008). These plants form thick mats that exclude native vegetation and associated wildlife (SFEI 2003).

Nontidal freshwater perennial emergent wetland natural community in the Plan Area supports many nonnative freshwater fish species, including centrarchids, common carp, inland silverside, fathead minnow, and western mosquitofish. Additionally, the nonnative bullfrog is frequently present. These nonnative species prey on or compete with native fish and amphibian species both directly and indirectly for resources.

2.3.4.7.4 Ecosystem Functions

Nontidal freshwater perennial emergent wetland natural community generally forms the boundary around the nontidal perennial aquatic natural community, and with that community is embedded in other communities. Generally, its most significant ecosystem functions include providing an alternative source of primary productivity through its aquatic food web and providing an aquatic habitat for native fish, amphibians, and reptiles such as giant garter snake, a BDCP covered species. Its importance as a source of primary productivity can increase or decrease if the body of water is dominated by algal phytoplankton or aquatic plants depending on whether the body of water is in a turbid- or clear-water state. The contribution of primary consumers and their feedback effects on the ecosystem depend on many factors and cause impacts to the secondary consumers such as planktivorous or benthivorous (cyprinids) fish (Scheffer 2004). Additionally, this community provides the structural substrate for predator avoidance and nesting of wildlife.

2.3.4.7.5 Environmental Gradients

Within the water column of the nontidal freshwater perennial emergent wetland natural community there are gradients of light, oxygen and other chemicals, pH, and temperature which combine in various ways and result in a range of micro-habitat types (Moss 1998, Scheffer 2004). External gradients to terrestrial ecosystems always exist at the boundary of this community because it is the boundary that lies between open water habitat and ecotonal transitions into riparian forest, grassland, or agricultural lands in the Plan Area.

2.3.4.7.6 Future Conditions with Climate Change

Ongoing and future climate change (Section 2.3.3.2, *Climate*) is expected to alter the nontidal freshwater perennial emergent wetland natural community. Sea level rise will affect the location, extent, and composition of this community in places where it exists at or below current sea level as a result of increased water elevation, increased saltwater intrusion, and the tidal hydrological regime. Nontidal freshwater perennial emergent wetland locations that exist at the water's edge will become more deeply immersed, or in the case of overtopped levees, deeply flooded. Where this community exists in flooded depressions in upland areas, which presumably already support the nontidal freshwater perennial emergent wetland natural community, it is not likely that natural processes could replace the area that will be lost.

2.3.4.8 Alkali Seasonal Wetland Complex

The alkali seasonal wetland complex natural community occurs on fine-textured soils that contain a relatively high concentration of dissolved salts. This natural community includes both saturated wetlands, sometimes with areas of shallow ponding during the wet season, and a surrounding matrix of various types of vegetation. It is typically found either at the historical locations of seasonal ponds in the Yolo Basin in and around the California Department of Fish and Game Tule Ranch Preserve (Witham 2003, EDAW 2007) where salts accumulated through evaporation, or in upland situations such as basin rims and seasonal drainages that receive salts in runoff from upslope salt-bearing bedrock such as areas near Suisun Marsh and the Clifton Court Forebay (CCF). Associations dominated by saltgrass cover the largest extent of the alkaline wetland alliances in the Plan Area (Hickson and Keeler-Wolf 2007), and the area of undetermined vegetation adjacent to Suisun Marsh is also likely dominated by saltgrass (Table 2-12). Vegetation associations containing salt-adapted shrubs and subshrubs, generally located in the CCF area (SFEI 2010), constitute most of the remaining acreage. Depending on its location, this community often transitions into other natural communities such as tidal brackish emergent wetland, vernal pool complex, grassland, valley/foothill riparian, and agricultural habitats. The distribution of the alkali seasonal wetland complex natural community in the Plan Area is shown in Figure 2-30.

2.3.4.8.1 Vegetation

Dominant species in the alkali seasonal wetland complex natural community include saltgrass, Baltic rush, pickleweed, iodine bush, and alkali heath (Table 2-12) (Hickson and Keeler-Wolf 2007). Other abundant plant species include toad rush, bush seepweed, brass buttons, gum plant, and perennial pepperweed. Annual grasses associated with this natural community include the native Pacific foxtail as well as nonnative grasses such as rabbitsfoot grass, swamp timothy, and Italian ryegrass. In associations that are dominated by woody plants in the Clifton Court Forebay area, shrubs characteristic of desert regions such as iodine bush (*Allenrolfea occidentalis*) may form an open shrub cover with an intermittent herbaceous strata that is dominated by saltgrass, wild barley, and curved sicklegrass (Hickson and Keeler-Wolf 2007).

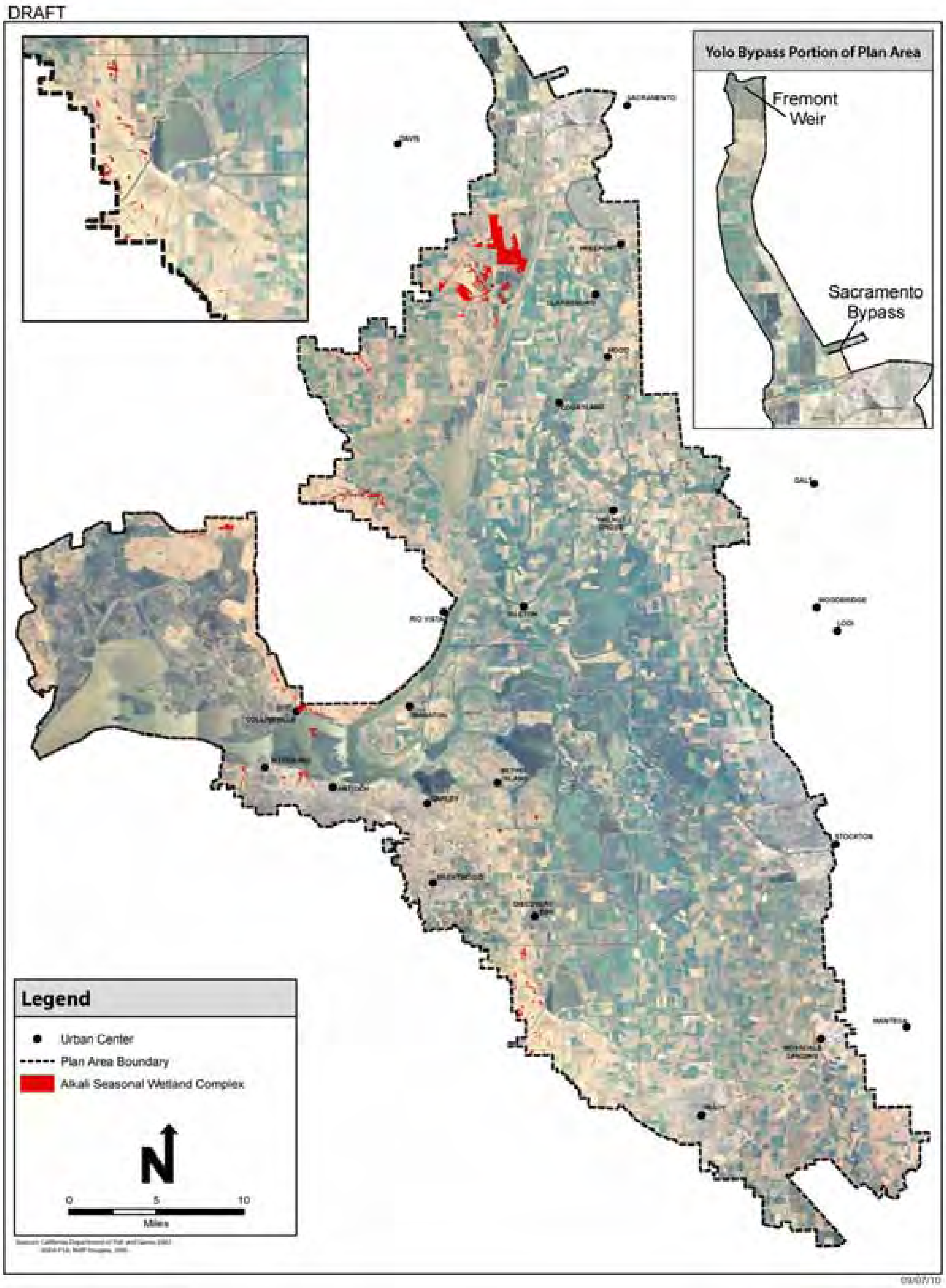

Figure 2-30. Distribution of Alkali Seasonal Wetland Complex Natural Community in the BDCP Plan Area

Table 2-12. Plant Alliances within the Alkali Seasonal Wetland Complex Natural Community in the Plan Area

Mapping Unit[1]	*Plant Alliance (Sawyer and Keeler-Wolf 1995)*	*Acreage*
Distichlis spicata Alliance	Saltgrass (*Distichlis spicata*)	122
Distichlis spicata-Annual grasses Provisional	*Distichlis spicata* - Annual Grasses	3,044
Distichlis spicata- Salicornia virginica[2] Provisional	*Distichlis spicata - Salicornia virginica*[2]	20
Distichlis spicata-Juncus balticus	*Distichlis spicata - Juncus balticus*	30
Distichlis/Salicornia[2] *maritimus*	-	1
Leymus triticoides Alliance	Creeping Wild Rye Grass (*Leymus triticoides*)	3
-	*Juncus balticus* - meadow vegetation	45
-	Alkaline vegetation mapping unit	28
Allenrolfea occidentalis Alliance	*Allenrolfea occidentalis* mapping unit	29
Suaeda moquinii Alliance	*Suaeda moquinii* - (*Lasthenia californica*) mapping unit	21
Frankenia salina Alliance	Alkali Heath (*Frankenia salina*)	2
Frankenia salina Alliance	*Frankenia salina - Distichlis spicata*	24
Salicornia virginica[2] Alliance	Pickleweed (*Salicornia virginica*[2])	16
Salicornia virginica[2]*-Distichlis spicata* Provisional	*Salicornia virginica*[2] *- Distichlis spicata*	5
Salicornia[2]/Annual Grasses	-	0
Salicornia virginica[2]*-Cotula coronopifolia* Provisional	*Salicornia virginica*[2] *- Cotula coronopifolia*	3
Annual Grasses generic	-	22
Annual Grasses/Weeds	-	10
Typha species (generic)	-	1
Managed Wetland	-	0
Freshwater Drainage	-	12
-	Salt scalds and associated sparse vegetation	47
Bare Ground	-	5
Undetermined[3]	Undetermined[2]	233
Total		**3,722**

[1]Some of the mapping units provided here are newly described associations or alliances. For more detailed information concerning these mapping units and plant associations/allicances, as well as on methods of classification used, see Hickson and Keeler-Wolf (2007) and Boul and Keeler-Wolf (2008).
[2]*Salicornia virginica* is now *Sarcocornia pacifica.*
[3]Extent of this natural community present in the Plan Area for which DFG did not delineate plant alliances. As described in Section 2.3.1, *Data Sources and Natural Community Classification*, these areas were delineated as this natural community type from aerial photography interpretation.
Note: Acreage total accommodates for rounding.

Covered plant species that occur in this community include Delta button-celery growing on alluvium in the Discovery Bay area, San Joaquin saltbush on basin rims, brittlescale and heartscale growing in alkaline drainages; and growing in the vernal pool complex natural community, which is sometimes interspersed within this community, are alkali milk-vetch, dwarf downingia, Boggs Lake hedge-hyssop, legenere, and Heckard's pepper-grass (Table 2-4).

2.3.4.8.2 Fish and Wildlife

In the Plan Area, the alkali seasonal wetland complex natural community, and in particular saltgrass-dominated grassland, supports breeding and/or foraging habitat for covered vertebrate species including California tiger salamander, western spadefoot toad, giant garter snake, Swainson's hawk, tricolored blackbird, western burrowing owl, white-tailed kite, Townsend's big-eared bat, and San Joaquin kit fox (Table 2-4). The vernal pool complex natural community, which is sometimes scattered within this community, supports covered invertebrate species including several fairy shrimp species and vernal pool tadpole shrimp.

2.3.4.8.3 Nonnative Species

The primary problematic nonnative plant species in this community are perennial pepperweed (Witham 2006, EDAW 2007, ESA 2007) and annual ryegrass (*Lolium multiflorum*) (Dawson et al. 2007) which form dense patches that exclude many native plant species. There are no data describing their effects on wildlife.

2.3.4.8.4 Ecosystem Functions

The alkali seasonal wetland complex natural community is found on relatively impermeable clay alluvial soils (Graymer et al. 2002, Water Resources & Information Management Engineering Inc. 2006, NRCS 2009) that remain saturated throughout the wet season and during the early part of the dry season. The two contrasting types of typical vegetation, either dominated by the perennial saltgrass as is the case in most areas, or the woody iodine bush scrub near the Clifton Court Forebay, largely control the ecosystem functions of this community. Saltgrass-dominated areas are generally vegetated more or less uniformly and provide a very simple and herbaceous physical structure with relatively fast nutrient and carbon cycling. In contrast, iodine bush-dominated areas tend to have a patchy distribution of shrubs that provide more structural variation and sequester nutrients and carbon for longer periods of time. Saltgrass areas are typically grazed by native wildlife and domestic livestock and function as grasslands. They are also relatively open habitat that provides foraging habitat for raptors. Iodine bush habitat provides open areas for foraging by wildlife as well as closed canopy areas for cover.

2.3.4.8.5 Environmental Gradients

The alkali seasonal wetland complex natural community transitions into wetter areas such as the tidal brackish emergent wetland natural community in the Suisun Marsh area (Collins and Grossinger 2004, Grossinger 2004) and the tidal freshwater emergent wetland in the Delta (Grossinger et al. 2008) and often has vernal pool inclusions in areas with depressions. In other areas, such as near the Montezuma Hills, it transitions into the drier grassland natural community (Collins and Grossinger 2004, Grossinger 2004, Grossinger et al. 2008).

2.3.4.8.6 Future Conditions with Climate Change

Ongoing and future climate change (Section 2.3.3.2, *Climate*) is expected to alter the alkali seasonal wetland complex natural community. Because this community is generally located well above sea level it will not be directly impacted by rising sea level except at locations where it abuts tidal communities which will move upslope, thus reducing its extent. The primary impact of climate change on this community is predicted to be driven by changes in the hydrological regime due to increased variability in precipitation. The species present in this community are adapted to existing hydrological conditions such that increased variability of precipitation would likely lead to a shorter and more variable wet season or similar changes in the inundation period. It is not known how the increased variability in seasonal hydrology will affect the plants and animals inhabiting this community, but because these species are adapted to current conditions, the impacts will likely result in changes to species composition. In addition, rising average temperatures could result in increased evapotranspiration rates and therefore more extended dry periods for this community; the impacts of which are expected to be adverse to native plants and wildlife.

2.3.4.9 Vernal Pool Complex

The vernal pool complex natural community is characterized by interconnected and isolated groups of vernal pools and seasonal swales that are generally within a matrix of either grassland or alkali seasonal wetland vegetation. This natural community is rare in the Plan Area and is generally found only in a few locations along the very margin of the Plan Area (Figure 2-31). The vernal pool complex natural community was mapped specifically for the BDCP using a range of methods because there were no available data sets with the appropriate level of detail or spatial extent. Details of the methods used to map vernal pool complex are presented in Section 2.3.1.5, *Vernal Pool Complex Dataset Development*, and an in-depth discussion is presented in Appendix L2, *Vernal Pool Complex Mapping for the BDCP*. Regions of the Central Valley to the east and west of the Plan Area support large areas of vernal pool complex natural community, especially in San Joaquin, Sacramento, and Solano counties.

In the Plan Area, vernal pools are found west of the Sacramento River from Putah Creek south to the gently sloped terraces immediately to the north and east of the Montezuma Hills, east of the Sacramento River in the Stone Lakes area, and west of the San Joaquin River from Byron to Discovery Bay (Witham 2003, ESA 2005, Leigh Fisher Associates 2005, Williamson et al. 2005, Witham 2006, Baraona et al. 2007, Kleinschmidt Associates 2008, Rains et al. 2008, SFEI 2010). The pools on the west side of the Delta formed on clay soils with relatively high salt content, while those on the east side formed on clays with little salt content. The plant species in vernal pools are generally adapted to a hydrological regime of standing water in winter and spring and desiccated soils in summer (CALFED 2000, Solomeshch et al. 2007). Vernal pools in California are also known for providing habitat for a number of endemic and rare species (Jain 1979, Jones and Stokes Associates 1990, Skinner and Pavlik 1994, Solomeshch et al. 2007). A single vernal pool may support over 100 species of native plants and animals (USFWS 2007). The conversion of large extents of the vernal pool complex natural community to agriculture and developed areas has led directly to greatly reduced population sizes of species covered in the BDCP such as alkali milk-vetch, Heckard’s pepper-grass, and legenere (Table 2-4).

DRAFT

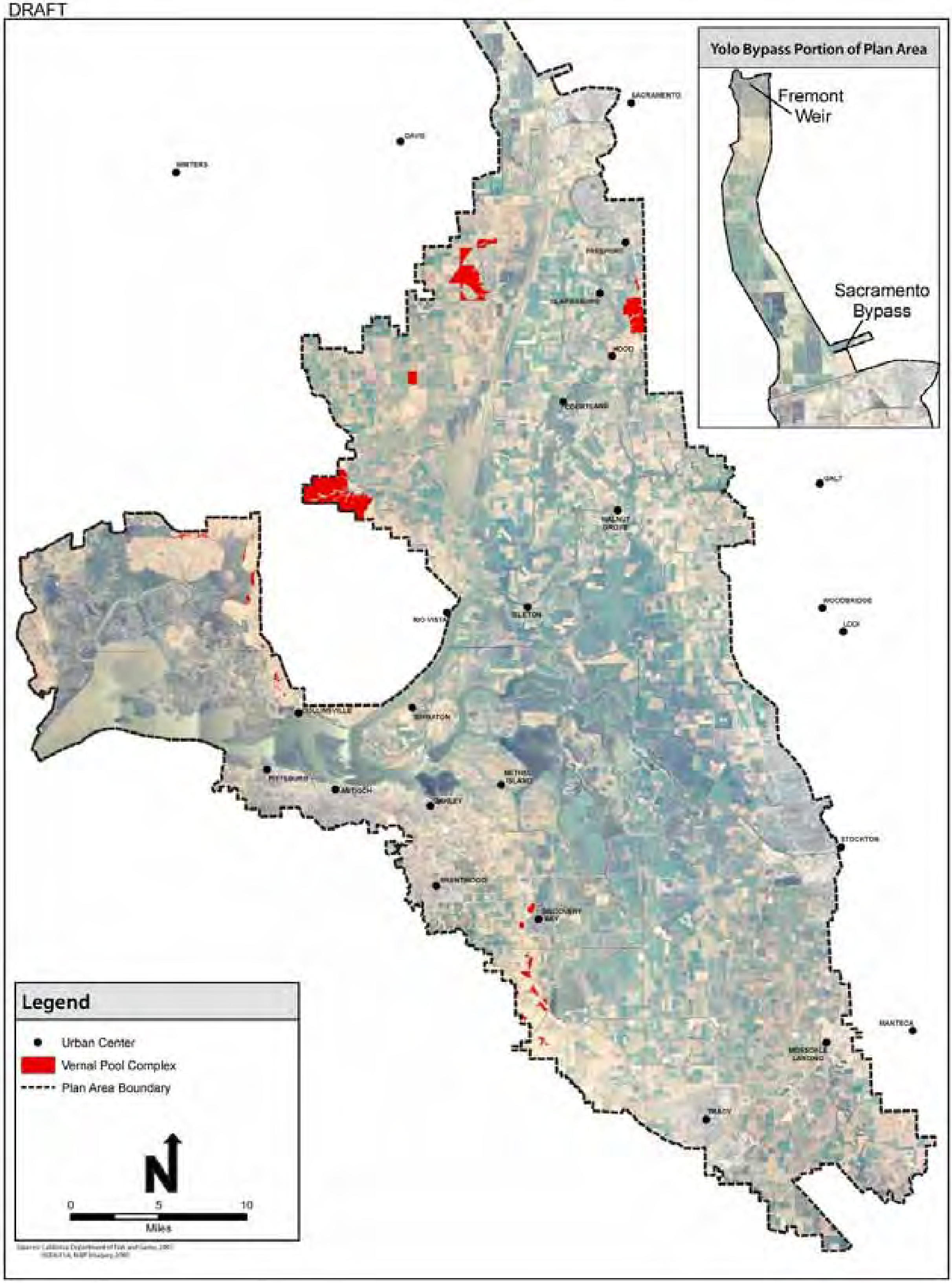

Figure 2-31. Distribution of Vernal Pool Complex Natural Community in the BDCP Plan Area

Table 2-13. Plant Alliances within the Vernal Pool Complex Natural Community in the Plan Area

Mapping Unit[1]	*Plant Alliance (Sawyer and Keeler-Wolf 1995)*	*Acreage*
Plan Area		
Vernal Pool Complex	Agriculture	0
Vernal Pool Complex	*Allenrolfea occidentalis* mapping unit	233
Vernal Pool Complex	Annual Grasses generic	232
Vernal Pool Complex	Annual Grasses/Weeds	23
Vernal Pool Complex	California Annual Grasslands - Herbaceous	4,475
Vernal Pool Complex	*Distichlis* (generic)	0
Vernal Pool Complex	*Distichlis spicata*	0
Vernal Pool Complex	*Distichlis spicata* - Annual Grasses	1,645
Vernal Pool Complex	*Distichlis*/Annual Grasses	4
Vernal Pool Complex	*Distichlis/S. maritimus*	6
Vernal Pool Complex	Italian Rye-grass (*Lolium multiflorum*)	17
Vernal Pool Complex	Mixed *Scirpus* Mapping Unit	1
Vernal Pool Complex	Ruderal Herbaceous Grasses & Forbs	14
Vernal Pool Complex	*Salicornia virginica*[2]	7
Vernal Pool Complex	*Salicornia*[2]/Annual Grasses	5
Vernal Pool Complex	Salt scalds and associated sparse vegetation	18
Vernal Pool Complex	Saltgrass (*Distichlis spicata*)	18
Vernal Pool Complex	Seasonally Flooded Grasslands	14
Vernal Pool Complex	*Suaeda moquinii* - (*Lasthenia californica*) mapping unit	50
Vernal Pool Complex	Vernal Pools	196
Vernal Pool Complex	Undetermined[3]	1
Total		**6,959**

[1]Some of the mapping units provided here are newly described associations or alliances. For more detailed information concerning these mapping units and plant associations/alliances, as well as on methods of classification used, see Hickson and Keeler-Wolf (2007) and Boul and Keeler-Wolf (2008).
[2]*Salicornia virginica* is now *Sarcocornia pacifica.*
[3]Extent of this natural community present in the Plan Area for which DFG did not delineate plant alliances. As described in Section 2.3.1, *Data Sources and Natural Community Classification*, these areas were delineated as this natural community type from aerial photography interpretation.

Vernal pools are uniquely defined by their hydrology and by the presence of endemic plant and invertebrate species (Keeley and Zedler 1998). The hydrological regime has three components: 1) the source of water; 2) the durations of the inundated and the waterlogged soil phases; and 3) the seasonal timing of these phases. In general, rainfall is the primary source of water to vernal pools as it falls directly into the vernal pool or is transported a short distance across the watershed of the vernal pool. This direct rainfall and watershed model is the simplest case, but there may be groundwater transport to the vernal pool through a shallow perched aquifer or a combination of rainfall and creek flooding (ESA 2005, Williamson et al. 2005, Rains et al. 2008). The duration and timing of the inundation and waterlogged soil phases are also variable with hardpan vernal pools generally having shorter phases centered during the middle of the wet season while claypan and clay vernal pools have longer phases extending earlier and later into the wet season (ESA 2005, Williamson et al. 2005, Rains et al. 2008). Similar complications occur in determining the presence of the characteristic endemic species. Using endemic plants as an example, the cover of many of them can vary by orders of magnitude from season to season, and they may only be present in the soil seed bank in some years (Barbour et al. 2007). These unique characteristics can also be blurred to varying degrees by human-driven impacts such as land leveling and ripping, altering the supply of water through flood irrigation, or through the intentional or inadvertent introduction of exotic plant species.

Note that the vernal pool complex natural community was mapped separately from the other vegetation data used for the BDCP and the mapped polygons of the community overlay of DFG vegetation types that are described in this chapter. There are 6,959 acres of the vernal pool complex natural community (including both wetted surface and upland matrix) within the Plan Area, of which 4,730 acres are found in annual grassland vegetation, 1,673 acres are found in saltgrass vegetation, 233 acres are found in iodine bush scrub, and 196 acres were mapped as vernal pools by DFG.

2.3.4.9.1 Vegetation

The flora of vernal pools has adapted in different ways to the unique physical and chemical constraints imposed by the inundated lacustrian phase. The duration of inundation has been found to be strongly correlated with two clear functional groups (Zedler 1987, 1990, Barbour et al. 2003, 2005, Barbour et al. 2007). An edge-of-pool plant functional group is adapted to the fluctuating hydrology of shallow vernal pools or to the edges of deep vernal pools, while the long inundation functional group is adapted to the deeply inundated basins of vernal pools. The edge or saturated soil species are especially prone to elimination by competition with upland exotic grass species or through thatch accumulation (Barry 1995, Griggs 2000, Marty 2005), while the basins are prone to invasion by low mannagrass (Gerlach et al. 2009).

The vernal pool complex natural community in the Plan Area can be classified into four fairly uniform types: annual grassland vernal pool complexes in the Stone Lakes area; clay alluvium vernal pools and playa pools running from Putah Creek south to Cache Slough; Montezuma Block vernal pools and playa pools in the Jepson Prairie/Montezuma Hills area; and alkaline sink/meadow vernal pools near the Byron/Clifton Court Forebay area.

Annual grassland vernal pool complexes have uplands that are dominated by Eurasian annual grasses with a varying mixture of native grasses and herbs depending on the farming history of the site. These vernal pools are found in the lowest local topographic positions on soils that were deposited in and alongside ancient stream channels and are underlain by a discontinuous claypan (Williamson et al. 2005, Rains et al. 2008) or clay alluvial lens. The endemic plant species present in the vernal pools are generally considered to be adapted to non-alkaline soils, but some characteristic species of alkaline vernal pools, such as Heckard's pepper-grass or saline clover, may be present. Typical plant species found in these vernal pools are: Pacific foxtail (*Alopecurus saccatus*), bristled downingia (*Downingia bicornuta* var. *bicornuta*), low mannagrass (*Glyceria declinata*), rayless goldfields (*Lasthenia glaberrima*), shining peppergrass (*Lepidium nitidum* var. *nitidum*), small stipitate popcorn-flower (*Plagiobothrys stipitatus* var. *micranthus*), Sacramento mesamint (*Pogogyne zizyphoroides*), and woolly marbles (*Psilocarphus brevissimus*).

Clay alluvium vernal pools and playa pools have uplands that are dominated in the spring by either Eurasian annual grasses or a variable mixture of saltgrass and native herbs, and are dominated in the summer by native tarweeds or the exotic yellow starthistle. These vernal pools and playa pools can be found on extremely thick clay alluvium (Bryan 1923, Thomasson Jr. et al. 1960, State of California 1987) in a range of topographic positions, from scoured areas above the main flood distribution channels of Putah Creek to mid-elevations where a swale may connect a series of vernal pools (ESA 2005), to low elevation playas in the Yolo Bypass that are periodically flooded by the Sacramento River (Witham 2003), to much older vernal pools and playa pools in the greater Jepson Prairie area (Bryan 1923, Thomasson Jr. et al. 1960, Witham and Kareofelas 1994, Williamson et al. 2005, Witham 2006, Baraona et al. 2007, Rains et al. 2008). The rare endemic species found in these vernal pools and playa pools include Solano grass, Colusa grass, alkali milk-vetch, San Joaquin spearscale, dwarf downingia, legenere, and Heckard's pepper-grass.

Montezuma Block vernal pools and playa pools have uplands that are similar to those of the clay alluvium vernal pools and playa pools, but extensive areas are also in agricultural production as dry-farmed wheat. These vernal pools and playa pools can also be found in a range of topographic positions from intermittent stream channels in the Montezuma Hills, to the mid-elevation divide that is characteristic of the Jepson Prairie area, to the near tidal elevation vernal pools found along Cache Slough (Witham and Kareofelas 1994) and upland of Suisun Marsh (Wildlands Inc. 2005, SFEI 2006). The rare endemic species found in these vernal pools and playa pools include Colusa grass, alkali milk-vetch, San Joaquin spearscale, dwarf downingia, legenere, and Heckard's pepper-grass.

Alkaline sink/meadow vernal pools, as the name implies, are found scattered within alkaline meadows and alkaline sinks near the Byron/Clifton Court Forebay area (Carpenter and Cosby 1939, SFEI 2010). Hydrologically, these vernal pools are similar to the clay alluvium vernal pools and playa pools as their hydrology is a mixture of local rainfall, groundwater flow, and long distance stream transport. The surrounding vegetation is unique as it is typically dominated by native grasses such as saltgrass and alkali ryegrass, or by woody shrubs like iodine bush (*Allenrolfea occidentalis*) and subshrubs such as bush seepweed (*Suaeda moquinii*) and alkali heath (*Frankenia salina*). Recent BDCP field surveys (DWR 2009 and 2010 unpublished data) found that the herbaceous vernal pool species include: Pacific foxtail (*Alopecurus saccatus*), brass-buttons (*Cotula coronopifolia*), rayless goldfields (*Lasthenia glaberrima*), alkali peppergrass (*Lepidium dictyotum* var. *dictyotum*), small stipitate popcorn-flower (*Plagiobothrys stipitatus* var. *micranthus*), and Sacramento mesamint (*Pogogyne zizyphoroides*).

2.3.4.9.2 Wildlife

Much less is known about the adaptations of animals to vernal pool conditions than about the adaptations of vernal pool plants. Most animals that are endemic to vernal pools have a combination of behavioral, structural, and physiological adaptations to avoid, resist, or tolerate desiccation during the dry season or during long droughts. Amphibians such as California tiger salamander and western spadefoot toad use vernal pools for breeding, but otherwise are essentially terrestrial animals. The six crustacean species covered under the BDCP (California linderiella, midvalley fairy shrimp, Conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, and vernal pool tadpole shrimp) tend to occur in separate vernal pools with different inundation periods (Table 2-4). These species are typically not found in vernal pools that have been heavily invaded by low mannagrass, as the fauna of these invaded vernal pools is typically dominated by mosquito and midge larvae (Rogers 1998). Waterfowl may forage in vernal pools during the wet season with ducks and shorebirds consuming invertebrates and geese consuming vegetation (Medeiros 1976, Reiner and Swenson 2000).

The upland watersheds associated with the vernal pool complex natural community provide foraging habitat for BDCP covered species such as western burrowing owl, Swainson's hawk, white-tailed kite, and San Joaquin kit fox (Table 2-4).

2.3.4.9.3 Nonnative Species

Vernal pools in the vernal pool complex natural community are invaded by different nonnative species at different points along the moisture gradient. The margins of vernal pools throughout the Central Valley are often dominated by the nonnative annual ryegrass. The deeper portions of many pools are being rapidly invaded by low mannagrass (Gerlach et al. 2009). Other parts of vernal pool complexes are being invaded by perennial pepperweed (Swiecki and Bernhardt 2002, Witham 2003, ESA 2005, Witham 2006, ESA 2007).

2.3.4.9.4 Ecosystem Functions

This is essentially an amphibious ecosystem with greatly differing functions depending on whether it is in its flooded or dry stages. When flooded, this community supports an aquatic food web that is functionally similar to that found in shallow lakes (Alexander 1976, Barclay and Knight 1981, Scheffer 2004, Williams 2006). As the water recedes, its ecosystem characteristics change from those of a fully aquatic system to those of a wetland and then to those of a terrestrial ecosystem (Williams 2006), and its food web linkages break down as the community becomes more integrated with the terrestrial landscape in which it is embedded. When flooded, it teems with a variety of ephemeral pond-adapted invertebrates, the immature stages of amphibians, and waterfowl. When dry, it is integrated with the surrounding terrestrial ecosystems and provides foraging habitat for native wildlife, and is typically managed as rangeland and grazed by sheep or cattle.

2.3.4.9.5 Environmental Gradients

The dominant environmental gradient in the vernal pool complex natural community is driven by the different chemical and physical attributes of water versus air. Water is a polar solvent that is important in many chemical exchanges, and those exchanges control pH and the oxidation state of many chemicals and compounds. It also has a high heat capacity so temperature changes are buffered, and it is extremely viscous compared to air so exchanges between the air and water as well as movement within the water are very slow (Scheffer 2004, Williams 2006). Ecological gradients in vernal pools are characterized by depth and ponding/saturation duration from the pool center to the surrounding grassland community.

2.3.4.9.6 Future Conditions with Climate Change

Ongoing and future climate change (Section 2.3.3.2, *Climate*) is expected to alter the vernal pool complex natural community. Because this community is generally located at elevations that will not be directly impacted by rising sea level, the primary impact of climate change is predicted to be driven by changes in the hydrological regime due to increased variability in precipitation. The species present in this community are adapted to existing hydrological conditions such that increased variability of precipitation would likely lead to a shorter and more variable wet season or similar changes in the inundation period. It is not known how increased variability in pool hydrology would affect the plants and animals inhabiting them, but because these species are adapted to current conditions, the impacts will likely result in changes to species composition. In addition, rising average temperatures could result in increased evapotranspiration rates and therefore shorter wetted periods for vernal pools; the impacts of which are expected to be adverse to native plants and wildlife.

2.3.4.10 Managed Wetland

The managed wetland natural community consists of areas that are intentionally flooded and managed during specific seasonal periods to enhance habitat values for specific wildlife species (CALFED 2000). Ditches and drains associated with this community are also included. The managed wetland natural community includes some areas of the CALFED Ecosystem Restoration Program "managed seasonal wetlands" habitat, and it fits into the "fresh emergent wetland" classification from the California Wildlife Habitat Relationships (DFG 2005).

Soils are composed predominantly of silts and clays, although coarser sediments and organic material may be intermixed. In some areas, such as Suisun Marsh, organic soils (peat) may constitute the primary growth medium.

Managed wetland is distributed largely in the northern, central, and western portions of the Delta, as well as in Suisun Marsh (Boul and Keeler-Wolf 2006, Hickson and Keeler-Wolf 2007). Substantial acreage of this type occurs in the Yolo Bypass, Stone Lakes National Wildlife Refuge, Cosumnes River Preserve, and Suisun Marsh (Suisun Ecological Workgroup 1997, Suisun Ecological Workgroup 2001, Brown 2004, EDAW 2007, USFWS 2007, Kleinschmidt Associates 2008). Several islands in the central Delta support large areas of this community type, including Mandeville Island, Medford Island, Holland Tract, and Bradford Island. The far western edge of the Delta, including Van Sickle and Chipps islands, and Suisun Marsh also includes managed wetland (Figure 2-32). Water at the far western border of the Plan Area and in the Suisun Marsh can be more brackish compared to other portions of the Delta where this community occurs (Suisun Ecological Workgroup 1997, Suisun Ecological Workgroup 2001, Brown 2004).

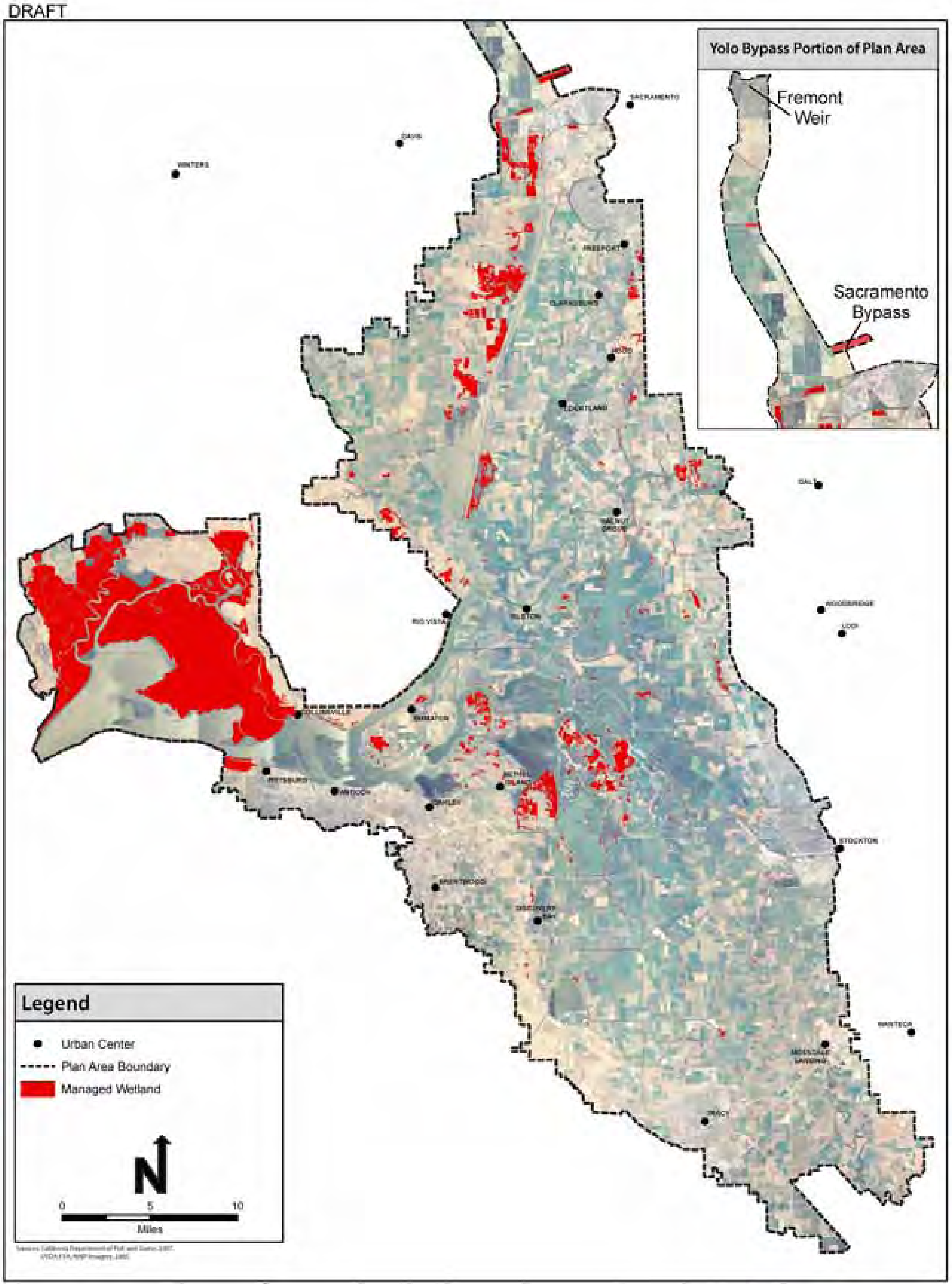

Figure 2-32. Distribution of Managed Wetland Natural Community in the BDCP Plan Area

The typical hydrologic management regime includes flooding during the winter in anticipation of the arrival of migratory birds followed by a slow drawdown of water to manage plant seed production (Fredrickson and Taylor 1982, Naylor 2002) and to control mosquito populations (Kwasny et al. 2004). Summer irrigation may also be conducted (USFWS 2007). The management of Suisun Marsh is unique as water salinity is a significant management issue, and water use is tightly regulated (Suisun Ecological Workgroup 1997, Suisun Ecological Workgroup 2001, Brown 2004).

2.3.4.10.1 Vegetation

The managed wetland natural community is characterized by robust, perennial emergent vegetation and annual-dominated moist-soil grasses and forbs in freshwater areas (Fredrickson and Taylor 1982, Naylor 2002, Hickson and Keeler-Wolf 2007) and often by pickleweed and brass buttons in brackish water areas. The plant associations present and their extent within the managed wetland natural community are shown in Table 2-14. Vegetation that is important to waterfowl includes alkali bulrush, grand redstem, brass buttons, smartweed, barnyard grass, burhead, and swamp timothy (Fredrickson and Taylor 1982, Suisun Ecological Workgroup 1997, Suisun Ecological Workgroup 2001, Naylor 2002, Brown 2004). During periods when water is drained from the habitat, a wide variety of annual grasses and forbs germinate and grow beneath and in the interstitial space around the emergent plants.

Table 2-14. Plant Alliances within the Managed Wetland Natural Community in the Plan Area

Mapping Unit[1]	*Plant Alliance (Sawyer and Keeler-Wolf 1995)*	*Acreage in Plan Area*
Undetermined[3]	Undetermined[3]	764
Annual Grasses[4]	-	5,300
-	*Arundo donax*	4
Atriplex[4]	-	953
-	*Baccharis*/Annual Grasses	98
Bare/Barren Ground[4]	-	1,551
-	Bulrush-Cattail Freshwater Marsh NFD Super Alliance	52
-	*Conium maculatum*	1,005
-	*Cotula coronopifolia*	236
Crypsis[4]	-	442
-	Cultivated Annual Graminoid	18
Distichlis[4]	-	6,770
Ditches and Sloughs[4]	-	1,975
Eucalyptus[4]	-	146
Exotic Vegetation Stands[4]	-	1,326
-	Fallow Disced Field	42
-	*Foeniculum vulgare*	86
-	Flooded Managed Wetland	7,924
Frankenia[4]	-	102
-	*Fraxinus latifolia*	2
-	Freshwater Drainage	24
Intermittently/Temporarily Flooded Annual Grasses and Forbs[4]	-	3,623

Table 2-14. Plant Alliances within the Managed Wetland Natural Community in the Plan Area (continued)

Mapping Unit[1]	*Plant Alliance (Sawyer and Keeler-Wolf 1995)*	*Acreage in Plan Area*
Juncus[4]	-	358
-	Landscape Trees	1
Lepidium[4]	-	569
-	*Leymus*	6
Lolium[4]	-	223
-	*Lotus corniculatus*	189
-	Managed Annual Wetland Vegetation (Non-specific grasses and forbs)	603
-	Managed Alkali Wetland (*Crypsis*)	2,917
Herbs[4]	-	1,265
-	Medium Upland Shrubs	8
Graminoids[4]	-	1,100
Quercus[4]	-	4
-	Perennial Grass	29
-	Perennial Pepperweed (*Lepidium latifolium*)	1,671
Phragmites[4]	-	704
Polygonum[4]	-	1,083
-	*Potentilla anserine* (generic)	0
-	Road	0
Rosa[4]	-	90
-	*Rubus discolor*	66
Salicornia[4,5]	-	8,747
Salix[4]	-	9
Scirpus[4]	-	7,049
-	Seasonally flooded undifferentiated annual grasses and fordbs	802
Sesuvium[4]	-	262
-	Shallow flooding with minimal vegetation at time of photography	370
-		
-	*Spergularia*/*Cotula*	6
-	Structure	58
-	Temporarily Flooded Grasslands	8
-	Tidal Mudflat	19
Typha[4]	-	4,184
-	*Vulpa*/*Euthamia*	1
Total		**64,845**

[1]Some of the mapping units provided here are newly described associations or alliances. Additionally, for Suisun Marsh SFEI (2005) tidal data were used to determine the nontidal areas and were intersected with the Boul and Keeler-Wolf (2008) vegetation data. For more detailed information concerning these mapping units and plant associations/alliances, as well as on methods of classification used, see Hickson and Keeler-Wolf (2007); TAIC (2008); SAIC 2009 reclassification of Boul and Keeler-Wolf (2008).

[2]Currently known as *Schoenoplectus*.

[3]Extent of this natural community present in the Plan Area for which DFG did not delineate plant alliances. As described in Section 2.3.1, *Data Sources and Natural Community Classification*, these areas were delineated as this natural community type from aerial photography interpretation.

[4]DFG vegetation types were combined to form this mapping unit in order to condense the list.

[5]The genus of pickleweed is now *Sarcocornia* instead of *Salicornia*.

Note: Acreage total accommodates for rounding.

2.3.4.10.2 Fish and Wildlife

Managed wetland is managed specifically to promote use by wildlife, particularly birds, and as a result, a wide variety of waterfowl and other birds migrating along the Pacific Flyway use the habitat when inundated (Fleskes et al. 2005, EDAW 2007, USFWS 2007, Kleinschmidt 2008). Sandhill cranes forage and roost, and many ducks, geese, wading birds, and shorebirds commonly forage and loaf in managed wetland in the Plan Area (USFWS 2007). This natural community includes abundant and diverse plant assemblages and invertebrate populations that provide important food resources for migrating waterfowl, bats, and many other wildlife species that forage in and over these wetlands. During winter flood flow inundation, the managed wetland areas in the Yolo Bypass floodplain can provide spawning and rearing habitat for Sacramento splittail and refuge habitat for other fish species (Feyrer et al. 2006, Sommer et al. 2007). In Suisun Marsh, managed wetland provides habitat for waterfowl, rails, Suisun song sparrow, and salt marsh harvest mouse (Suisun Ecological Workgroup 1997, Suisun Ecological Workgroup 2001, Brown 2004).

Covered wildlife species that are associated with the managed wetland natural community within the Plan Area include salt marsh harvest mouse, greater sandhill crane, Swainson’s hawk, and giant garter snake (Table 2-4).

2.3.4.10.3 Nonnative Species

Managed wetland is subjected to the same invasive nonnative plant taxa as tidal brackish emergent wetland and tidal freshwater emergent wetland natural communities; however, because management operations include discing and the manipulation of flooding duration, there are more control opportunities. Perennial pepperweed (*Lepidium latifolium*) is one of the most serious threats to this community. It is difficult to control and may be spread through discing (Brown 2004, Vaghti and Keeler-Wolf 2004, EDAW 2007, ESA 2007, Boul and Keeler-Wolf 2008). Other large stature invasive plant species that are problematic include pampas grass (*Cortaderia selloana*), giant reed (*Arundo donax*), and the nonnative genotype of common reed (*Phragmites australis*) (Vaghti and Keeler-Wolf 2004, Boul and Keeler-Wolf 2008). Managed wetland supports nonnative animals, including red fox (*Vulpes vulpes*), feral cats (*Felis domesticus*), and rats (*Rattus* spp.) (Brown 2004, Takekawa et al. 2006), that are predators of native wildlife and have been shown to significantly reduce populations of BDCP covered species including salt marsh harvest mouse, California black rail, and California clapper rail (Suisun Ecological Workgroup 2001, Brown 2004).

2.3.4.10.4 Ecosystem Functions

As a surrogate for natural marshes, managed wetland is managed to support highly productive seasonal wetlands interspersed with permanent wetlands to sustain large populations of waterfowl and shorebirds through the production of seed and invertebrates (Brown 2004, EDAW 2007). The structure of the community is managed to provide nesting and resting or loafing areas. The nutrients and primary productivity are often transferred to adjacent natural wetlands through water management activities (Brown 2004) and by the daily and seasonal movements of waterfowl and shorebirds.

2.3.4.10.5 Environmental Gradients

Because they are often confined behind levees, environmental gradients in managed wetland are generally controlled through management actions. Discing and soil contouring provide a variety of ponding depths and widths of shallow water habitat (Brown 2004, EDAW 2007). Flooding timing, duration, and water quality controls species composition, primary productivity, water temperature, salinity, and the timing of exports of primary productivity.

2.3.4.10.6 Future Conditions with Climate Change

The managed wetland community is particularly sensitive to increased variability in precipitation associated with global climate change (Nicholls et al. 1999). Reduced and more variable water flows through the Central Valley are likely to reduce the amount of water available for management actions that require the flooding of the managed wetland community at precise times of the season to provide habitat and food for waterfowl. Additionally, sea level rise is expected to be especially significant in the Delta, where much of the land has subsided to below sea level and is currently protected from flooding by levees. The current subsided island condition, combined with higher sea level, increased winter river flooding, and more intense winter storms, will significantly increase the hydraulic forces on the levees. With sea level rise exacerbating current conditions, a powerful earthquake in the region could collapse levees, leading to major seawater intrusion and flooding throughout the Delta if flows were sufficiently low, altering the tidal prism, and causing substantial changes to the community (Mount and Twiss 2005). Areas within the levees that are currently covered by the managed wetland community would be lost.

2.3.4.11 Other Natural Seasonal Wetland

The other natural seasonal wetland natural community encompasses all the remaining natural (not managed) seasonal wetland communities that are not the vernal pool complex and alkali seasonal wetland complex natural communities (Figure 2-33). The vegetation types included in the other natural seasonal wetland natural community, as mapped by DFG (Hickson and Keeler-Wolf 2007), include seasonally ponded, flooded, or saturated soils dominated by grasses, sedges (*Carex* spp.), or rushes (*Juncus* spp.), and DFG-mapped vernal pools that were not included in the vernal pool complex natural community because they do not support characteristic vernal pool hydrology or vegetation (Table 2-15) (see Section 2.3.1.5, *Vernal Pool Complex Dataset Development*). A review of the aerial photography (Google Inc. 2009) indicated that approximately half of the other natural seasonal wetland natural community consists of seasonally ponding areas in agricultural fields, and the other half consists of a temporarily flooded perennial forbs vegetation type that is exclusively found in a field near the Cosumnes River that has been the subject of restoration efforts through a levee breach and the creation of two ponds (Trowbridge 2005, Trowbridge et al. 2005) (Figure 2-33).

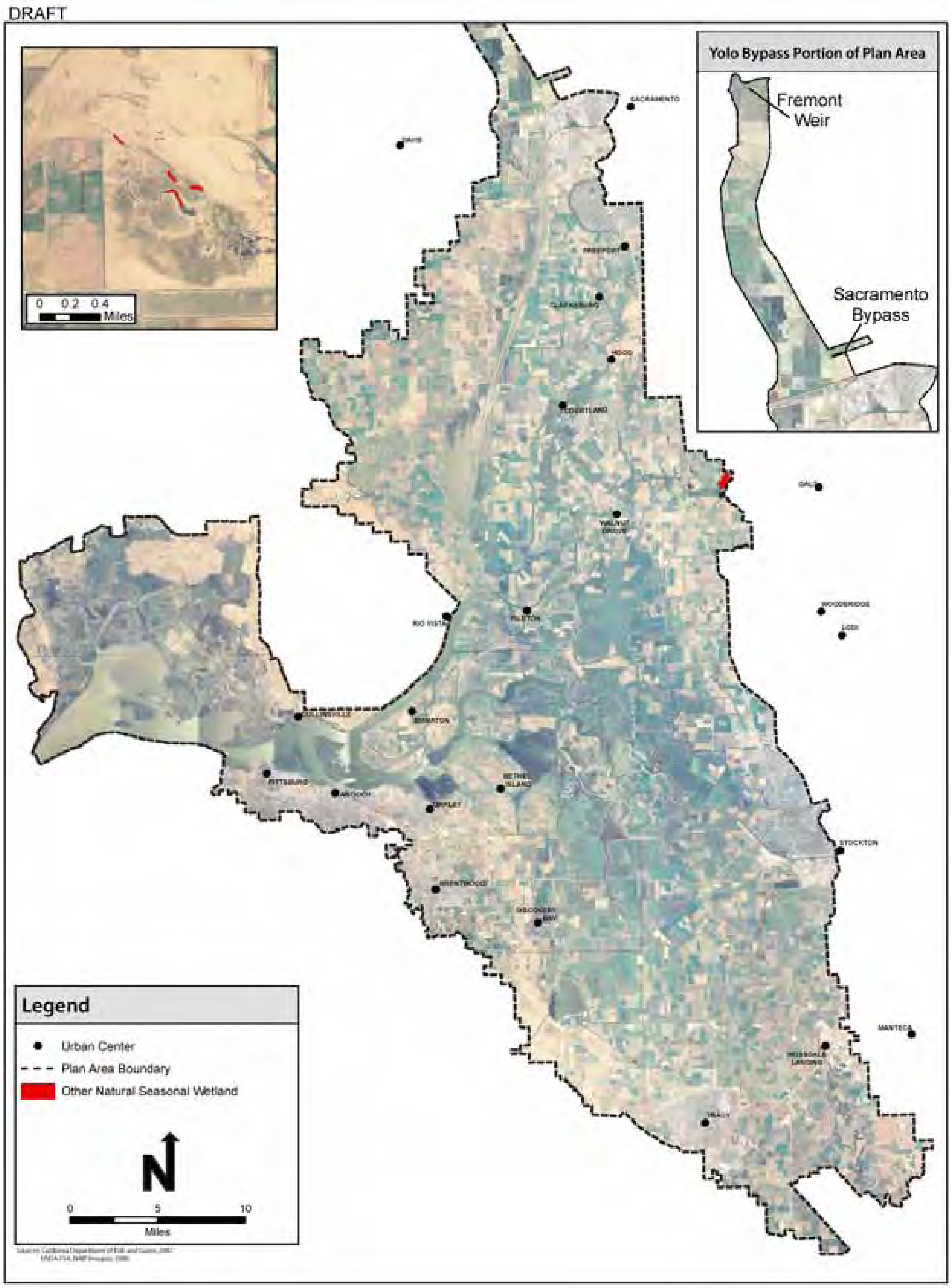

Figure 2-33. Distribution of Other Natural Seasonal Wetland Natural Community in the BDCP Plan Area

Table 2-15. Plant Alliances within the Other Natural Seasonal Wetland Natural Community

Mapping Unit[1]	*Plant Alliance (Sawyer and Keeler-Wolf 1995)*	*Acreage in Plan Area*
Carex barbarae Alliance	Santa Barbara Sedge (*Carex barbarae*) Stands	15
Seasonally flooded temperate or subpolar grassland	Seasonally Flooded Grasslands	36
Juncus bufonius non-classified stands	*Juncus bufonius* (salt grasses)	6
Vernal Pool stands[1]	Vernal Pools	9
-	Degraded Vernal Pool Complex	13
Temporarily Flooded Perennial Forbs	-	185
Total		**264**

[1]Vernal pool stands identified here were mapped by DFG (Hickson and Keeler-Wolf 2007) for the Delta vegetation layer, however, a separate vernal pool complex natural community mapping was conducted by SAIC that overlaid and expanded on DFG's more coarse-level vernal pool mapping. See Section 2.3.1.5 *Vernal Pool Complex Dataset Development.*

2.3.4.11.1 Vegetation

Vegetation found in the other natural seasonal wetland natural community consists of a mixture of exotic and native perennial forbs, grasses, sedges, and rushes tolerant of temporary flooding, ponding, or soil saturation during winter and spring months.

2.3.4.11.2 Fish and Wildlife

The other natural seasonal wetland natural community supports common invertebrates that are the main source of food for waterfowl and shorebirds (Silveira 1998) which also use the wetlands in their dry state as resting and seed foraging areas (USFWS 2007, Kleinschmidt Associates 2008).

2.3.4.11.3 Nonnative Species

Problematic invasive nonnative plant species in the other natural seasonal wetland natural community include low mannagrass, Italian ryegrass, and perennial pepperweed (Hogle et al. 2006, Dawson et al. 2007, Gerlach et al. 2009).

2.3.4.11.4 Ecosystem Functions

When flooded, this natural community supports an aquatic food web that is functionally similar to undisturbed vernal pools (Alexander 1976, Barclay and Knight 1981, Scheffer 2004, Williams 2006). As the water recedes, its ecosystem characteristics change from a fully aquatic system to a terrestrial ecosystem (Williams 2006), and its food web linkages break down as the community becomes more integrated with the terrestrial landscape in which it is embedded.

2.3.4.11.5 Environmental Gradients

The dominant environmental gradient in the other natural seasonal wetland community is driven by the different chemical and physical attributes of water versus air. Water is a polar solvent that is important in many chemical exchanges, and those exchanges control pH and the oxidation state of many chemicals and compounds. It also has a high heat capacity so temperature changes are buffered; and it is extremely viscous compared to air, so exchanges between the air and water as well as movement within the water are very slow (Scheffer 2004, Williams 2006). The ecological gradient between seasonal wetlands and surrounding terrestrial communities is marked by transitions in plant and wildlife species and is most pronounced during the wetted phase.

2.3.4.11.6 Future Conditions with Climate Change

Ongoing and future climate change (see Section 2.3.3.2, *Climate*) is expected to alter the other natural seasonal wetland natural community. The primary impact of climate change is predicted to be driven by changes in the hydrological regime due to increased variability in precipitation. The species present in this community are adapted to existing hydrological conditions, therefore increased variability of precipitation would likely lead to a shorter and more variable wet season or similar changes in the inundation period. It is not known how the increased variability in seasonal hydrology would affect the plants and animals inhabiting this community; however, because these species are adapted to current conditions, the impacts will likely result in changes to species composition. Additionally, rising average temperatures could result in increased evapotranspiration rates and therefore shorter wetted periods for this community; the impacts of which are expected to be adverse to native plants and wildlife.

2.3.4.12 Grassland

The grassland natural community encompasses a management spectrum ranging from natural to intensively managed vegetation dominated by grasses. At the more natural end of the spectrum, it is comprised of upland vegetation associations dominated by introduced or native annual and perennial grasses and forbs (non-grass herbaceous species) (D'Antonio et al. 2007, Keeler-Wolf et al. 2007). At the intensively managed end of the spectrum, it includes non-irrigated pasturelands (CALFED 2000). The grassland natural community is often found adjacent to wetland and riparian habitats and is the dominant community on managed levees in the Plan Area (Hickson and Keeler-Wolf 2007). The distribution of the grassland natural community in the Plan Area is shown in Figure 2-34.

The extent of this community in its natural landscape position around the periphery of the Plan Area has declined over the past century due to land conversion to intensive agriculture and losses to urban development (CALFED 2000, SFEI 2010). Anthropogenic changes to the natural disturbance regimes (e.g., dry-land grain farming, grazing, and diseases) since European settlement have also eliminated many native plant communities (D'Antonio et al. 2007, SFEI 2010). Depending upon how intensively and how long a natural variant of the grassland natural community has been impacted, its suite of native species may have largely been replaced by nonnative species (D'Antonio et al. 2007) and is often dominated by near monocultures of nonnative annual grasses and forbs (D'Antonio et al. 2007, USFWS 2007). In the historical tidal areas of the Delta, grassland has expanded on the dry land created on and behind levees.

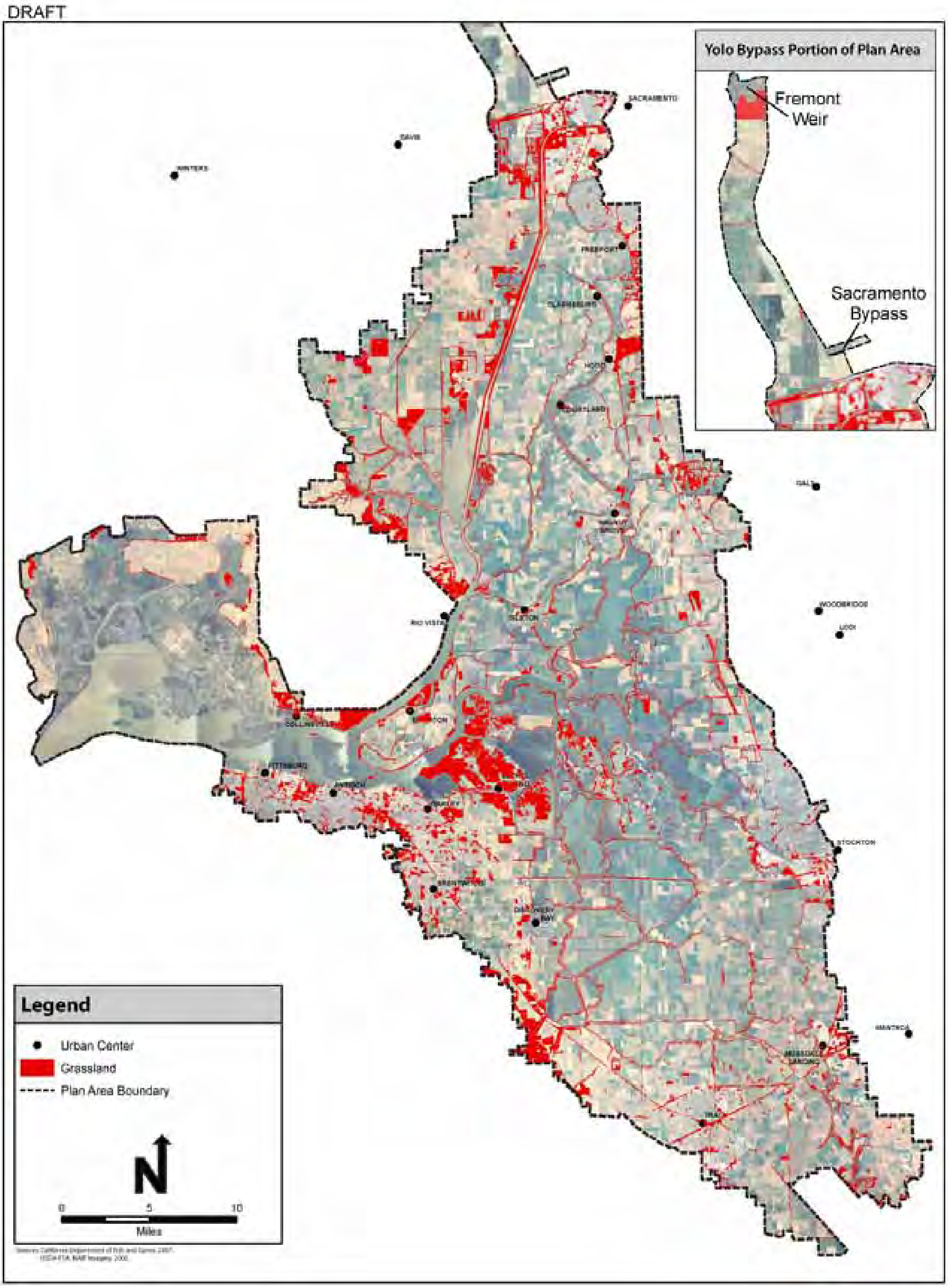

Figure 2-34. Distribution of Grassland Natural Community in the BDCP Plan Area

Vegetation types dominated by native grasses in the Plan Area were historically limited to a narrow border of either alkaline or freshwater meadows on clay rich soils in the uplands, adjacent to either marshes or alkaline sink scrub and dominated by saltgrass (*Distichlis spicata*). In higher topographic positions on coarser textured soils, there was a unique community with a significant component of native perennial and annual grasses (*Distichlis*, *Elymus*, *Melica*, *Nassella*, *Poa,* and *Vulpia*), geophytes (*Calochortus*, *Chlorogalum*, *Dichelostemma*, and *Triteleia*), and a phenological succession of many species of early spring-, spring-, and summer-flowering annual dicots (Bryan 1923, Thomasson Jr. et al. 1960, Collins and Grossinger 2004, Grossinger 2004, Grossinger et al. 2008, SFEI 2010).

In the southwestern portion of the Plan Area, from the Clifton Court Forebay to Oakley, there was a narrow band of alkali meadow dominated by saltgrass which was sandwiched between tidal marshes and alkaline sink scrub on one side and oak savanna on the other (Carpenter and Cosby 1939, SFEI 2010). Similar conditions occurred around the Montezuma Hills (Collins and Grossinger 2004). Using the historical conditions of the south San Francisco Bay, old charts, and current floras to reconstruct the vegetation, along the borders of Suisun Marsh and the Cache Slough area there were alkali meadows dominated by saltgrass located between the marshes with the unique seasonal community in higher topographic positions (Collins and Grossinger 2004, Grossinger 2004).

Along the west side of the Yolo Basin from the Cache Slough area to the current sinks of Putah Creek, there was a unique landform called the Putah Plain that consisted of numerous small floodwater distributaries of Putah Creek (Bryan 1923, Thomasson Jr. et al. 1960, Graymer et al. 2002, Witham 2003, Grossinger et al. 2008, Gerlach 2009). The distributaries were aligned perpendicular to the Yolo Basin as a continuous parallel repeating geomorphic series of shallow basin, low natural levee, channel, low natural levee, shallow basin features. These hydrological features disappear at lower elevations in the Yolo Basin because they were periodically eroded away by large Sacramento River flood events into the Yolo Basin. The channels were, and where they are still intact, are dominated by vernal pool species characteristic of non-alkaline, short inundation period, clay-bottom, swale/pool complexes. Good examples are the relatively undisturbed channels at the DFG Tule Ranch. The basins in topographically higher positions than the channels were likely highly alkaline areas that resulted from the accumulation of salts transported by floodwaters from west of the Yolo Basin. These basins are dominated by saltgrass, tarweeds, tarplants, and seepweed at higher elevation edges and by typical clay-bottom vernal pools species and salt pans species at their bottoms. These bottoms are the local habitat of Solano grass and Colusa grass; a good example is found at the Yolo County Grasslands Regional Park (Witham 2003, ESA 2005, Gerlach 2009).

Along the east side of the Plan Area in the vicinity of Stone Lakes NWR there are areas of the unique seasonal community interspersed with partially filled former tidal drainages of the Cosumnes Basin that grade upslope into claypan vernal pool/swale complex as reflected in the current flora and aerial imagery (USFWS 2007, Google Earth 2010). These communities abut tidal and reclaimed former tidal marshes and are periodically cut by small creeks and tidal channels running down to the Cosumnes Basin.

Direct and indirect anthropogenic influences on the landscape of the Plan Area have resulted in the reduction, conversion, and fragmentation of the meadows and unique seasonal communities. These changes have led to diminished ecological conditions necessary for sustaining well-functioning grassland natural community. In the Plan Area, the grassland natural community currently comprises one of the most common natural communities, but a large portion of this grassland is in areas that were historically tidal marsh and the vegetation is dominated by invasive nonnative grasses. While many native plant species have been reduced in abundance or distribution through these processes, they persist and coexist with nonnative plant species where the meadows and unique seasonal community once existed. Some animal species have also adjusted well to the new type of grassland community. Thus, the current grassland natural community still offers valuable habitats to many grassland-dependent species.

2.3.4.12.1 Vegetation

The plant associations present and their extent within the grassland natural community are shown in Table 2-16. Common nonnative annual grass species in this natural community include Italian ryegrass, soft chess, ripgut brome, red brome, wild barley, wild oats, and foxtail fescue. Native perennial grasses are generally found only in areas that have not been plowed and include creeping wildrye, blue wildrye, saltgrass, California melic, California brome, meadow barley, tuffed hairgrass, one-sided bluegrass, and purple needlegrass (Witham 2003, 2006, Keeler-Wolf 2007, USFWS 2007). If unplowed, the grassland natural community can be rich in species in the lily family that may include Ithuriel's spear, white hyacinth, harvest brodiaea, gold nugget, paper onion, blue dicks, common muilla, and narrow-leaved soap plant. In some parts of the Plan Area, the grassland natural community is interspersed with the vernal pool complex, alkali seasonal wetland complex, and other natural seasonal wetland natural community types (Witham 2003, 2006, Baraona et al. 2007). The Manual of California Vegetation (Sawyer et al. 2009) recognizes the broad spectrum of grassland types and includes vegetation types that are completely dominated by nonnative annual grasses to grasslands that are dominated by perennial native grasses. Plant species that can sometimes be found within grassland that contains patches of other natural communities covered by the BDCP include alkali milk-vetch, Heckard's pepper-grass, and San Joaquin spearscale (Table 2-4).

Table 2-16. Plant Alliances within the Grassland Natural Community in the Plan Area

Mapping Unit[1]	*Plant Alliance (Sawyer and Keeler-Wolf 1995)*	*Acreage*
Annual ryegrass (*Lolium multiflorum*)	Ruderal Herbaceous Grasses & Forbs	5,111
Baccharis/Annual Grasses	-	5
Bare Ground	-	11
California Annual Grassland/Herbaceous Alliance	California Annual Grasslands-Herbaceous	27,911
Calystegia/Euthamia	-	0
Centaurea spp.	-	24
Conium maculatum	-	1
Cultivated Annual Graminoid	-	22
Cynodon dactylon Alliance	Ruderal Herbaceous Grasses & Forbs	25,784
Degraded Vernal Pool Complex	-	2,480
Distichlis spicata	-	45
Ditch	-	0
Eucalyptus globulus	-	3
Foeniculum vulgare	-	11
Landscape Trees	-	5
Lepidium latifolium (generic)	-	1
Leymus triticoides (generic)	-	5
Managed Wetland	-	5
Medium Wetland Graminoids	-	1
Medium Wetland Herbs	-	1
Pasture	-	0
Perennial Grass	-	19
Salicornia[2] spp.	-	10
Scirpus[3]/*Typha*	-	1
Sesuvium/*Distichlis*	-	0
Structure	-	2
Undetermined[4]	-	1,423
Total		**62,880**

[1]Because of the fine scale mapping of many slightly different vegetation units in the Delta, Yolo Bypass, and Suisun Marsh plant alliances dominated by the same groups of species, nonnative annual grasses for example, were combined into a composit mapping unit. For more detailed information concerning the original mapping units and plant associations/alliances, as well as on methods of classification used, see Hickson and Keeler-Wolf (2007), Boul and Keeler-Wolf (2008), and TAIC 2008. The degraded vernal pool mapping unit was generated from existing vegetation types using the methods described in Section 2.3.1.5, *Vernal Pool Dataset Development*.
[2]Now known as *Sarcocornia*.
[3]Now known as *Schoenoplectus*.
[4]Extent of this natural community present in the Plan Area for which DFG did not delineate plant alliances. As described in Section 2.3.1, *Data Sources and Natural Community Classification*, these areas were delineated as this natural community type from aerial photography interpretation.
Note: Acrege total accommodates for rounding.

2.3.4.12.2 Wildlife

The grassland natural community provides important breeding and foraging habitat for many species of wildlife. Common mammals found in grasslands include mule deer, California ground squirrel, California vole, pocket gopher, desert cottontail, black-tailed jackrabbit, coyote, and badger. Grasslands are important to raptors and nesting waterfowl (CALFED 2000). Raptors for which grasslands provide important foraging habitat include Swainson’s hawk, white-tailed kite, red-tailed hawk, northern harrier, golden eagle, American kestrel, burrowing owl, great horned owl, and barn owl. Common songbirds that use the grasslands include loggerhead shrike, horned lark, water pipit, western bluebird, savannah sparrow, and western kingbird. Common reptiles and amphibians in the grasslands include gopher snake, common garter snake, California king snake, western fence lizard, Pacific tree frog, and western toad.

Grasslands provide habitat for many BDCP covered wildlife species, including California tiger salamander, California red-legged frog, Swainson's hawk, greater sandhill crane, and San Joaquin kit fox (Table 2-4).

2.3.4.12.3 Nonnative Species

California's grasslands have been invaded by a large number of exotic plant species which were primarily introduced and spread through farming and ranching agricultural practices (D'Antonio et al. 2007). A large number of exotic annual grass species dominate non-irrigated grasslands (D'Antonio et al. 2007, Keeler-Wolf et al. 2007) with annual ryegrass, medusahead (*Taeniatherum caput-medusae*) and barbed goatgrass (*Aegilops triuncialis*) being the most problematic in the Plan Area (Swiecki and Bernhardt 2002, Witham 2003, ESA 2005, USFWS 2007, Hopkinson et al. 2008). Dicot species that are especially problematic include Italian thistle (*Carduus pycnocephalus*), purple starthistle (*Centaurea calcitrapa*), yellow starthistle (*Centaurea solstitialis*), and perennial pepperweed (*Lepidium latifolium*) (Swiecki and Bernhardt 2002, Witham 2003, ESA 2005, Witham 2006, USFWS 2007, Hopkinson et al. 2008). Much of the grassland natural community in the Plan Area is classified as "ruderal" vegetation because it is dominated by nonnative opportunistic plants on disturbed soils such as levees and old tilled fields.

Problematic vertebrate exotic species that adversely affect wildlife in the grassland natural community include feral dogs (*Canis lupus familiaris*) and feral cats (*Felis silvestris*) (USFWS 2007).

2.3.4.12.4 Ecosystem Functions

The grassland natural community in the Plan Area is primarily managed for its function as a source of primary productivity to feed domestic grazing animals (Jackson and Bartolome 2007) and for its small herbivore productivity to sustain birds of prey such as Swainson's hawk. Burrows excavated by small rodents provide terrestrial habitat for California tiger salamander and nesting habitat for California burrowing owl (Witham 2006, EDAW 2007, USFWS 2007). Other ecosystem functions include effects on carbon sequestration and on the water and nutrient cycles by the grassland natural community (Eviner and Firestone 2007, Jackson, Potthoff et al. 2007, Reever-Morghan et al. 2007).

2.3.4.12.5 Environmental Gradients

Because of its extensive distribution in California, the grassland natural community often serves as the matrix in which other natural communities are embedded. In the Plan Area, it is generally located in higher topographic positions with steep environmental gradients to lower and wetter communities such as the alkali seasonal wetland complex and valley/foothill riparian natural community. A less obvious gradient exists between subsurface environments such as rodent burrows which maintain high humidity for California tiger salamander during the hot dry season (Storer 1925, Loredo and Van Vuren 1996, Petranka 1998, Trenham 1998).

2.3.4.12.6 Future Conditions with Climate Change

Ongoing and future climate change (see Section 2.3.3.2, *Climate*) may negatively impact the grassland natural community; although, there is no consensus on what the impacts will be (Dukes and Shaw 2007, Jackson et al. 2009). Because this community is generally located at elevations that will not be directly impacted by rising sea level, the primary impact of climate change is predicted to be driven by the increased variability in precipitation. The species present in this community are adapted to the existing precipitation regime, and an increase in the variability of precipitation is likely to lead to a shorter and more variable wet season. It is uncertain how the community or its individual species may respond to this increased variability (Dukes and Shaw 2007).

2.3.4.13 Inland Dune Scrub

Inland dune scrub is a dense to open shrub and sub-shrub dominated community of remnant dune soils with a unique mix of rare, endemic species of plants and insects. Inland dune scrub occurs only on the disturbed remnants of the former dune that existed along the southern shore of the San Joaquin River, immediately east of the city of Antioch (Figure 2-35). The 190-acre dune paralleled the shore for 2 miles, and was 0.15 mile wide and 120 ft tall (Howard and Arnold 1980, SFEI 2010). Beginning in 1865, the sand of the dune was mined to manufacture pottery, and in the late 1880s the sand was mined to manufacture bricks. The rate of sand mining greatly accelerated after the 1906 San Francisco earthquake for the manufacturing of bricks to rebuild the city. In the 1920s, mining increased again for the manufacture of asphalt and concrete. Sand mining then continued at a declining rate until World War II when it increased again.

After World War II, extensive commercial development spread across the area where the dune had been mined away, and sand mining continued eastward. The mining continued on the last two parcels of the dune even as USFWS was negotiating to establish the 55-acre Antioch Dunes National Wildlife Refuge (NWR). By the time the purchase was complete, the highest elevations of the remains of the dune were only 50 feet above mean higher high water (MHHW) of the San Joaquin River, with a slightly more dune-like area on an adjacent 12-acre Pacific Gas and Electric (PG&E) transmission line corridor 80 feet above MHHW (Howard and Arnold 1980, USFWS 1984, 2001, SFEI 2010). When measured from the landward side, the highest point on the Antioch Dunes NWR is 30 ft; the PG&E elevation is 60 ft.

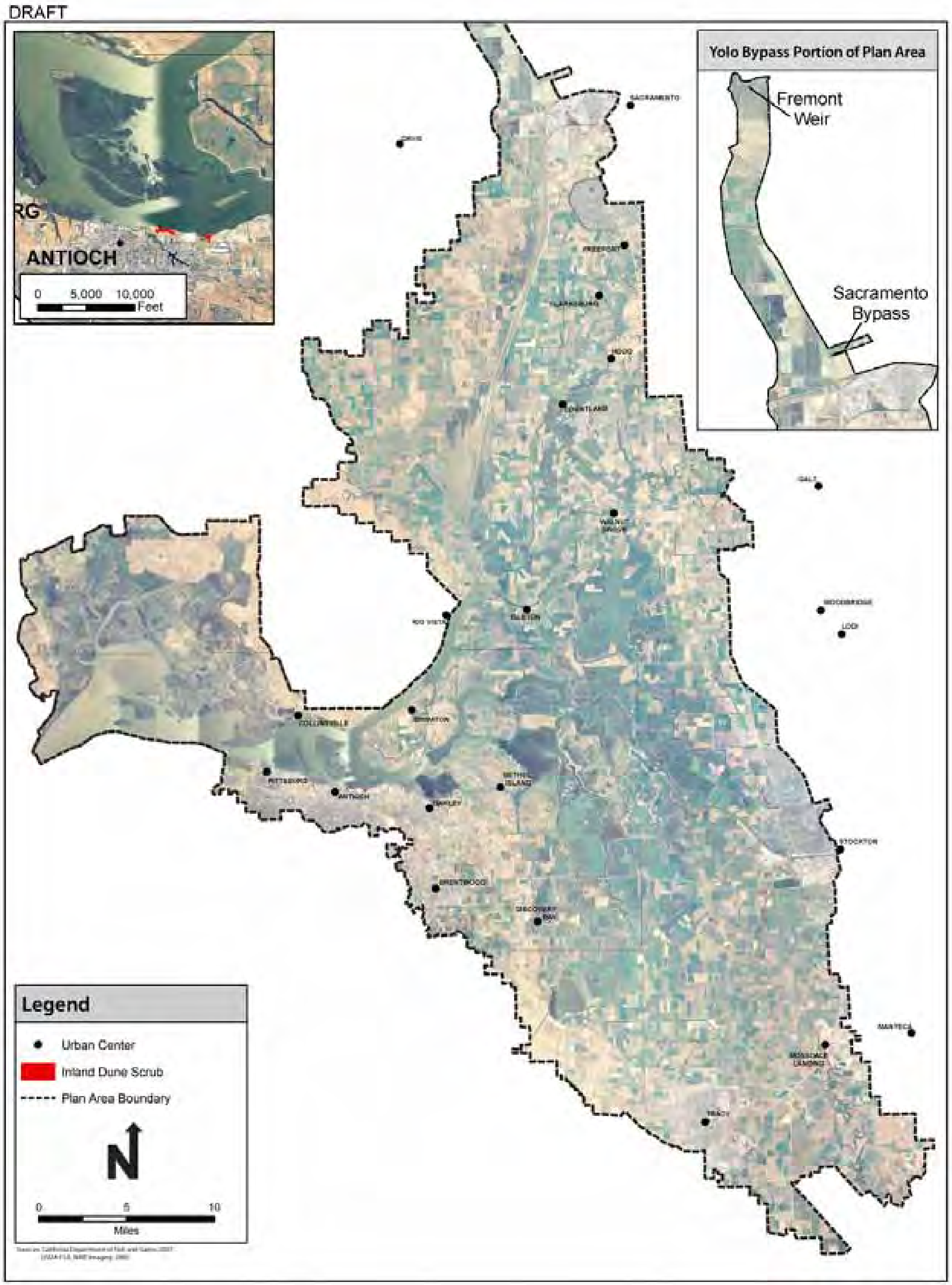

Figure 2-35. Distribution of Inland Dune Scrub Natural Community in the BDCP Plan Area

A description of the combined area of the Antioch Dunes NWR and PG&E properties with dune-like characteristics at the time of acquisition stated that “only an extremely small percentage of the area is in the configuration of a dune” (USFWS 1984). Management actions to increase the dune-like characteristics of Antioch Dunes NWR have included creating small dunes with 7,000 cubic yards of dredged sand material that had been stockpiled on the PG&E property (which proved unsuitable due to its clay content), and bulldozing the residual sand on the Antioch Dunes NWR into the shape of small dunes (USFWS 1984, 2001).

The geological origin of the dune has not been determined; however, regardless of its original source, the sand was sorted from a mixture of fine- and coarse-textured material and redeposited by wind (not water), as indicated by its extremely low clay content (soil survey), and it appears to have had a deep, older layer as well as a more recent layer (USFWS 2001). It has been speculated that the sand was brought to the location by the San Joaquin River approximately 140,000 years ago, and that the most recent dune probably established prior to the post-ice age sea level rise approximately 15,000 years ago (USFWS 1984, 2001).

Most accounts incorrectly describe the sand as the result of glaciation even though glaciated material would consist of very fine clay and silt like particles (glacial milk). Instead, the sand probably originated during warm humid periods as the granitic rock of the southern Sierra Nevada was chemically transformed into grus and then transported to the San Joaquin Valley during enormous slope failures (Wahrhaftig 1965, Twidale and Vidal Romaní 2005, Graham et al. 2010). While the dune was a unique formation, the sand is distributed southwestward from the dune in a 5.5 mile by 2 mile oblong patch (Carpenter and Cosby 1939, SFEI 2010).

In the 1933 soil survey of the area, the sand was classified as the Oakley sand soil series, and it was determined to be infertile, slightly acidic, and consisting of 2 percent coarse sand, 65 percent fine sand and 1 percent clay (Carpenter and Cosby 1939). In contrast, the much more heterogeneous riverine deposit of Piper fine sandy loam on the low islands of the nearby Delta is slightly alkaline and consists of 12 percent coarse sand, 45 percent fine sand, and 4 percent clay.

2.3.4.13.1 Vegetation

The plant associations present and their extent within the inland dune scrub natural community are shown in Table 2-17. Inland dune scrub is more similar to the vegetation of sandy soils in the San Joaquin Valley and Mohave Desert than to coastal scrub communities (Howard and Arnold 1980). Unfortunately, the pre-disturbance species composition of the vegetation was never well described before the sand mining and extensive oak cutting in the early 1900s and post-World War II (USFWS 2001). Based on early charts and a postcard dating from the early 1900s, the vegetation contained widely scattered large valley oaks, live oaks, various shrub species, and numerous herbaceous species (Howard and Arnold 1980, SFEI 2010). Very similar vegetation occurred 1.5 miles southeast of the dune as a 3-mile by 1.5-mile, 3,000-acre oblong patch on the Oakley sand soil southwest of Oakley (SFEI 2010). That area of chaparral/scrub was described as nearly impenetrable, but was cleared for grain production, later planted as almond orchards, and now is almost entirely developed (SFEI 2010).

Antioch Dunes NWR vegetation surveys conducted by Susan Bainbridge of the UC Berkeley Jepson Herbarium and the California Native Plant Society (CNPS) were used by DFG (Hickson and Keeler-Wolf 2007) to map two Antioch Dunes unique vegetation types that have one or more shrubs in the overstory which may have very sparse cover. The data were not formally analyzed by the DFG Delta mapping project, and the BDCP inland dune scrub community is defined by the presence of either of the two vegetation types. One vegetation type consists of a broadleaf shrubland that was classified as the *Lupinus albifrons* Antioch Dunes alliance (5 acres), and the other is a dwarf shrub vegetation type classified as the *Lotus scoparius* Antioch Dunes alliance (15 acres). Given that *L. albifrons* is primarily a coastal species, while the vegetation of the dune is primarily the northern-most expression of desert vegetation, it is more likely the species is the *L. excubitus*, an interior and desert species that is indistinguishable from *L. albifrons* (Rosatti ed. 2010). Other plant species present include ripgut brome (*Bromus diandrus*), yellow starthistle (*Centaurea solstitialis*), elegant clarkia (*Clarkia unguiculata*), naked stem buckwheat (*Eriogonum nudum* var. *auriculatum*), Contra Costa wallflower (*Erysimum capitatum* var. *angustatum*), California poppy (*Eschscholzia calfornica*), California croton (*Croton californicus*), Grindelia (*Grindelia* spp.), California matchweed (*Gutierrezia californica*), telegraph weed (*Heterotheca grandiflora*), Antioch Dunes evening-primrose (*Oenothera deltoides* ssp. *howellii*), vetch (*Vicia* spp.), and Russian thistle (*Salsola tragus*) (USFWS 2001). Contra Costa wallflower and Antioch Dunes evening-primrose are rare, endemic dune species and are BDCP covered species.

2.3.4.13.2 Wildlife

Recent observations of wildlife on the Antioch Dunes NWR include coyote *(Canis latrans)*, long-tailed weasel *(Mustela frenata)*, muskrat *(Ondatra zibethica)*, raccoon *(Procyon lotor)*, Townsend's mole *(Scapanus townsendi)*, Beechy ground squirrel *(Otospermophilus beecheyi)*, black-tailed jackrabbit *(Sylvilagus bachmani)*, Botta's pocket gopher *(Thomomys bottae)*, gray fox *(Urocyon cinereoargenteus)*, red fox *(Vulpes vulpes)*, racers *(Coluber constrictor)*, gopher snake *(Pituophis melanoleucus)*, western fence lizard (*Sceloporus occidentalis*), and common side-blotched lizard (*Uta stansburiana*). Numerous bird species have been observed on the Antioch Dunes NWR (migratory and resident), and gadwalls *(Anas strepera)* and mallards *(A. platyrhynchos)* have nested there. Historically, the dunes represented the northernmost occurrences for reptiles adapted to arid conditions, including the California legless lizard (*Anniella pulchra*), glossy snake (*Arizona elegans*), San Joaquin whipsnake (*Masticophis flagellum ruddocki*), and side-blotched lizard (*Uta stansburiana*) (Howard and Arnold 1980, USFWS 1984, 2001, 2008).

2.3.4.13.3 Invertebrates

The Antioch Dunes have been known as an entomological hotspot since the 1930s when research entomologists began collecting in what is now the Sardis Unit of the Antioch Dunes NWR (Howard and Arnold 1980, Arnold 1983). The area attracted extensive academic attention for its large and colorful species with desert affinities. In the 1930s, many species of wasps and flies, particularly the giant flower-loving fly (*Thaphiomydas trochilus*), were completely new to the region's collectors. A total of 27 taxa were described from the Antioch Dunes during that decade. Eight of those taxa are endemic to the Antioch Dunes; four are now extinct, three are of uncertain status, and one is the federally and state endangered Lange's metalmark butterfly (*Apodemia mormo langei*). Lange's metalmark is a covered species under the BDCP.

Table 2-17. Plant Associations within the Inland Dune Scrub Natural Community in the Plan Area

Mapping Unit[1]	*Plant Association (Sawyer and Keeler-Wolf 1995)*	*Acreage*
Plan Area		
Lupinus albifrons Antioch Dunes Association	Antioch Dunes Unique Association	15
Lotus scoparius Antioch Dunes Association	Antioch Dunes Unique Association	5
Total		**20**

[1]The mapping units provided here are newly described associations. For more detailed information concerning these mapping units, plant associations, and methods of classification used, see Hickson and Keeler-Wolf (2007).

2.3.4.13.4 Nonnative Species

The primary problematic nonnative plant species in this community are annual grasses such as ripgut brome, vetches, and yellow starthistle (*Centaurea solstitialis*) which form dense patches that crowd native plant species and reduce habitat quality for wildlife and invertebrates (USFWS 2001).

2.3.4.13.5 Ecosystem Functions

The inland dune scrub natural community is found on infertile sandy soil that historically was a large dune. There are only two patches totaling 20 acres of this natural community currently in existence, all of which have been severely degraded by a century of sand mining. Currently, the degraded remnants of the community are being managed exclusively for the three endangered species for which the Antioch Dunes NWR was established to protect.

2.3.4.13.6 Environmental Gradients

Inland dune scrub transitions into the tidal brackish emergent wetland natural community along its border with the San Joaquin River (USFWS 1984, 2001). Its other three sides are bordered by commercial developments.

2.3.4.13.7 Future Conditions with Climate Change

Because this community is generally located at elevations that will not be directly impacted by rising sea level, the primary impact of climate change is predicted to be driven by changes in the hydrological regime due to increased variability in precipitation. The species present in this community are adapted to a highly variable precipitation, and it is uncertain how they will be affected by increased variability.

2.3.4.14 Agricultural Habitats

The majority of lands in the Delta are currently in agricultural use (Figure 2-36). Major Delta region crops and cover types in agricultural production include small grains (such as wheat and barley), field crops (such as corn, sorghum, and safflower), truck crops (such as tomatoes and sugar beets), forage crops (such as hay and alfalfa), pastures, orchards, and vineyards (CALFED

2000, DWR 2007b). Of the total Plan Area, 66 percent is in agricultural use. Of the total acreage of irrigated land in the Delta, which encompasses both seasonally flooded and upland cropland agriculture, corn is currently the predominant cover type (28 percent), followed by alfalfa (21 percent), pasture (12 percent), and tomatoes (8 percent). Orchards cover 4 percent of the total irrigated land acreage in the Delta, and asparagus covers 3 percent (DWR 2007b). The distribution of seasonal crops in the Plan Area varies annually, depending upon crop-rotation patterns and market forces. Vegetable crops are the most abundant crops in the region (Fleskes et al. 2005). Changes in agricultural crops in the Delta over the past 30-40 years have shown dramatic trends, including a six-fold reduction in asparagus acreage (lowering it from the number one crop to the number eight crop in acreage grown), a two-fold increase in corn acreage (making it the number one crop in acreage grown), and an 18-fold increase in vineyards (DWR 2007b). These changes can have substantial effects on the habitat value of agricultural habitats for wildlife, particularly for birds.

2.3.4.14.1 Vegetation

Vegetation in the agricultural habitats community is variable and dynamic in terms of structure, growth, and harvesting patterns. Croplands do not conform to natural habitat successional stages. Instead, cropland is regulated by the artificial crop cycle. Vegetation can be either annual or perennial and can germinate at various times of the year. The largest proportion of the Plan Area landscape includes annually cultivated irrigated croplands that are seasonally or annually rotated to conserve soil nutrients and maintain soil productivity. This portion of the landscape, which includes most field, truck, and grain crops, changes seasonally as crops grow, are harvested, and with the rotational sequence of different crop types. These changes influence the value and use of cultivated habitats to covered wildlife species on a seasonal basis. Other cover types, such as orchards, vineyards, rice, and irrigated pasture remain uncultivated for many years and are considered perennial crop types because they do not seasonally or annually rotate to other crop or cover types. Still other crops, particularly alfalfa and other hay crops, while regularly harvested, may remain uncultivated for multiple years, but eventually are rotated to other uses and are thus referred to as semi-perennial crop types.

While planting timeframes are variable, most annually cultivated croplands are planted in spring and harvested in late summer or early fall. Much of the Plan Area remains unplanted and bedded during the winter season, although a second crop may be planted during the same growing season in some areas. Cropland vegetation is grown as a monoculture, using tillage or herbicides to eliminate unwanted vegetation.

However, interspersed within the agricultural landscape are small patches or linear corridors of natural vegetation and other natural features, such as riparian woodland and scrub, wetlands, ponds, hedgerows, tree rows, and small patches of isolated native or nonnative trees. Agricultural habitats in the Plan Area are not known to support any covered plant species (Table 2-4). Soil often dictates the type of crops grown in the Plan Area. Corn, for instance, requires better soil than barley, which can grow in poor quality soil; and rice does well in clay soil not suitable for other crops. Leaching can remove contaminants in areas of high salt or alkali levels, making the soil highly productive. Local climate variation also influences the type of crops grown (DFG 2005).

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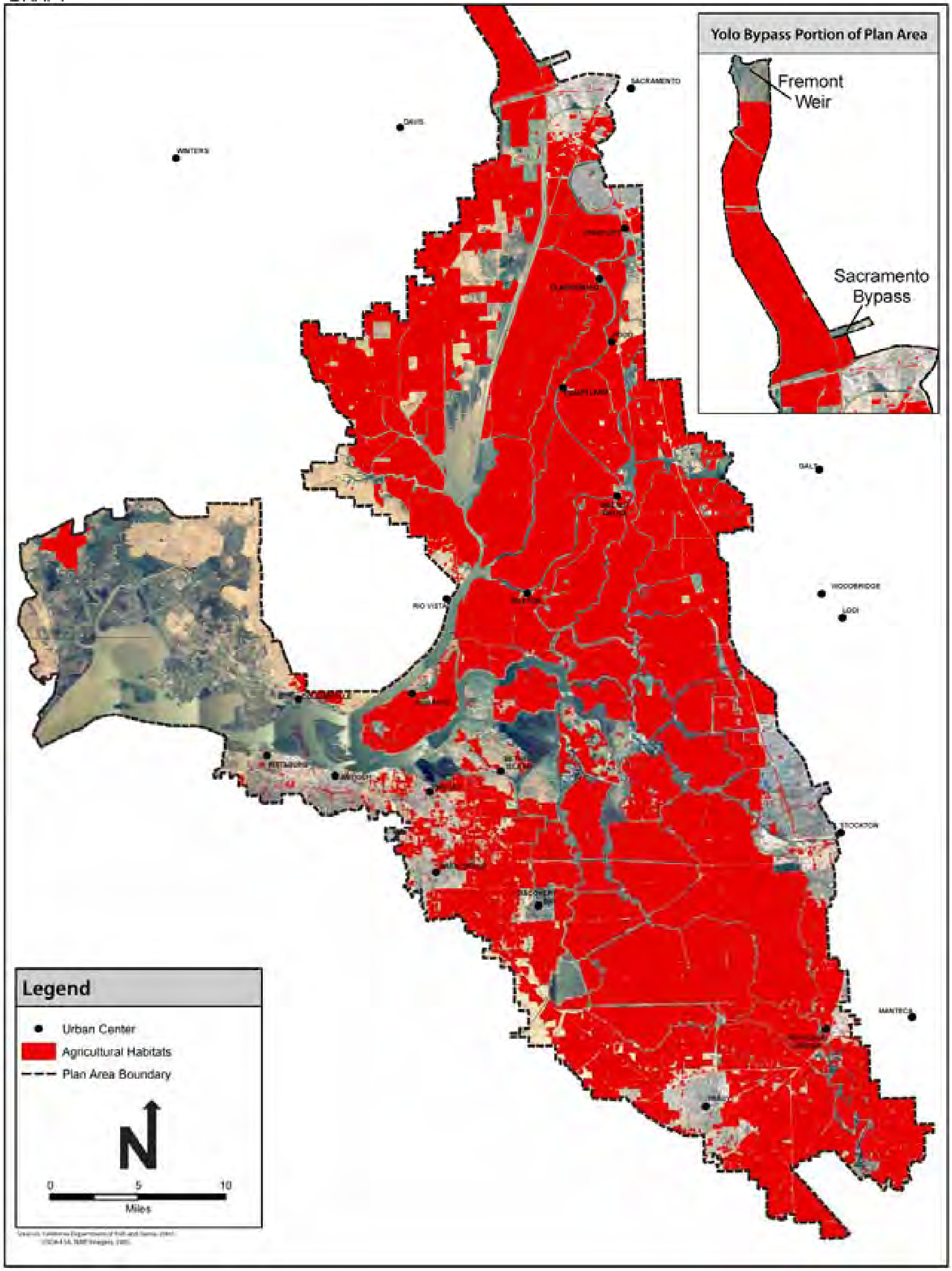

Figure 2-36. Distribution of Agricultural Habitats in the BDCP Plan Area

Orchard crops are categorized as deciduous or evergreen, with deciduous orchards far more common in the Delta region than evergreen orchards. Deciduous orchards include commercially productive tree crops in which the trees lose their leaves at some point in the year and include fruit and nut trees (e.g., pear and walnut), and bush crops. Bush crops are similar to orchards, but they may be configured in rows rather than a matrix, and are much shorter in height. Evergreen orchards include commercially productive tree crops, including citrus, avocado, and olive groves, in which the trees retain their leaves throughout the year (Hickson and Keeler-Wolf 2007). Agricultural habitats also include eucalyptus, tree-of-heaven, and other exotic vegetation stands (Table 2-18).

Table 2-18. Plant Alliances within the Agricultural Habitats in the Plan Area

Mapping Unit[1]	***Plant Alliance (Sawyer and Keeler-Wolf 1995)***	***Acreage in Plan Area***
Undetermined[2]	Undetermined[2]	1,034
-	Agriculture	473,404
Annual Grasses[3]	-	487
Atriplex[3]	-	9
-	Bare Ground	8
Exotic Vegetation Stands[3]	-	5,668
Field Crops[3]	-	5,632
Distichlis[3]	-	32
Eucalyptus[3]	-	220
Ditches and Sloughs[3]	-	11
-	Fallow Disced Field	40
-	Flooded Managed Wetland	800
-	*Lotus corniculatus*	4
Oaks[3]	-	5
-	Perennial Grass	215
-	Rice	7,573
Salicornia[3,4]	-	17
Scirpus[3]	-	20
Salix[3]	-	4
-	Sparsely or Unvegetated Areas; Abandoned Orchards	7,401
-	Structure	2
-	Truck/Nursery/Berry Crops	1,173
Typha[3]	-	19
Total		**503,779**

[1]Some of the mapping units provided here are newly described associations or alliances. For more detailed information concerning these mapping units and plant associations/alliances, as well as on methods of classification used, see Hickson and Keeler-Wolf (2007); TAIC (2008); SAIC 2009 reclassifications of Boul and Keeler-Wolf (2008).
[2]Extent of this natural community present in the Plan Area for which DFG did not delineate plant alliances. As described in Section 2.3.1, *Data Sources and Natural Community Classification*, these areas were delineated as this natural community type from aerial photography interpretation.
[3]FG vegetation types were combined to form this mapping unit in order to condense the list.
[4]The genus of pickleweed is now *Sarcocornia* instead of *Salicornia*.

2.3.4.14.2 Fish and Wildlife

Agricultural habitats in the Plan Area formerly consisted of extensive wetlands, open grasslands, broad riparian systems, and oak woodlands. The conversion of natural vegetation to agriculture has eliminated large areas of these native habitats. However, although they generally support a less diverse community of wildlife compared with most native habitats, agricultural systems continue to support abundant wildlife and provide essential breeding, foraging, and roosting habitat for many resident and migrant wildlife species (Fleskes et al. 2005, EDAW 2007, USFWS 2007, Kleinschmidt 2008). Agricultural habitats in the Plan Area provide habitat for several federal and California listed species covered by the BDCP, including Swainson's hawk, giant garter snake, and greater sandhill crane (Table 2-4).

Agricultural habitats in the Delta provide essential upland habitat for many wildlife species. Crop patterns that include a variety of hay, grain, and row crops support abundant rodent populations. Field edges, woodlots, and watercourses that support riparian habitat also provide breeding sites and refugia for prey species and other wildlife. Because of this abundance of food, the Central Valley supports one of the largest concentrations of raptors during the winter and breeding seasons. Raptors, such as red-tailed hawk, Swainson's hawk and white-tailed kite, nest throughout the Central Valley and forage in a variety of agricultural crop types including hay, grain, row crops and irrigated pastures. Conversion of pastures, row crops, and similar agricultural habitats to orchards and vineyards has been noted as a factor affecting raptors such as Swainson's hawk (Estep in prep). Grain, corn, and rice fields also provide important foraging habitats for sandhill cranes, waterfowl, wading birds, and shorebirds. Upland and seasonally flooded agricultural habitats and wetlands of the Delta support an estimated 10 percent of the waterfowl population that winter annually in California (CALFED 1998).

The Yolo Bypass Wildlife Area is an example of an area that utilizes agriculture to manage wildlife habitats while providing income from agriculture (EDAW 2007). Many agricultural practices occurring in the Yolo Bypass Wildlife Area provide habitat for a diverse assemblage of wildlife species. Rice is grown, harvested, and flooded to provide food for thousands of waterfowl. Corn fields are harvested to provide forage for geese and cranes. Working with local farmers, the Yolo Bypass Wildlife Area provides fields of grain sorghum, corn and sudan grass specifically for wildlife forage purposes. Crops such as safflower are cultivated and mowed to provide seed for upland species such as ring-necked pheasant and mourning dove (EDAW 2007).

When inundated, the Yolo Bypass provides habitat for at least 42 fish species, including delta smelt, splittail, Chinook salmon, steelhead, and white sturgeon (Sommer et al. 2001a, 2007, Feyrer et al. 2006). Evidence suggests that splittail and Chinook salmon benefit substantially from floodplain inundation because of increased food supply, lower water velocity, and warmer water. Further, extensive grading of the Yolo Bypass for agricultural drainage and relatively slow water stage decreases has likely contributed to reduced stranding of juvenile salmonids and splittail.

Native and nonnative vegetation growing along field margins and riparian vegetation growing along permanent agricultural ditches also provides habitat for migrant and resident songbirds, raptors, reptiles, amphibians, and small mammals. Filter strips of vegetation planted in agricultural areas to improve water quality also provide wildlife habitat. Natural seasonal wetlands associated with agricultural drainage and irrigation channels provide habitat for a number of wildlife and fish species.

The wildlife habitat value of agricultural cover types is a function of several variables, including accessibility to prey, prey density, and proximity to other habitat types. However, due to the dynamic nature of the agricultural landscape, to best evaluate the wildlife value of agricultural cover types in the Plan Area over a long timeframe, cover types can be characterized at a broad scale according to seasonal or perennial condition. Although perennial or semi-perennial cover types can be evaluated independently, seasonal crop types are best evaluated more generally by combining all seasonally and annually cultivated crop types into a single category. Specific crop type requirements or preferences can be addressed at the species-specific or preserve management level. Agricultural habitats in the Plan Area are thus characterized and evaluated according to subtypes presented in Figure 2-37, and acreages for each subtype are shown in Table 2-19[2]. Characteristics and wildlife use of each agricultural subtype are described below.

Table 2-19. Acreages of Agricultural Habitats Categories in the Plan Area

Agricultural Habitats Subtype	*Acreage*		
	Plan Area	*Upper Yolo Bypass*	*Suisun Marsh*
Alfalfa	82,280	3	0
Irrigated Pasture	49,205	0	489
Rice	5,034	7,603	0
Orchards	18,020	0	0
Vineyards	28,901	0	0
Other Cultivated Crops	223,676	6,151	1

Source: DWR Land Use 2007

Alfalfa. Alfalfa is an ungrazed irrigated hay crop used for livestock feed. Alfalfa is regarded as a semi-perennial crop type typically remaining uncultivated for 4 to 5 years, and occasionally longer. During this time, it is not rotated to other crop types. Alfalfa is considered to be the agricultural cover type with the highest foraging value to Swainson's hawk and the white-tailed kite, and is an important foraging cover type for the greater sandhill crane and tricolored blackbird. Its value is largely a function of its relatively low vegetation structure, and the practice of regular mowing and flood irrigating during the spring and summer, which enhances prey accessibility for foraging birds. This crop type is distributed throughout the Plan Area, including portions of the Yolo Bypass.

Irrigated Pasture. Irrigated pastures are irrigated grasses or hays grazed by livestock and periodically cut for hay. They include large pasturelands found in the Yolo Bypass, Sherman Island, and other Delta islands, and smaller pastures associated with farm residences or smaller cattle operations. While smaller irrigated pastures may be rotated to other cover types periodically, most irrigated pasturelands remain intact for many years. Like alfalfa, irrigated pastures provide foraging value to several covered species, including Swainson's hawk, white-tailed kite, burrowing owl, greater sandhill crane, and tricolored blackbird.

[2] The source data for this graphic and table, DWR Land Use 2007, is different from the source data for Figure 2-36 and Table 2-18, DFG 2007.

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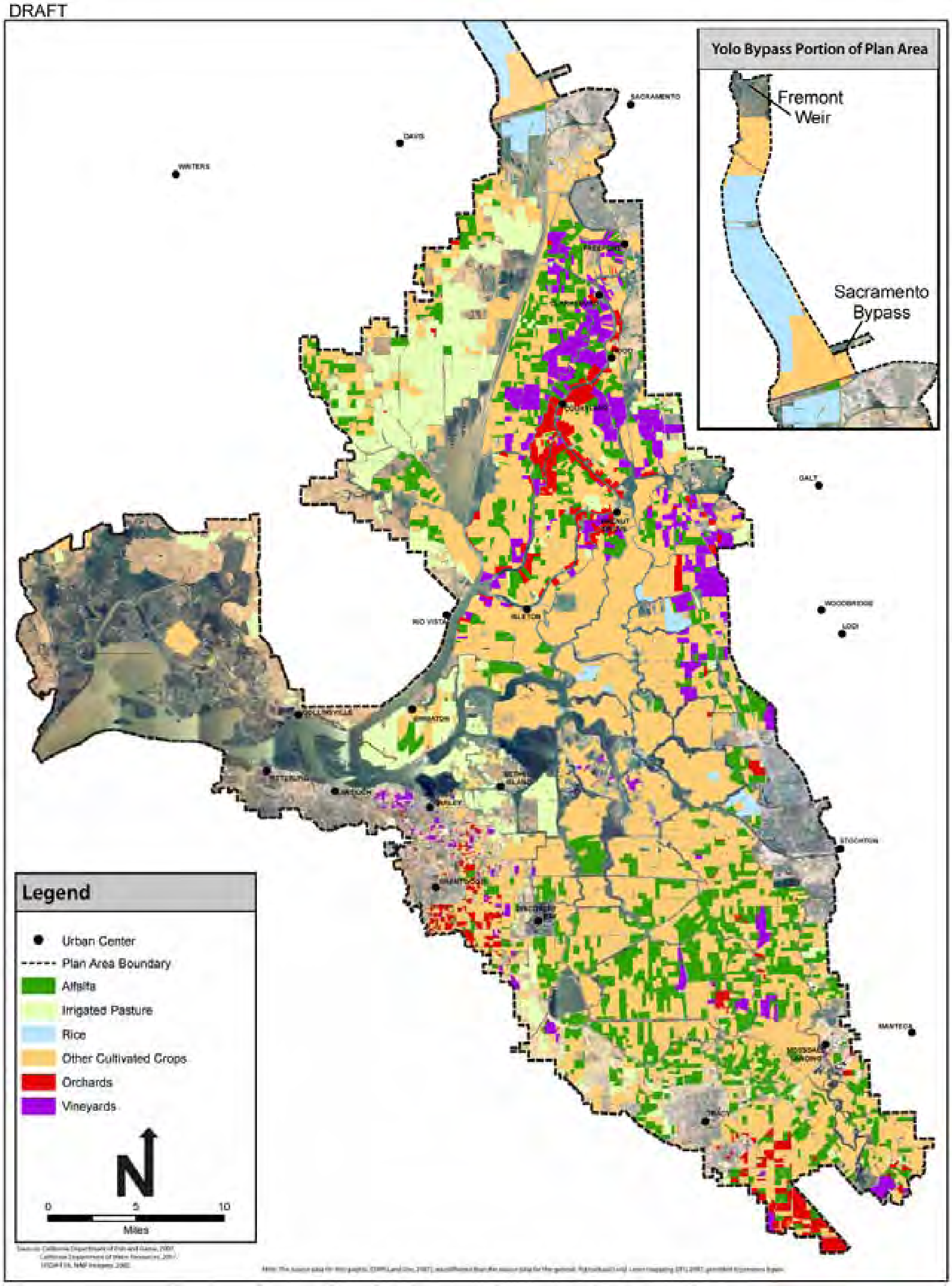

Figure 2-37. Distribution of Agricultural Habitats Subtypes in the BDCP Plan Area

Rice. Because rice cultivation requires a narrow range of soil conditions and because of the infrastructure required to effectively manage ricelands, this crop is not typically rotated and remains for many consecutive years, sometimes decades. Thus, rice is also considered a perennial crop type. Rice fields are active beginning as early as March when fields are initially flooded, to September and October when fields are drained and harvested. During the fall and winter, some rice fields are flooded to provide habitat for wintering waterfowl. Rice fields provide important aquatic habitat for giant garter snakes during the active season, as well as foraging habitat for many bird species during the active and inactive seasons.

Orchards. Orchards are perennial crops that provide limited wildlife value, particularly to covered species. Orchards develop a vegetation overstory that generally precludes access by foraging Swainson's hawks, white-tailed kites, burrowing owls, and other agricultural land-associated covered species. Orchards are planted in rows and eventually develop a dense overstory canopy. Some bats and birds find roosting and nesting opportunities in orchard trees, but overall, orchard trees receive limited use and are of negligible value to covered species.

Vineyards. Like orchards, the structure of vineyards also limits use by covered species and most other wildlife. This crop type also remains for many consecutive years and is considered a perennial cover type. Planted in rows, a relatively dense overstory develops that prohibits use by most agriculture-associated wildlife species. The increase in vineyard acreage in the Plan Area has removed other agricultural habitats more suitable to wildlife.

Other Cultivated Crops. This type is defined as areas dominated by crop patterns that involve annual or seasonal cultivation and rotation. This is the dominant cover type in the Plan Area and consists of most of the field, truck, and grain crops. These types are generally characterized as having seasonal or fluctuating habitat value depending on the planting and harvesting regime and vegetation structure. Thus, there is substantial variation in habitat value among the many crop types included within this category. Because they are seasonally or annually rotated, the value of individual fields changes each year. In addition, lands that are farmed to rotated irrigated crops generally have periods – usually during the fall post-harvest and winter months – when the fields are disked or bedded and support no vegetation. Therefore, for purposes of general classification and modeling habitat value, these crop types are not differentiated based on their individual seasonal value but are instead combined into a category of seasonally rotated croplands.

2.3.4.14.3 Nonnative Species

The agricultural landscape within the Plan Area supports primarily nonnative cultivated crops interspersed with small linear features (e.g., riparian corridors) or small patches (e.g., wetlands) that support native vegetation. The modified and disturbed conditions inherent to agricultural habitats have also encouraged a variety of undesirable nonnative species, commonly referred to as agricultural weeds, that occur around the perimeter of agricultural fields and that rapidly germinate in idle fields. These nonnative agricultural weeds usually require ground disturbance, such as tillage and irrigation, to establish and persist. Many have been persistent in the agricultural landscape for generations. Active and ongoing agricultural activity, including regular cultivation and herbicide application, is required to suppress expansion in active fields.

Agricultural habitats also attract a variety of nonnative wildlife species, particularly where patches of natural habitat persist within the landscape that provides refuge from regularly cultivated lands. Nonnative birds, such as the European starling and house sparrow, and nonnative mammals such as the Norway rat and house mouse commonly occur in agricultural habitats and adjacent riparian and wetland habitats in the Delta and throughout the Central Valley. These and other nonnative wildlife species are not unique to agricultural habitats, but also occur in many natural habitats. In an agricultural landscape, nonnative species are generally considered with respect to their impacts on cropland productivity and agricultural economics; however, some species can also invade adjacent riparian and wetland habitats.

2.3.4.14.4 Ecosystem Functions

While important for providing essential human services (e.g., food, fuel, fiber), agricultural landscapes are generally considered detrimental to most ecosystem functions. The regular and intensive cultivation of lands within the Delta can be contrary to the natural patterns of nutrient cycling, soil and sediment retention, water flow and water quality regulation, climate and air quality regulation, flood protection, and the protection of biodiversity. While some elements of ecosystem function can be partially retained, such as providing flooded habitat for wintering waterfowl and other waterbirds, a more comprehensive approach to agricultural land management that incorporates natural systems and functions is generally required to retain or enhance most ecosystem functions, such as incorporation of small patches or linear corridors of natural vegetation or wetlands.

The native Delta landscape was an extensive tidal marsh complex made up of freshwater and brackish marshes. By the mid-1800s, reclamation of wetlands began to transform the Delta into an agricultural region with a complex system of channelized waterways and Delta “islands.” This transformation of the Delta into an intensively managed agricultural landscape has substantially reduced its ecosystem functions and led to the development of several major resource issues that have affected agricultural productivity and stability of the Delta environment including flooding, salinity intrusion, and subsidence.

Agricultural habitats can, however, provide important habitats for wildlife; and if appropriately managed, can serve as surrogate habitats for native grasslands and wetlands that were converted to an agricultural landscape. Several covered species rely on agricultural habitats to meet life requisites. For example, flooded rice fields provide surrogate wetland habitats for the giant garter snake and western pond turtle during the spring and summer, hay crops and some annually cultivated crops provide important foraging habitat for Swainson’s hawk and the white-tailed kite, and winter-flooded croplands provide essential foraging and roosting habitat for the greater sandhill crane as well as waterfowl and other waterbirds along the Pacific Flyway.

2.3.4.14.5 Environmental Gradients

In general, agricultural habitats have a detrimental effect on natural gradients due to the removal of native habitats, grading and leveling of land, and changes in both groundwater and surface water movement. As a result, environmental gradients associated with agricultural habitats tend to be abrupt. The majority of the Plan Area consists of agricultural habitats with little to no topographic relief. These lands transition to grassland habitats in several areas, including portions of the southwestern, northeastern, and western edges of the Plan Area, and portions of the Yolo Basin. Tidal perennial aquatic habitats occur within the agricultural landscape, such as Franks Tract, Clifton Court Forebay, and the Sacramento and San Joaquin rivers; however, because these areas are confined by levees and water flow is highly regulated, there is little natural transition between these features and agricultural habitats. Agricultural habitats also transition to some wetland habitats, primarily in the Yolo Basin.

2.3.4.14.6 Future Conditions with Climate Change

Agricultural habitats may be particularly sensitive to long-term sea level rise associated with global climate change (see Section 2.3.3.2, *Climate)* (Nicholls et al. 1999). More variable flows through the Central Valley could reduce the reliability of water supply available for irrigating crops at critical times of the year. With sea level rise exacerbating current conditions, a powerful earthquake in the region could collapse levees; leading to major saltwater intrusion and flooding throughout the Delta if flows were sufficiently low, altering the tidal prism and causing substantial changes to agricultural areas (Mount and Twiss 2005). Areas within levees that are currently farmed would be impacted by the floodwaters.

Crop types are anticipated to change with elevated ambient temperatures. Jackson et al. (2009) asserted that over the next 50 years, cultivation of some warm season crops, such as tomatoes, cucumbers, sweet corn, and peppers, is expected to decline; whereas cultivation of hot season crops, including melons and sweet potatoes, are expected to increase as a result of climatic changes.

2.3.5 Covered Species

A total of 63 species are proposed for coverage under the BDCP, listed in Table 2-20. Detailed information about each of these species is provided in Appendix A, *Covered Species Accounts*, including life history characteristics, historical and current distribution, designated critical habitat, essential habitat, and key stressors that affect species distribution and abundance.

Table 2-20. Species Proposed for Coverage under the BDCP

Common name	*Scientific Name*
Fish	
Central Valley steelhead	*Oncorhynchus mykiss*
Sacramento River winter-run Chinook salmon	*Oncorhynchus tshawytscha*
Central Valley spring-run Chinook salmon	*Oncorhynchus tshawytscha*
Central Valley fall- and late fall-run Chinook salmon	*Oncorhynchus tshawytscha*
Longfin smelt	*Spirinchus thaleichthys*
Delta smelt	*Hypomesus transpacificus*
Sacramento splittail	*Pogonichthys macrolepidotus*
White sturgeon	*Acipenser transmontanus*
North American green sturgeon	*Acipenser medirostris*
Pacific lamprey	*Entosphenus tridentatus* (formerly *Lampetra tridentata*)
River lamprey	*Lampetra ayresii*
Mammals	
San Joaquin kit fox	*Vulpes macrotis mutica*
Riparian woodrat	*Neotoma fuscipes riparia*
Salt marsh harvest mouse	*Reithrodontomys raviventris*
Riparian brush rabbit	*Sylvilagus bachmani riparius*
Townsend's big-eared bat	*Corynorhinus townsendii*
Suisun shrew	*Sorex ornatus sinuosus*
Birds	
Tricolored blackbird	*Agelaius tricolor*
Suisun song sparrow	*Melospiza melodia maxillaris*
Yellow breasted chat	*Icteria virens*
Least Bell's vireo	*Vireo bellii pusillus*
Western burrowing owl	*Athene cunicularia hypugaea*
Western yellow-billed cuckoo	*Coccyzus americanus occidentalis*
California least tern	*Sternula antillarum browni*
Greater sandhill crane	*Grus canadensis tabida*
California black rail	*Laterallus jamaicensis coturniculus*
California clapper rail	*Rallus longirostris obsoletus*
White-tailed kite	*Elanus leucurus*
Swainson's hawk	*Buteo swainsoni*
Reptiles	
Giant garter snake	*Thamnophis gigas*
Western pond turtle	*Actinemys* (formerly *Emys* and *Clemmys*) *marmorata*
Amphibians	
California red-legged frog	*Rana draytonii*
Western spadefoot toad	*Spea hammondii*
California tiger salamander	*Ambystoma californiense*
Invertebrates	
Lange's metalmark butterfly	*Apodemia mormo langei*
Valley elderberry longhorn beetle	*Desmocerus californicus dimorphus*
Vernal pool tadpole shrimp	*Lepidurus packardi*
Conservancy fairy shrimp	*Branchinecta conservatio*
Longhorn fairy shrimp	*Branchinecta longiantenna*
Vernal pool fairy shrimp	*Branchinecta lynchi*
Midvalley fairy shrimp	*Branchinecta mesovallensis*
California linderiella	*Linderiella occidentalis*

Table2-20. Species Proposed for Coverage under the BDCP (continued)

Common name	*Scientific Name*
Plants	
Alkali milk-vetch	*Astragalus tener* var. *tener*
Heartscale	*Atriplex cordulata*
Brittlescale	*Atriplex depressa*
San Joaquin spearscale	*Atriplex joaquiniana*
Slough thistle	*Cirsium crassicaule*
Suisun thistle	*Cirsium hydrophilum* var. *hydrophilum*
Soft bird's-beak	*Cordylanthus mollis* ssp. *mollis*
Dwarf downingia	*Downingia pusilla*
Delta button-celery	*Eryngium racemosum*
Boggs Lake hedge-hyssop	*Gratiola heterosepala*
Carquinez goldenbush	*Isocoma arguta*
Delta tule pea	*Lathyrus jepsonii* var. *jepsonii*
Legenere	*Legenere limosa*
Heckard's pepper-grass	*Lepidium latipes* var. *heckardii*
Mason's lilaeopsis	*Lilaeopsis masonii*
Delta mudwort	*Limosella subulata*
Side-flowering skullcap	*Scutellaria lateriflora*
Suisun Marsh aster	*Symphyotrichum lentum*
Caper-fruited tropidocarpum	*Tropidocarpum capparideum*
Antioch Dunes evening-primrose	*Oenothera deltoides* spp. *howellii*
Contra Costa wallflower	*Erysimum capitatum* var. *angustatum*

2.4 BIOLOGICAL DIVERSITY

California is considered a global hotspot for biological diversity, where species diversity, endemism, and threats to this diversity are particularly high (Myers et al. 2000, Stein et al. 2000). California is particularly rich in unique plant species and contains globally important sites of plant diversity (Davis et al. 1997).

By most measures of biological diversity, California stands out as unique in North America. For example, California contains more native biological diversity than any other state, including more endemic species than any other state (1,295 species) (Stein 2002). Compared to other states, California is ranked first in the United States in the number of endemic species of freshwater fish, vascular plants, amphibians, reptiles, and mammals (Stein et al. 2000). In terms of total species, California supports approximately one-third of all species of vascular plants and reptiles in the United States, 47 percent of mammal species, and 56 percent of bird species (DFG 2003).

The Plan Area supports a great diversity of habitats. DFG has identified over 100 different plant associations, as defined by Sawyer and Keeler-Wolf (1995), in the Plan Area within the general biological communities of aquatic, seasonal wetlands, tidal and nontidal perennial wetlands, grasslands, riparian, and agricultural lands (Hickson and Keeler-Wolf 2007). The Delta is part of the Pacific flyway, one of the major north-south migratory routes for avifauna in the Americas. Surveys of the California Central Valley, including the Delta, document that it is one of the most important regions in western North America to migratory and wintering shorebirds (Shuford et al. 1998).

One measure of the degree of biological diversity in the Plan Area is the number of species known to inhabit the Delta and surrounding uplands. Based on information from various sources, an estimated 345 species of vertebrates could occur in the biological communities of the Plan Area, representing approximately 40 percent of all the vertebrate species known to occur in California (Table 2-21). Table 2-21 presents the number and percentage of species found in the Plan Area compared to the entire State of California by taxonomic group. The Plan Area represents less than one percent of the land area of California but is disproportionately rich in fish and bird species. Nearly 50 percent of all of California's bird species potentially use the Plan Area, a testament to its importance as part of the Pacific flyway. The Plan Area has a high diversity of native fish species with 61 percent of California's native fish species found in the Delta (31 of 51 species) (see list of all Delta fish species in Table 2-6). Of all fish species found in California, both native and nonnative, nearly half can be found in the Delta.

Over 300 taxa (species, subspecies, and varieties) of native and nonnative (naturalized) vascular plants were recorded in sampled vegetation stands in the Plan Area by DFG during its vegetation mapping effort (Hickson and Keeler-Wolf 2007). Since this mapping effort only sampled at various specific sites across the Plan Area, the total number of vascular plant taxa in the Plan Area is certainly much higher.

Table 2-21. Number of Vertebrate and Plant Species Present in the Plan Area

Taxonomic Group	*Number of Species in Plan Area*	*Number of Species in California*[6]	*Percent of California Species in Plan Area*
Vertebrates	345	876	39%
Mammals	58[1]	197	29%
Birds	200[2]	433	46%
Reptiles	22[3]	84	26%
Amphibians	9[3]	51	18%
Fish	55[4]	111[7]	49%
Vascular Plants	Over 300[5]	6,272	Over 4%
Total	**Over 643**	**7,231**	**Over 8%**

[1]From Eder, T. 2005. Mammals of California. Lone Pine Publishing; California Department of Fish and Game. 2008. Yolo Bypass Wildlife Area Management Plan; http://www.cosumnes.org/flora_fauna/; http://www.suisunwildlife.org/sumarsh.html.
[2]From Sibley, D.A. 2006. The Sibley Field Guide to Birds of Western North America. Alfred A. Knopf, Inc.; California Department of Fish and Game. 2008. Yolo Bypass Wildlife Area Management Plan; http://ebird.org/content/ebird/; http://www.cosumnes.org/flora_fauna/; http://www.suisunwildlife.org/sumarsh.html.
[3]From California Department of Fish and Game. 2008. Yolo Bypass Wildlife Area Management Plan; http://www.californiaherps.com/; http://www.cosumnes.org/flora_fauna/; http://www.suisunwildlife.org/sumarsh.html.
[4]From USFWS, Stockton Office, unpublished data.
[5]From Hickson and Keeler-Wolf (2007) Appendix C Plant Species recorded in sampled vegetation stands in the Delta. Includes native and nonnative (naturalized) plant species, subspecies, and varieties.
[6]California Department of Fish and Game. 2007. Atlas of the biodiversity of California. Sacramento, CA. 103 pp.
[7]Inland Fishes of California, Revised and Expanded (Moyle 2002); 51 nonnative and 60 native fish species (approximately).

CHAPTER 3. CONSERVATION STRATEGY

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CHAPTER 3. CONSERVATION STRATEGY

[***Note to Reviewers****: This is a revised version of BDCP Chapter 3, Conservation Strategy prepared by the Consultant. The drafts of various subsections of Chapter 3 were provided by the Consultant to the Steering Committee between July 2009 and November 2010. This version of Chapter 3 combines the various subsections for the first time. Revisions to draft subsections have been made throughout the text to address comments received, to clarify concepts, and to bring the document up to date with the progress on the subsections. The BDCP Steering Committee members have submitted comments to various drafts subsections of this chapter during development, which may or may not have been incorporated into this November 18, 2010 draft. While the text of this chapter is subject to change and revision as the BDCP planning process progresses, the chapter has been drafted and formatted to appear as it may in a completed draft HCP/NCCP. Although the chapter includes declarative statements (e.g., the Implementation Office will…), it is nonetheless a "working draft" that will undergo further modification based on input from the BDCP Steering Committee, state and federal agencies, and the public.*

Chapter 3 includes statements that describe the anticipated results of the Effects Analysis. As stated in the note to reviewer in Chapter 5, Effects Analysis, the effects analysis is not complete and is ongoing. Statements in Chapter 3 regarding the Effects Analysis may need to be revised once the Effects Analysis is complete. The Steering Committee may revise, add, or delete one or more conservation measures to better achieve goals specified in the planning agreement and objectives may be revised or developed through the logic chain process.

The most recent draft of the Terrestrial Resources Conservation Strategy was provided to the Steering Committee on November 4, 2010. Work is continuing with Steering Committee representatives to further refine the Terrestrial Resource Goals and Objectives and Conservation Strategy. Due to the ongoing development and refinement of the Terrestrial Conservation Strategy, the terrestrial effects analysis will need to be revisited to reflect any changes in the strategy.]

3.1 INTRODUCTION

This chapter sets out the BDCP Conservation Strategy, which consists of multiple components that are designed collectively to achieve the BDCP overall planning goals and objectives of ecosystem restoration and water supply and reliability. The chapter further describes the Plan's intended biological outcomes and details the means by which these outcomes will be achieved. The Conservation Strategy includes the BDCP's biological goals and objectives, and identifies a set of conservation measures necessary to provide for the conservation and management of covered species and natural communities upon which they depend, and to avoid, minimize, and compensate for the potential impacts of covered activities on these resources (*see* Chapter 4, *Description of Covered Activities and Associated Federal Actions*). The Conservation Strategy also includes comprehensive programs for monitoring, research, and adaptive management. The

BDCP Conservation Strategy has been developed to meet the regulatory standards of Sections 7 and 10 of the federal Endangered Species Act (ESA), the state's Natural Community Conservation Planning Act (NCCPA), and, as appropriate, the California Endangered Species Act.

The Conservation Strategy responds to the challenge of restoring key ecosystem functions in the highly altered environment of the Delta. The Delta was once a vast marsh and floodplain intersected by meandering channels and sloughs that provided habitat for a rich diversity of fish, wildlife, and plants. The Delta of today is a system of artificially channeled and dredged waterways constructed into static geometries, initially designed to support farming and, later, urban development. These channels also serve to convey water supplies across the Delta for export to cities and farms in the San Francisco Bay Area, San Joaquin Valley and southern California. Physical disturbances within the Delta, the introduction of nonnative species that have disrupted the foodweb, and multiple other environmental challenges to the ecosystem have contributed to declines in native fish, wildlife, and plant species and other organisms. In recent years, these factors have caused a significant drop in the population of key native fish species.

There is a growing urgency to address the challenges of the Delta from both an ecological and water supply perspective. At-risk species have become further imperiled, litigation contesting the adequacy of existing approaches to meet conservation and water supply objectives has intensified and regulatory requirements governing the water system have continuously shifted in response, resulting in increasing unpredictability. To further compound these challenges, fundamental changes to the Delta are certain to occur, as the Delta is not a static ecological system. The anticipated effects of climate change will result in elevated sea levels, altered annual and inter-annual hydrological cycles, changed salinity and water temperature regimes, and accelerated shifts in species composition and distribution in and around the Delta. In addition, the risk of significant flood events has greatly increased, in part because of the likelihood that significant seismic events will occur over the next several decades. These expected environmental changes add to the difficulty of resolving the increasingly intensifying conflict between the ecological needs of a range of at-risk Delta species and natural communities and the need to provide adequate and reliable water supplies for people, communities, agriculture, and industry. Anticipating, preparing for, and adapting to these changes are key underlying drivers for the BDCP.

The approach embodied in the BDCP and its Conservation Strategy reflects a significant departure from the manner in which at-risk Delta fish species and their habitats have been managed in the past. The BDCP will contribute to the restoration of the health of the Delta's ecological systems by focusing on ecological functions and processes at a broad landscape scale, rather than by focusing on discrete parts. Unlike past regulatory approaches that have relied almost exclusively on iterative adjustments to the operations of the State Water Project (SWP) and the Central Valley Project (CVP), including those reflected in recent biological opinions issued by the U.S. Fish and Wildlife Service (USFWS)[1] the National Marine Fisheries Service (NMFS),[2] the BDCP proposes actions that will allow for fundamental, systemic, long-term physical changes to the Delta, including substantial alterations to water conveyance infrastructure and water management regimes and extensive restoration of habitat. These ecosystem-wide changes are intended to enhance substantially the productivity of ecological processes and advance the conservation of multiple species and communities that depend upon them.

The geographic scope of the BDCP Plan Area includes the statutory Sacramento-San Joaquin Delta, as defined in California Water Code Section 12220; Suisun Marsh; and the Yolo Bypass (see Section 1.4.1 *Geographic Scope of the Plan Area*). The boundaries of the Plan Area may also encompass over time additional areas within Delta counties that are protected through BDCP actions to advance the Plan's goals and objectives for terrestrial species and habitats. Because the state and federal water infrastructure operates as an integrated system, the effects of the BDCP will extend beyond the Plan Area, both upstream and downstream, and will implicate both water operational parameters and species and their habitats. Therefore, the BDCP will take into account these upstream and downstream effects, both positive and negative, to ensure that the overall effects of the BDCP are fully analyzed and understood.

While the initial focus of the BDCP was to address the conservation of Delta fish species that are currently at very low population levels, such as delta smelt, longfin smelt, winter-run Chinook salmon, spring-run Chinook salmon, and green sturgeon, the Conservation Strategy has evolved to include measures to address a broad range of species and habitats. The Conservation Strategy will provide for the conservation and management of 63 species of fish, wildlife, and plants (Section 1.4.3, *Covered Species*) and 14 natural communities (Section 1.4.2, Covered *Natural Communities*) in the Plan Area. The strategy sets forth actions to reduce the effects of environmental stressors on these biological resources at various ecological scales, including ecosystem-level actions to address physical and chemical processes and foodwebs; natural community-level actions to address the habitats of many species, and species-level actions to address individual populations and occurrences of species.

The Conservation Strategy is built upon and reflects the extensive body of scientific investigation, study, and analysis of the Delta compiled over several decades (see The State of Bay-Delta Science, 2008). The BDCP Steering Committee, for instance, took into account the results and findings of numerous studies initiated under the CALFED Bay-Delta Science program (now the Delta Science Program) and Ecosystem Restoration Program (ERP), the long-term monitoring programs conducted by the Interagency Ecological Program (IEP), research and monitoring conducted by state and federal resource agencies, and research contributions of academic investigators. In addition, the Steering Committee considered a number of other recent

[1] Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP) (U.S. Fish and Wildlife Service 2008).

[2] Biological Opinion and Conference Opinion on the Long-Term Central Valley Project and State Water Project Operations Criteria and Plan (National Marine Fisheries Service 2004, 2009).

reports on the Delta, including reports of the Governor's Delta Vision Blue Ribbon Task Force (January and October 2008) and several recent reports of the Public Policy Institute of California.[3] Many elements of the BDCP Conservation Strategy parallel the recommendations of these other reports and reflect broad agreement that the Delta is dysfunctional from both an ecological and water supply reliability perspective and that fundamental change is necessary.

To ensure that the BDCP would be based on the best scientific and commercial data available, the BDCP Steering Committee also undertook a rigorous process to develop new and updated information and to evaluate a wide variety of issues and approaches as it formulated a cohesive, comprehensive Conservation Strategy. This effort included an evaluation, early in 2009, conducted by multiple teams of experts of BDCP conservation options using the CALFED Bay-Delta Ecosystem Restoration Program's DRERIP[4] evaluation process (results are provided in Appendix F, *DRERIP Evaluation Results*). Reflecting the requirements of the NCCPA planning process, the Steering Committee also sought and utilized independent scientific advice at several key stages of the planning process, enlisting well-recognized experts in ecological and biological sciences to produce recommendations on a range of relevant topics, including approaches to conservation planning for both aquatic and terrestrial species, establishing adaptive management and monitoring programs, and devising biological goals and objectives (see Appendix G, *Independent Science Advisors Reports*).[5]

In the fall of 2009, the Steering Committee conducted a "mini" effects analysis that focused on the expected effects of draft water operations conservation measures on salmonids, smelt, and sturgeon. The results of the mini effects analysis informed decisions to revise proposed water operations criteria to further increase benefits to fish species consistent with water supply goals. Early in 2010, the BDCP Steering Committee initiated a full analysis of the likely effects of the draft Conservation Strategy and proposed covered activities on species and habitats covered by the Plan (see Chapter 4, *Description of Covered Activities*). The BDCP effects analysis was comprehensive in scope, identifying the beneficial and adverse effects that would be expected to occur through the implementation of covered activities and conservation measures (Chapter 5, *Effects Analysis*). Through an iterative process, the results and conclusions from the effects analysis provided the basis for multiple adjustments, modifications, and revisions to be made to the conservation measures to enhance their likely effectiveness.

This chapter sets out the Conservation Strategy for the BDCP. The chapter begins with a description of the overall approach to the development of a strategy sufficient to provide for the conservation and management of key Delta species and their habitats (Section 3.2). In Section 3.3, the biological goals and objectives of the Plan are identified. Section 3.4 sets out the specific conservation measures that will be implemented to achieve those biological goals and objectives. Section 3.5 identifies "potential conservation measures" that may later be adopted

[3] Envisioning Futures for the Sacramento-San Joaquin Delta (Lund et al. 2007); Comparing Futures for the Sacramento-San Joaquin Delta (Lund et al. 2008).

[4] Delta Regional Ecosystem Restoration Implementation Plan

[5] Insert citation to additional information identifying experts.

through the adaptive management program to further address the adverse effects of various stressors on the aquatic system. The biological monitoring and research program is described in Section 3.6, and the adaptive management program is described in Section 3.7.

3.1.1 Biological Goals and Objectives

The BDCP biological goals and objectives reflect the expected ecological outcomes of the Plan. The biological goals set out the broad principles that were established to guide the development of the Conservation Strategy; the biological objectives express specific, measurable targets that the conservation measures are designed to meet. Progress toward achieving objectives will be generally measured on the basis of outcomes related to ecological processes, habitat conditions, and species distribution.

BDCP biological goals and objectives are expressed in an ecological-scale hierarchy with ecosystem-level, natural community-level, and species-specific goals and objectives. For example, the Plan includes an ecosystem goal to "improve hydrodynamic conditions to support the movement of adult life stages of native fish species to natal spawning habitats"; a natural community goal to "protect, enhance, and restore natural communities to provide habitat and ecosystem functions to increase the natural production (reproduction, growth, and survival), abundance, and distribution of native Delta species;" and a species goal to "create conditions that support a self-sustaining population of delta smelt in the Delta and Suisun Bay." As such, the goals and objectives reflect the comprehensive scope of the BDCP, including its focus on both broad-scale ecological processes and species-specific needs.

3.1.2 Conservation Measures

The BDCP conservation measures comprise the specific actions that will be implemented to achieve the biological goals and objectives of the Plan. The conservation measures have been grouped into the same ecological hierarchy as the biological goals and objectives. Ecosystem-level conservation measures are designed to improve the method, timing, and amount of flow and quality of water into and through the Delta for the benefit of covered species and covered natural communities. They are also focused on the establishment of an interconnected system of conservation lands across the Plan Area. Natural community-level conservation measures include actions to restore physical habitat to expand the extent and quality of intertidal, floodplain, and other habitats. Species-level "other stressors" conservation measures are designed to reduce the adverse effects of various stressors on covered species, including toxic contaminants, nonnative predators, illegal harvest, and genetic threats. This comprehensive suite of actions is expected to significantly contribute to the conservation of covered species and to the restoration of ecosystem processes in the Delta, while providing for a reliable water supply for human use.

The conservation measures were developed in the context of the time frame governing the implementation of the BDCP, which has been designed as a fifty year conservation plan. Under the scope of the BDCP, the type of water conveyance infrastructure for SWP and CVP operations serves to demarcate near-term and long-term components of the Plan. Specifically, the near-term component of the BDCP encompasses those actions related to the operations of the projects under existing water conveyance infrastructure, including conservation measures associated with this operational framework. The long-term component of the BDCP comprises those actions related to project operations under new isolated conveyance infrastructure, including the construction of and operation of the infrastructure and the implementation of an array of conservation measures. A number of conservation measures cannot be implemented until the north Delta diversion is operational and therefore are considered to be long-term actions. Those measures that are not dependent on operations of the new facilities will largely be initiated in the near-term phase. These actions include habitat restoration to accelerate new productivity in the Delta, the installation of non-physical barriers to divert young salmonids from high risk areas, removal of habitat features that promote nonnative predators, and enhancement of the Yolo Bypass floodplain habitat. Prompt and decisive implementation of these measures pending the completion of systemic changes in the water conveyance system is likely to be central to the success of the BDCP Conservation Strategy.

The conservation measures address biological needs on a broad spatial scale, an important feature of the overall Conservation Strategy. The Delta-wide focus of the Plan requires that restoration actions be implemented in proper sequence and timing across the northern, western, eastern and southern regions of the Delta. These restoration actions must also be closely integrated with the measures affecting water facilities and operations to ensure that the flow and physical habitat parameters are all met.

Under the BDCP, certain conservation measures are also covered activities. In some cases, actions that are intended to advance the biological objectives of the Plan may also result in the incidental take of covered species. Certain activities may provide benefits for some covered species, and have either no effect or some limited negative effect on other species. For instance, the restoration of tidal habitats to provide new physical habitat and enhanced food production for covered fish species and certain covered wildlife and plants, will necessarily remove terrestrial habitat that supports other covered wildlife and plant species. Another example is the proposed construction and operation of a new isolated conveyance system, which may provide substantial benefits to certain aquatic species over the existing system, but will also entail adverse impacts on terrestrial wildlife and plants. Consequently, these conservation measures are characterized as covered activities to ensure their coverage under the regulatory authorizations issued under the BDCP and enable their implementation.

This chapter also identifies “potential conservation measures,” which do not qualify as conservation measures at present, but may during the implementation of the BDCP be adopted as conservation measures through the adaptive management program. The efficacy of these potential conservation measures will be evaluated over time by the Implementation Office to determine whether they should be incorporated into the Conservation Strategy as conservation measures (see Section 3.5, *Potential Conservation Measures to Address Other Stressors*).

3.1.3 Monitoring, Research, and Adaptive Management

The monitoring, research and adaptive management components of the Conservation Strategy are intended to inform decision-making during plan implementation, provide indicators of progress, enable modifications to be made to improve the efficiency and effectiveness of the conservation measures in achieving the BDCP biological goals and objectives, and to allow for adjustments to be made to conservation measures as more is learned about the Delta. The monitoring and research program, described in Section 3.6, *Monitoring and Research Program*, includes a combination of system-wide and conservation measure-specific monitoring and research to provide information on the effectiveness of conservation actions.

Adaptive management is central to the success of the Plan. The adaptive management program described in Section 3.7, *Adaptive Management Program*, will integrate new data, knowledge, and scientific information to enhance the efficacy of the BDCP conservation measures. The adaptive management program will provide the mechanism by which conservation measures can be modified or discontinued in response to results from BDCP monitoring and research programs and other new scientific information.

3.2 METHODS AND APPROACHES USED TO DEVELOP THE CONSERVATION STRATEGY

This section describes the methods and the approaches used to develop the BDCP Conservation Strategy. Section 3.2.1, *Framework for the Conservation Strategy,* describes the regulatory and temporal contexts for the Conservation Strategy. It also describes the role of the adaptive management and monitoring programs in reinforcing the effectiveness of the Conservation Strategy over time. The Conservation Strategy addresses two ecologically interconnected categories of species, habitats, and natural communities: aquatic resources, encompassing the aquatic ecosystem and the covered fish species, and terrestrial resources, encompassing nontidal natural communities and covered wildlife and plant species. The approach to the development of the aquatic resources component of the Conservation Strategy is described in Section 3.2.3, *Development of the Aquatic Resources Component of the Conservation Strategy*. The approach to the development of the terrestrial resources component is described in Section 3.2.4, *Development of the Terrestrial Resources Component of the Conservation Strategy*. While these approaches are described separately, the two are closely interrelated and together are reflected in the overall BDCP Conservation Strategy. Background on the planning process for the major elements of Conservation Strategy is provided Appendix D, *Background on the Process of Developing the BDCP Conservation Measures*.

3.2.1 Framework for the Conservation Strategy

The Conservation Strategy is designed to meet the regulatory requirements of federal ESA and the NCCPA. Consistent with the requirements of the NCCPA, the Conservation Strategy will provide for the conservation and management of covered species through the protection, restoration, and enhancement of ecosystem processes, natural communities, and species habitat. Specifically, the Conservation Strategy will achieve the following:

- Conserve, restore, and provide for the management of representative natural and seminatural[6] landscapes;
- Establish reserves that provide for conservation of covered species within the BDCP geographic area and linkages to adjacent habitat outside the study area;
- Protect and maintain habitat areas that are large enough to support sustainable populations of covered species;
- Incorporate in the reserves, a range of environmental gradients and high habitat diversity to provide for shifting species distributions in response to changing circumstances; and
- Sustains the effective movement and interchange of organisms between habitat areas in a manner that maintains the ecological integrity of the system of BDCP conservation lands.

Of the 63 species covered under the BDCP (see descriptions of these species in Appendix A, *Covered Species Accounts*), 11 are fish and 52 are wildlife and plants (including 6 mammal species, 12 birds species, 5 reptile and amphibian species, 8 invertebrate species, and 21 plant species). The Conservation Strategy, which is based on the best scientific and commercial data available (see Chapter 2, *Existing Ecological Conditions*, and Appendix A, *Covered Species Accounts*), has been developed to achieve BDCP biological goals and objectives for ecosystems, natural communities, and covered species. Biological goals and objectives for aquatic resources were developed using an approach that took into account desired biological outcomes as well as an assessment of feasible conservation measures that would meet the dual objectives of the Plan[7] (see Section 3.2.3.1, *Aquatic Resources Conservation Strategy Development Process*). With respect to terrestrial species, goals and objectives were developed using approaches that appear in several recently-approved terrestrial HCPs and NCCPs and following technical guidance provided by DFG and USFWS.

The BDCP Conservation Strategy reflects a multi-scale ecological approach to conservation guided by principles of conservation biology. At the broadest scale, biological goals and objectives were developed that describe intended outcomes related to ecological processes, environmental gradients, biological diversity, and regional landscape connectivity. Conservation measures were developed to achieve these large scale, or “ecosystem-level,” goals and objectives. At the middle of the ecological scale, biological goals and objectives and conservation measures were developed for natural communities, many of which are focused on the enhancement, restoration, and management of physical habitat. This middle-level scale is referred to as the “natural community level.” At the smallest scale, biological goals and

[6] A seminatural landscape is defined as one that is disturbed by human activity but still provides important habitat for a variety of native species.

[7] The “logic chain” is a process relationship of linkages among the various components of the conservation strategy, including environmental stressors, biological goals and objectives, metrics, conservation measures, and expected outcomes developed specifically for the BDCP covered fish species.

objectives and conservation measures were identified for covered species. These "species-level" conservation actions were developed to supplement actions that are directed at ecosystem-level and natural community-level goals and objectives to ensure that the needs of covered species are addressed. This framework is discussed in greater detail in Section 3.3, *Biological Goals and Objectives*.

Biological goals and objectives and conservation measures were developed at the ecosystem level first to take into account the needs of the broadest array of covered natural communities and covered species as practicable. Next, each natural community was examined to determine additional conservation measures that would advance the biological goals and objectives for natural communities. Finally, each covered species was evaluated to determine whether species-specific measures would provide additional benefits to the species beyond those that would result from the ecosystem-level and natural-community-level conservation measures. Using this hierarchical approach, conservation measures associated with the ecosystem and natural community levels were generally considered to be sufficient to provide for the conservation of the individual covered species. In certain case, species-specific measures were adopted to ensure that the goals and objectives for the species would be met.

The BDCP conservation measures are set out in Section 3.4, *Conservation Measures*, and have been categorized by ecosystem level, natural community level, and species level. The Conservation Strategy includes several types of conservation measures, as decribed below:

- Water operations measures, through the management of flows, will support ecosystem functions associated with aquatic resources;
- Habitat protection measures will afford protection of existing functioning natural communities that are not currently protected;
- Habitat restoration/creation measures will provide for the physical restoration of natural communities in areas that do not currently support those communities;
- Habitat enhancement measures will result in improvements to habitat functions within existing natural communities;
- Habitat management measures will provide for ongoing management of natural communities and habitat to maximize the functional values of BDCP conservation areas over the long term;
- Other stressors measures will reduce the adverse effects of various stressors on fish species (aside from habitat and operations-related stressors), including the impacts of predation, toxic contaminants, and illegal harvest; and
- Avoidance and minimization measures will ensure that adverse effects of covered activities on covered species will be avoided or minimized to the maximum extent practicable.

All of the BDCP conservation measures have been developed at a sufficient level of detail and specificity to ensure their implementation. Because of the broad scope of the BDCP and its extended timeframe for implementation, a degree of flexibility has been built into many of the measures to accommodate changes in conditions and methods over time. For example, natural community–level actions provide broad management guidelines and principles such that land managers may implement specific techniques on the ground best suited to site conditions. Preserving this flexibility is an important part of the Conservation Strategy and is articulated in Section 3.7, *Adaptive Management Program*.

Implementation of habitat protection, enhancement, and restoration conservation measures will require the preparation of site-specific implementation documents. These site plans, as well as any additional environmental documentation, will be prepared in accordance with the schedule for the implementation of specific actions.

3.2.1.1 The Importance of Adaptive Management, Monitoring, and Research

Monitoring and adaptive management will play important roles in the implementation of the BDCP because of the inherently dynamic nature of the Delta ecosystems, the expected changes in these dynamics over time (e.g., effects of climate change on sea level and watershed hydrology), and uncertainties related to the likely response of certain covered species to certain conservation measures. To further support plan implementation, the BDCP provides for the establishment of a research program that will yield data and information over time that support adjustments and modifications to the conservation measures to increase their effectiveness.

The Conservation Strategy anticipates the potential for changes to occur in Delta conditions that result from climate change, seismic events, changes in land use, and other factors. The BDCP recognizes that monitoring, research, and adaptive management are necessary to allow for the incorporation of any new information and insight regarding actual changes and new projections of changing futures into plan implementation. As more is understood about the Delta ecosystem, refinements to the BDCP conservation measures may be necessary to enhance their effectiveness.

Information gathered through the BDCP monitoring and research program (Section 3.6, *Monitoring and Research Program*) and other research efforts will guide decision-making during implementation. The BDCP monitoring and research program is designed to establish cause and effect relationships between implementation of specific conservation measures and the type and magnitude of species and ecosystem responses to those measures, as well as species and ecosystem responses to the implementation of combinations of conservation measures. Should strong cause and effect relationships be established, adaptive management will provide the mechanism to concentrate efforts on the implementation of conservation measures that have been demonstrated to be more effective and to de-emphasize or discontinue implementation of conservation measures that prove to be less effective at achieving the BDCP biological goals and objectives.

As described in Section 3.7, *Adaptive Management Program*, all conservation measures will be implemented using an adaptive management approach that is informed by monitoring and research (Section 3.6, *Monitoring and Research Program*).

3.2.1.2 The Timing and Interrelatedness of Conservation Measures

The Conservation Strategy is divided into near-term and long-term implementation stages. The near-term implementation lasts until the north Delta diversion and tunnel/pipeline conveyance facilities are constructed and operational. This division of the implementation period was used because dual operation of separate diversions in the north and south Delta will bring significant flexibility and ecological changes to the system; hence, the interrelatedness of many of the conservation measures with operations of the new conveyance facility.

The implementation of conservation measures associated with the near-term will provide for immediate responses to degraded ecological conditions, while building the foundation to improve long-term ecological productivity. These near-term measures include early restoration actions for tidal habitats, implementation of conservation measures that address other stressors on covered fish species, and acquisition of terrestrial and wetland habitat to provide conservation for covered wildlife and plant species.

Completion and operation of the north Delta intakes and isolated tunnel/pipeline conveyance facility will facilitate the implementation of other key conservation measures, including restoration of tidal and floodplain habitat in the east and south Delta associated with the Mokelumne, Cosumnes, Middle, Old, and San Joaquin rivers. The close integration of conservation actions across both time and geography is central to the success of the BDCP Conservation Strategy. A complex web of important interrelationships exists among the conservation measures. There are interrelationships and interdependencies among all the water operations parameters because changes in water operations in any one part of the Delta affect hydrodynamics in other parts of the Delta. For example, diversions in the north Delta reduce Delta outflow but also reduce the need to export at the south Delta diversions, thereby reducing reverse flows in Old and Middle rivers. The coordinated operations of new and existing water facilities in a flexible and adaptable plan will allow for the optimal combination of improvements to aquatic habitat and reliability of water supply.

Restoration of large portions of the Delta to tidal habitat will affect the hydrodynamics and water quality in immediately surrounding channels and, in some cases channels distant from the restoration site, by increasing the tidal prism and reducing the tidal range. For example, restoration of tidal habitats in the Cache Slough area is projected to result in reduced tidal range and greater unidirectional flows in Sutter and Steamboat sloughs, which may reduce the risk of predation on juvenile salmonids migrating through these sloughs by speeding transport time. The reduction in contaminants, such as pesticides and herbicides that will result from restoring habitat on agricultural lands, is expected to interact synergistically with improvements in organic and nutrient input from restored tidal marsh and floodplains to benefit the aquatic food web. Hence, understanding the interconnections amongst the BDCP conservation measures across program elements, across the wide geography of the Delta, and across time is an important aspect of the strategy. In short, the Conservation Strategy is intended to be more than the sum of its parts.

The BDCP Implementation Office will also time and sequence the acquisition of conservation lands to protect and restore habitats to ensure that these conservation actions occur in a manner that is roughly proportional to and temporally aligned with the impacts of covered activities (see Chapter 6, *Plan Implementation*).

3.2.2 Identifying Conservation Zones and Restoration Opportunity Areas

To facilitate development of habitat protection and restoration elements of the Conservation Strategy, the Plan Area was subdivided into 11 Conservation Zones within which conservation targets for natural communities and covered species' habitats were established (Figure 3-1). Conservation Zones were delineated based on conservation opportunities afforded by different geographic locations.

Conservation Zones were delineated primarily on the basis of landscape characteristics and logical geographic or landform divisions to create a more structured organizational approach to how and where conservation actions will be carried out within the Plan Area. Conservation Zones were used as a planning tool to ensure that targets identified for natural communities and covered species habitat will be spatially distributed to achieve biological goals.

Criteria used to establish each Conservation Zone included:

- Distribution of covered species within and adjacent to the Plan Area;
- Distribution of natural communities supporting covered species habitats;
- Differences in the function of covered species habitats supported by natural communities in different portions of the Plan Area (e.g., high, medium, and low function as habitat for covered species);
- Natural features (e.g., watercourses);
- Locations of barriers to covered species movement among habitats; and
- Connectivity with existing habitat areas adjacent to the Plan Area.

A different set of planning units, Restoration Opportunity Areas (ROAs), were also established to assist in the development of the Conservation Strategy (Figure 3-2). ROAs are different from, but overlap with, the Conservation Zones. ROA's encompass those locations considered to be the most appropriate for the restoration of tidal habitats within the Plan Area and within which restoration goals for tidal and associated upland natural communities will be achieved (see Section 3.4.3.1, *CM4 Tidal Habitat Restoration*, for a description of ROAs and tidal habitat restoration conservation actions).

The extent of each natural community and covered species habitat in each of the Conservation Zones is presented in Tables 3-1a-c and Tables 3-2a-c, respectively. The existing distribution of natural communities within each of the Conservation Zones is presented in Figure 3-3 through Figure 3-8.

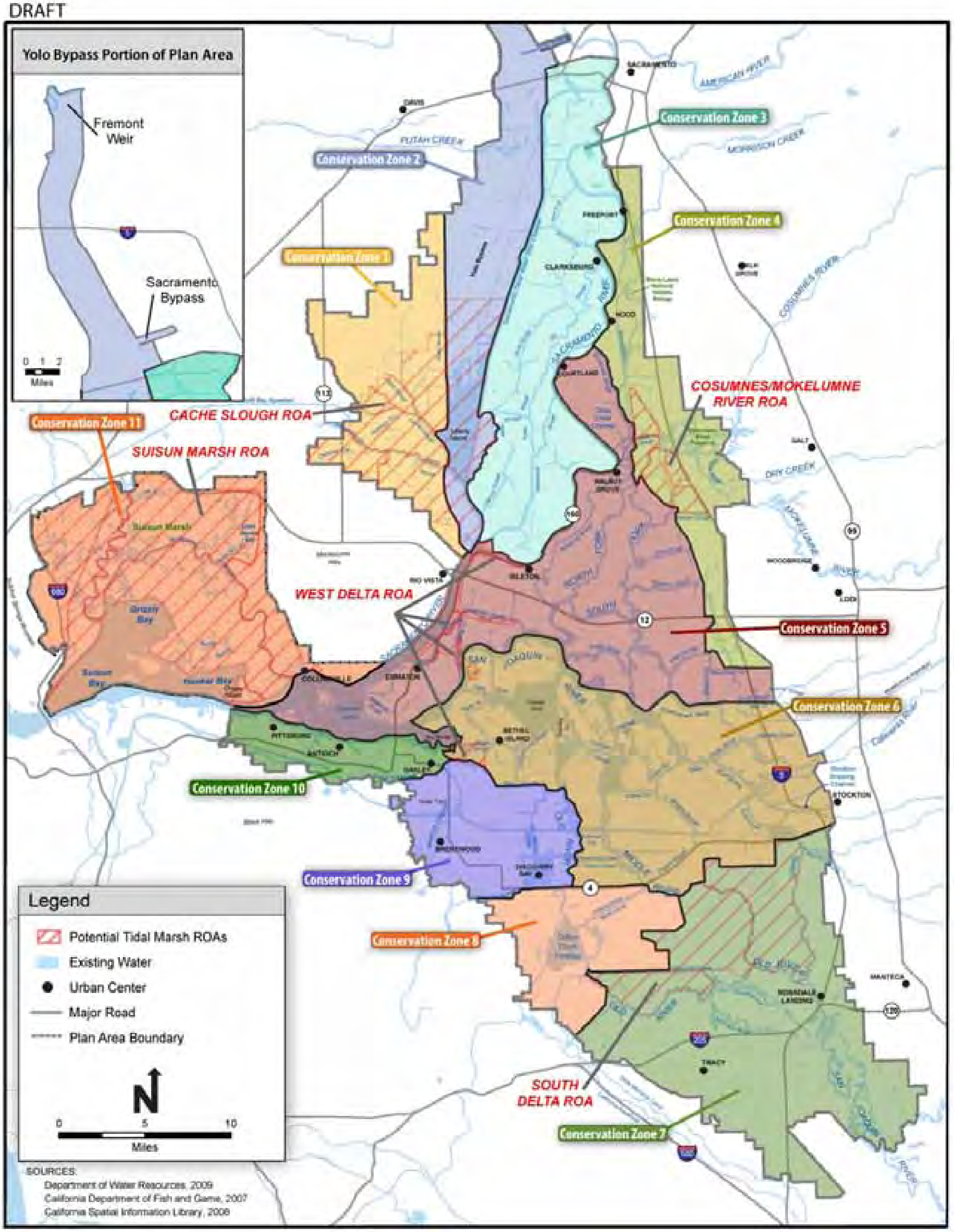


Figure 3-1. Conservation Zones and Restoration Opportunity Areas (ROAs)

DRAFT

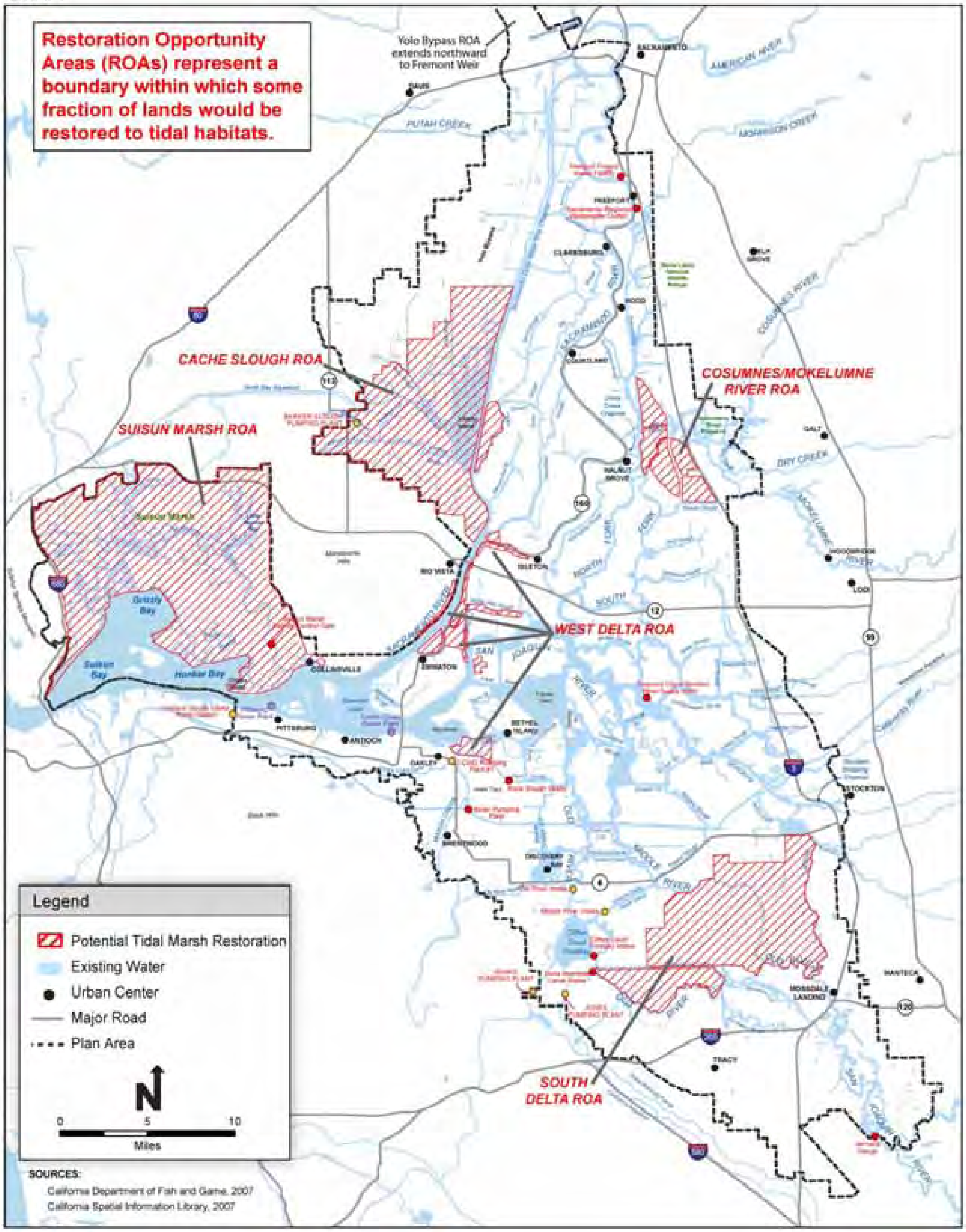


Figure 3-2. Restoration Opportunity Areas (ROAs)

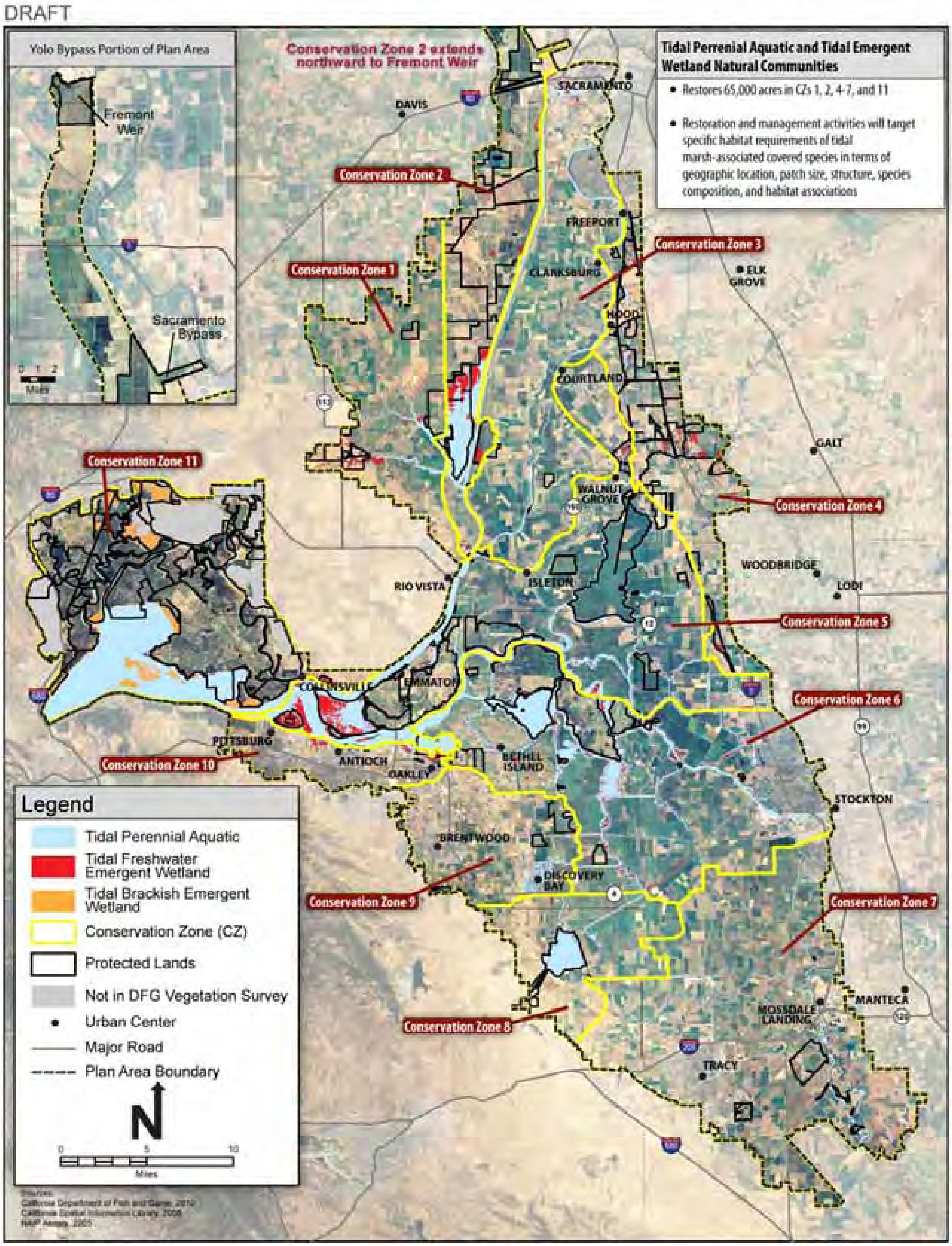


Figure 3-3. Tidal Perennial Aquatic and Tidal Emergent Wetland Natural Communities Distribution and Conservation Strategy

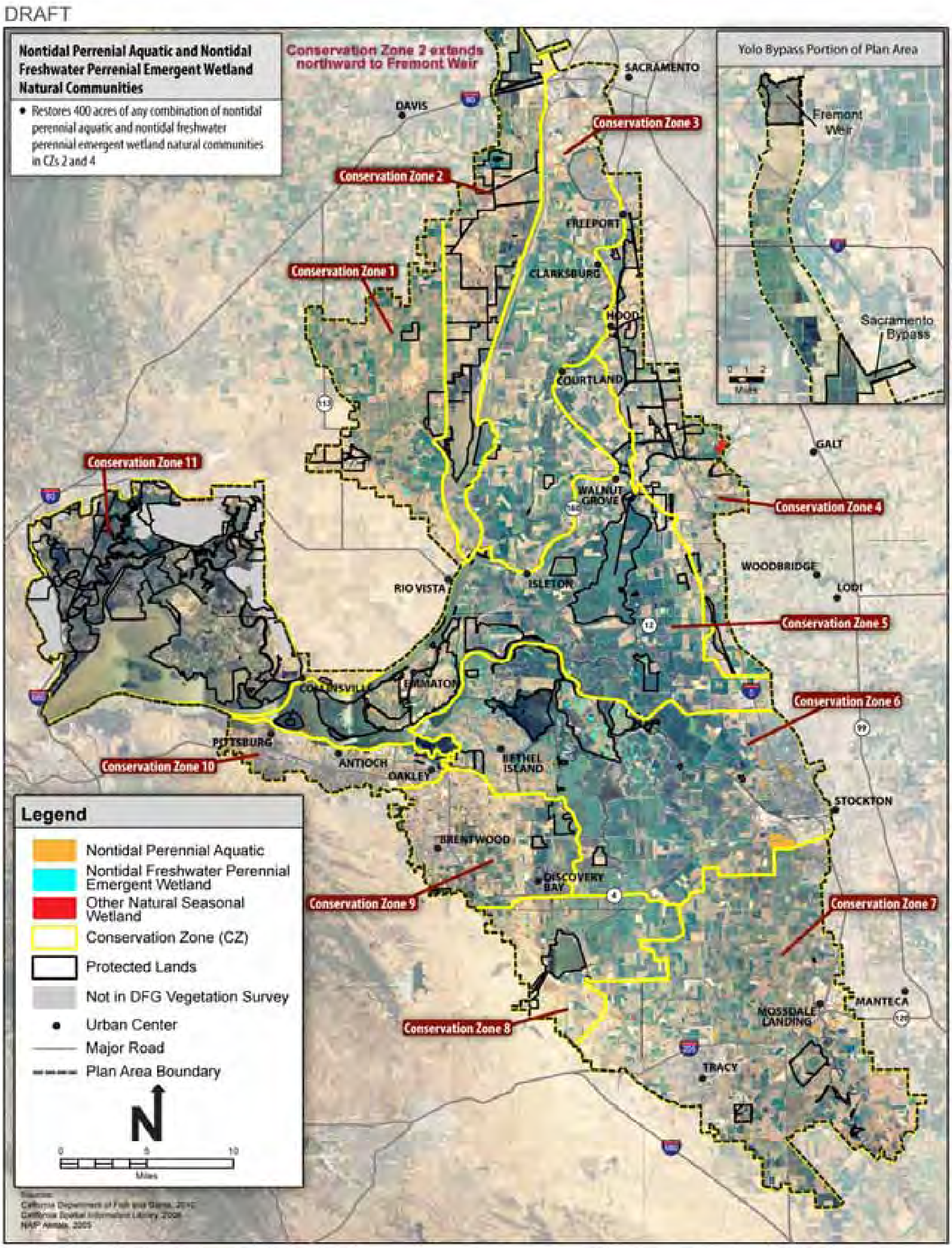
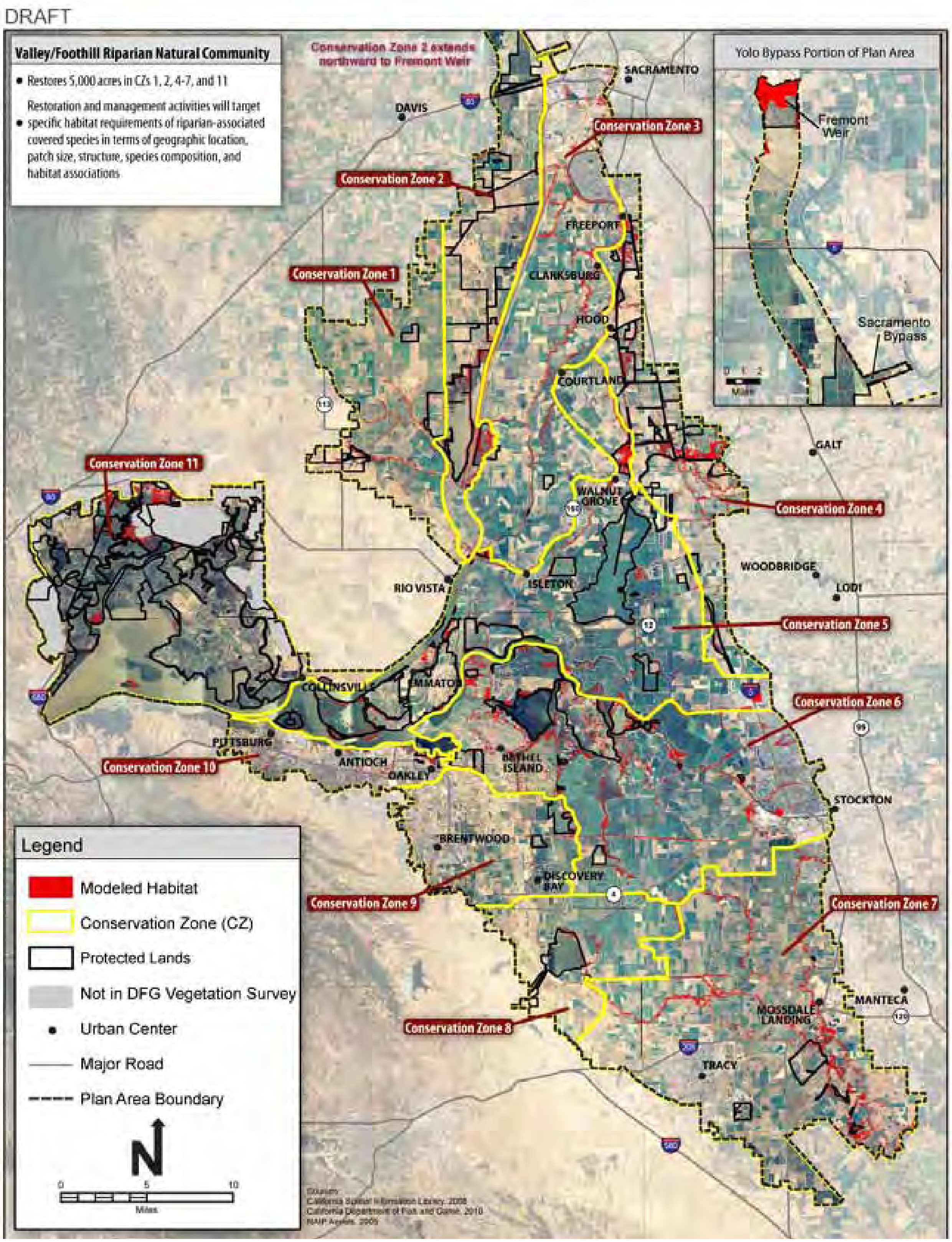


Figure 3-4. Nontidal Perennial Aquatic and Nontidal Freshwater Perennial Emergent Wetland Natural Communities Distribution and Conservation Strategy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Valley/Foothill Riparian Natural Community
Restores 5,000 acres in CZs 1, 2, 4-7, and 11
Restoration and management activities will target specific habitat requirements of riparian-associated covered species in terms of geographic location, patch size, structure, species composition, and habitat associations
Conservation Zone 2 extends northward to Fremont Weir
Yolo Bypass Portion of Plan Area
Fremont Weir
Sacramento Bypass
SACRAMENTO
DAVIS
Conservation Zone 1
Conservation Zone 2
Conservation Zone 3
Conservation Zone 4
Conservation Zone 5
Conservation Zone 6
Conservation Zone 7
Conservation Zone 8
Conservation Zone 9
Conservation Zone 10
Conservation Zone 11
FREEPORT
CLARKSBURG
HOOD
COURTLAND
GALT
WALNUT GROVE
WOODBRIDGE
LODI
RIO VISTA
ISLETON
COLLINSVILLE
EMMATON
PITTSBURG
ANTIOCH
OAKLEY
BETHEL ISLAND
STOCKTON
BRENTWOOD
DISCOVERY BAY
MOSSDALE LANDING
MANTECA
TRACY
Legend
Modeled Habitat
Conservation Zone (CZ)
Protected Lands
Not in DFG Vegetation Survey
Urban Center
Major Road
Plan Area Boundary
Miles

Figure 3-5. Valley/Foothill Riparian Natural Community Habitat Distribution and Conservation Strategy

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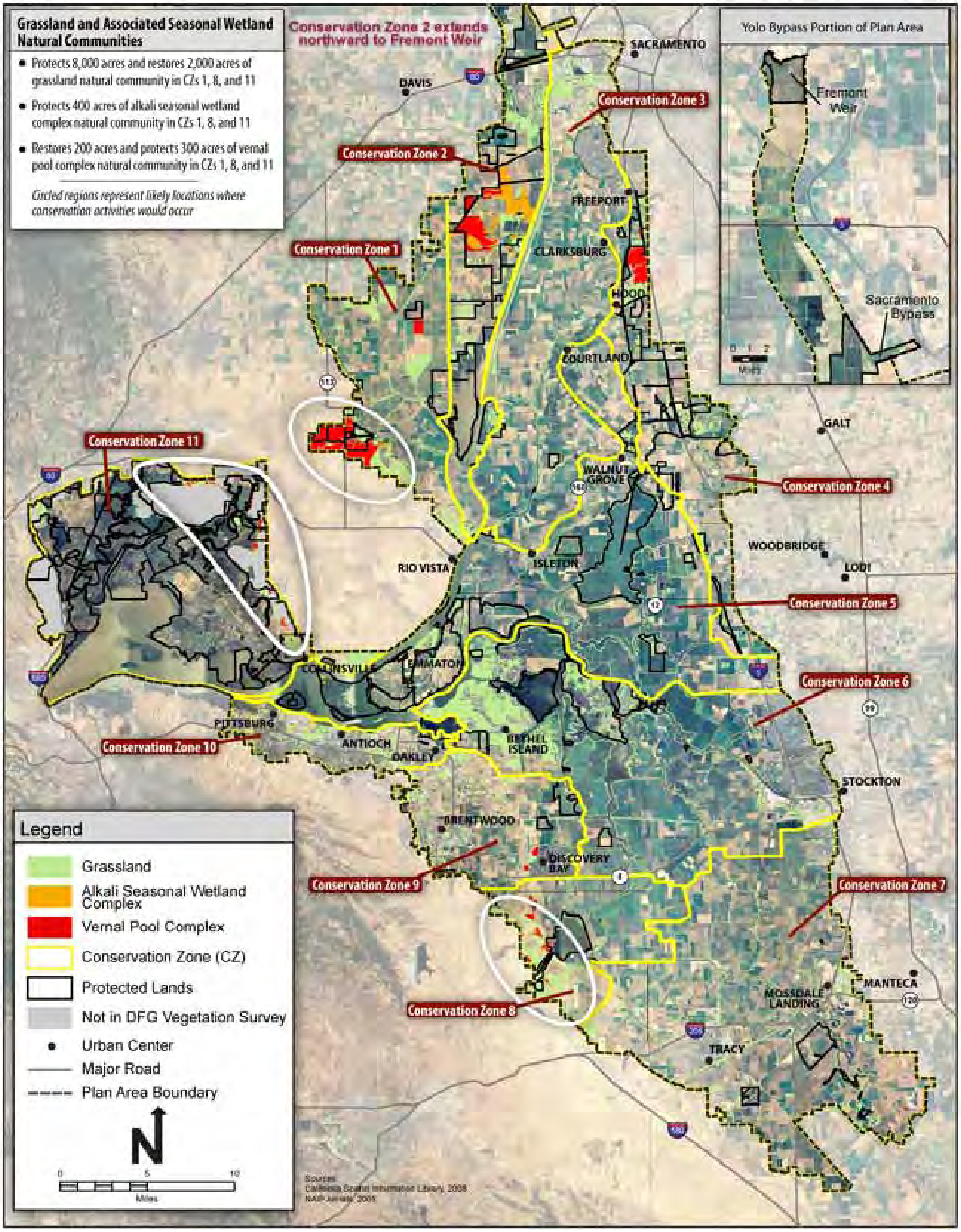

Figure 3-6. Grassland and Associated Seasonal Wetland Natural Communities Distribution and Conservation Strategy

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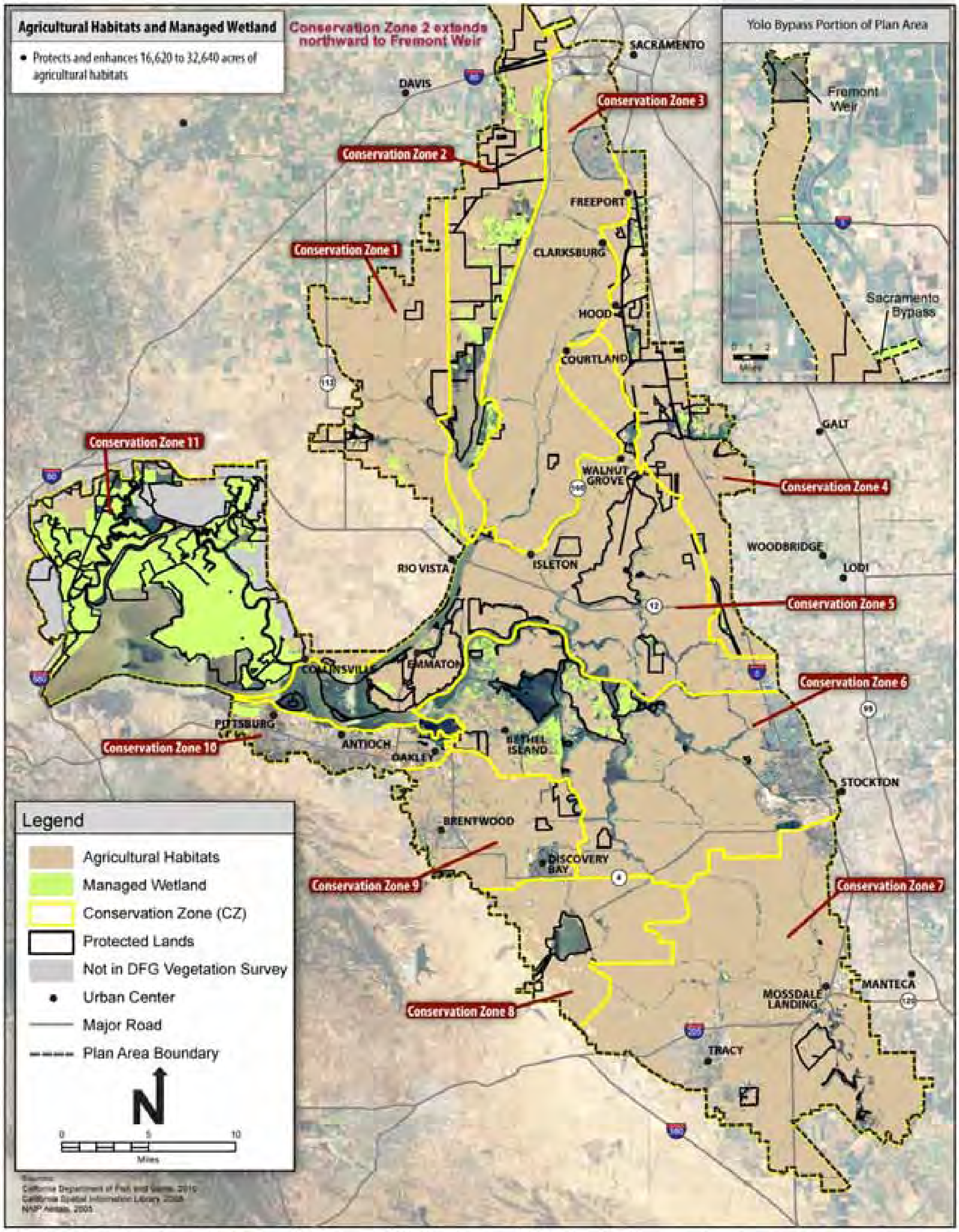

Figure 3-7. Agricultural Habitats and Managed Wetland Distribution and Conservation Strategy

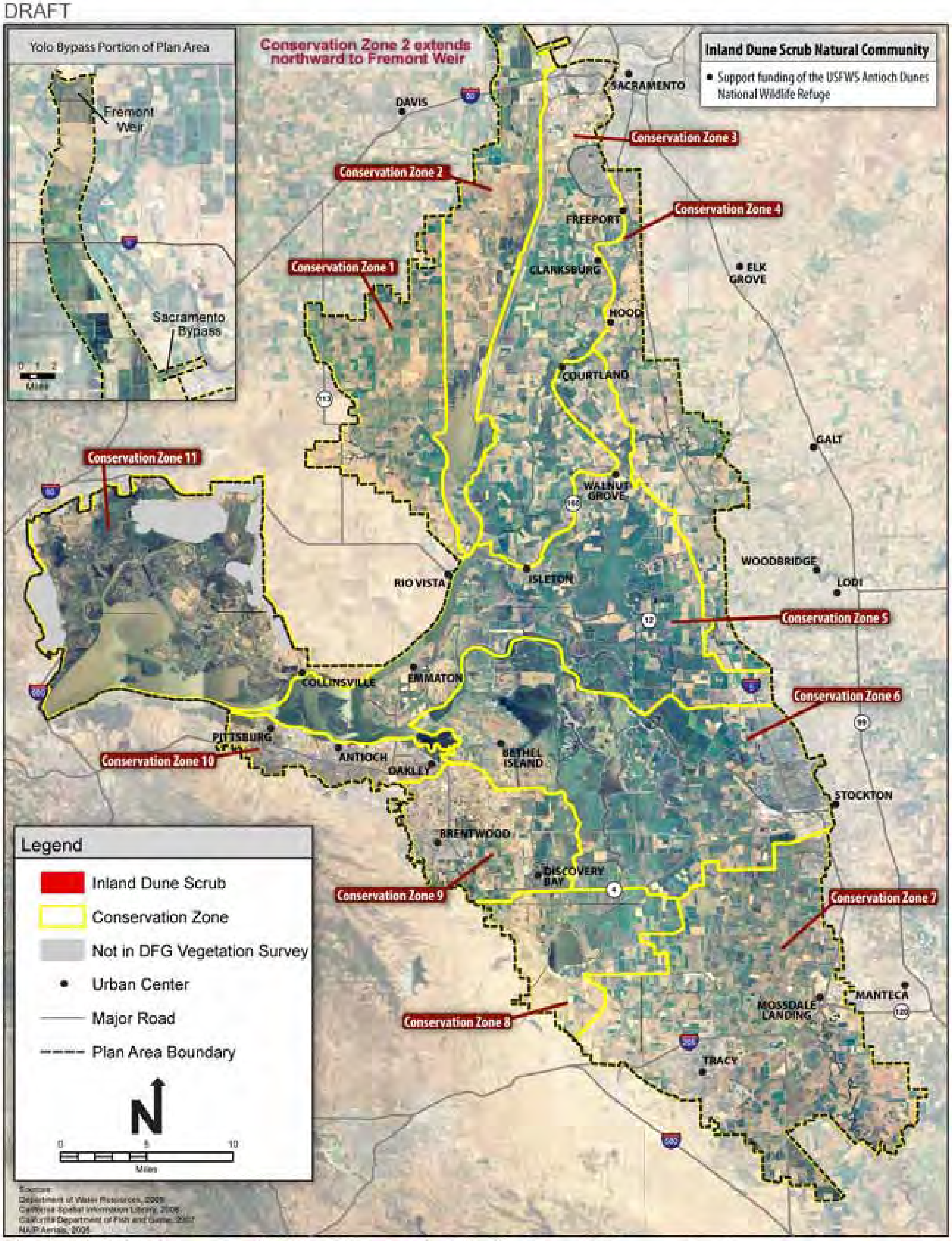

Figure 3-8. Inland Dune Scrub Natural Community Distribution and Conservation Strategy

Table 3-1a. Total Extent of Existing and Protected Natural Communities within BDCP Conservation Zones 1-11 (acres)

Natural Communities	*Total Extent*	*Total Existing Protected*	*Percent Existing Protected*
Tidal perennial aquatic	86,240	18,080	21%
Tidal mudflat[1]	Not available.	Not available.	Not available.
Tidal brackish emergent wetland	8,351	5,102	61%
Tidal freshwater emergent wetland	8,947	4,990	56%
Valley/foothill riparian	17,337	5,338	31%
Grassland	62,880	14,984	24%
Alkali seasonal wetland complex	3,723	2,769	74%
Vernal pool complex	6,958	4,379	63%
Other natural seasonal wetland	265	205	77%
Nontidal freshwater perennial emergent wetland	1,134	408	36%
Nontidal perennial aquatic	5,341	1,239	23%
Managed wetland	64,844	52,676	81%
Agricultural habitats	503,779	57,168	11%
Alfalfa	82,283	3,665	5%
Irrigate Pasture	49,693	12,748	26%
Vineyard	28,901	2,476	9%
Orchard	18,020	343	2%
Rice	12,637	2,202	17%
Other Cultivated Crops	229,828	24,736	11%
Subtotal: Cropland only	421,361	46,171	11%
Other Agricultural lands	82,418	10,997	13%
Subtotal: All agricultural land	503,779	57,168	11%
Total	**769,799**	**167,338**	**22%**

Table 3-1b. Current Extent of Existing and Protected Natural Communities in BDCP Conservation Zones 1-5

Natural Communities	***Conservation Zones (acres)***									
	1		**2**		**3**		**4**		**5**	
	Total Extent	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*
Tidal perennial aquatic	1,011	52	6,703	4,804	4,967	9	1,200	740	21,965	3,546
Tidal mudflat[1]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tidal brackish emergent wetland	0	0	0	0	0	0	0	0	0	0
Tidal freshwater emergent wetland	454	160	1,710	1,633	167	4	648	545	3,585	2,305
Valley/foothill riparian	357	107	2,427	1,674	2,080	20	2,575	1,711	2,718	1,065
Grassland	6,091	620	7,007	5,271	5,524	15	4,800	3,201	5,828	2,138
Alkali seasonal wetland complex	258	30	2,773	2,632	0	0	17	16	42	42
Vernal pool complex	3,355	1,425	1,738	1,716	0	0	1,082	1,082	0	0
Other natural seasonal wetland	38	9	8	8	0	0	193	187	1	0
Nontidal freshwater perennial emergent wetland	70	1	49	46	12	0	11	11	176	55
Nontidal perennial aquatic	289	23	718	343	692	0	645	510	437	133
Managed wetland	714	0	6,936	6,343	122	2	1,089	1,053	1,030	737
Agricultural habitats										
Alfalfa	5,909	0	1,703	412	14,556	155	4,896	747	6,872	1,726
Irrigated Pasture	18,107	390	10,178	5,703	2,033	57	2,688	991	7,311	4,874
Vineyard	0	0	0	0	10,233	0	8,330	2,319	5,065	11
Orchard	64	0	73	0	5,143	0	1,072	116	3,065	83
Rice	0	0	9,802	2,202	0	0	0	0	1,738	0
Other Cultivated Crops	9,741	353	12,714	3,783	28,583	1	12,466	3,945	54,243	12,205
Subtotal: Cropland only	33,821	743	34,470	12,101	60,549	213	29,452	8,158	78,294	18,899
Other Agricultural lands	7,605	1,276	4,364	3,126	9,131	197	7,119	2,800	9,602	1,999
Subtotal: All agricultural land	41,426	2,019	38,834	15,228	69,681	410	36,571	10,959	87,896	20,898
Total	54,061	4,443	68,904	39,697	83,246	460	48,832	20,014	123,679	30,919

Table 3-1c. Current Extent of Existing and Protected Natural Communities in BDCP Conservation Zones 6-11

Natural Communities	Conservation Zones (acres)											
	6		7		8		9		10		11	
	Total Extent	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*
Tidal perennial aquatic	16,721	3,521	2,355	77	3,475	2,295	1,443	5	738	195	25,662	2,837
Tidal mudflat[1]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tidal brackish emergent wetland	0	0	0	0	0	0	0	0	0	0	8,351	5,102
Tidal freshwater emergent wetland	1,415	156	83	1	102	1	150	5	477	136	154	45
Valley/foothill riparian	3,702	506	2,671	120	256	23	185	10	279	73	86	30
Grassland	13,603	3,774	5,951	194	4,517	763	3,692	100	2,536	70	3,333	926
Alkali seasonal wetland complex	35	0	12	0	188	7	22	0	105	0	270	42
Vernal pool complex	0	0	0	0	381	27	120	0	0	0	282	130
Other natural seasonal wetland	0	0	18	1	0	0	3	0	5	0	1	0
Nontidal freshwater perennial emergent wetland	628	264	69	0	39	2	33	17	37	5	9	6
Nontidal perennial aquatic	1,517	146	720	20	149	9	137	14	36	0	0	0
Managed wetland	4,530	1,890	71	7	57	17	73	40	624	2	49,597	42,585
Agricultural habitats												
Alfalfa	10,426	0	28,235	526	7,862	6	1,823	93	0	0	0	0
Irrigated Pasture	3,324	572	3,466	0	1,311	0	726	5	0	0	550	155
Vineyard	496	146	2,679	0	698	0	946	0	454	0	0	0
Orchard	402	1	5,776	126	61	0	2,339	17	23	0	0	0
Rice	1,097	0	0	0	0	0	0	0	0	0	0	0
Other Cultivated Crops	42,738	1,928	46,755	1,302	11,815	0	10,678	1,179	93	0	1	0
Subtotal: Cropland only	58,483	2,647	86,911	1,955	21,748	6	16,511	1,295	570	0	551	155
Other Agricultural lands	10,137	1,083	17,873	311	4,864	19	8,056	146	934	13	2,733	26
Subtotal: All agricultural land	68,620	3,730	104,785	2,266	26,612	26	24,567	1,441	1,505	13	3,284	181
Total	**110,771**	**11,939**	**116,734**	**2,686**	**35,776**	**3,170**	**30,426**	**1,632**	**6,342**	**494**	**91,027**	**51,885**

Table 3-2a. Extent of Existing and Protected Covered Species' Habitat Types within Conservation Zones 1-11 (acres)

Covered Species	*Total Extent*	*Total Existing Protected*	*Percent Existing Protected*
San Joaquin kit fox			
Breeding, foraging, and dispersal habitat	5,217	638	12%
Foraging and dispersal habitat	20,573	151	0.7%
Riparian woodrat	1,539	97	6%
Salt marsh harvest mouse			
Wetland habitat	11,124	9,600	86%
Upland habitat	2,815	2,334	83%
Riparian brush rabbit	2,894	138	5%
Townsend's western big-eared bat			
Primary foraging habitat	10,880	3,641	34%
Roosting and primary habitat	6,892	1,876	27%
Secondary foraging habitat	753,408	162,668	22%
Suisun shrew	28,741	22,590	79%
Tricolored blackbird			
Nesting habitat	24,036	14,372	60%
Foraging habitat: non-agriculture	99,587	40,818	41%
Foraging habitat: agriculture	275,937	33,097	12%
Suisun song sparrow	26,959	21,177	79%
Yellow-breasted chat			
Primary nesting and migratory habitat[1]	8,640	3,125	36%
Secondary nesting and migratory habitat	5,530	1,896	34%
Least Bell's Vireo	14,139	5,008	35%
Western burrowing owl			
High-value habitat	78,447	26,261	34%
Moderate value habitat	52,800	16,214	31%
Low-value habitat	243,129	27,833	11%
Western Yellow-Billed Cuckoo			
Breeding Habitat	6,826	2,763	41%
Migratory Habitat	4,891	1,325	27%
California Least Tern			
Foraging habitat	86,240	18,080	21%
Greater sandhill crane			
Roosting/Foraging habitat	11,829	6,743	57%
Foraging habitat	184,257	33,259	18%
California black rail	33,563	24,593	73%
California clapper rail	7,895	5,013	64%
Swainson's hawk			
Foraging habitat	436,417	75,743	17%
Nesting habitat	10,149	3,258	32%
White-tailed kite			
Breeding habitat	13,714	4,518	33%
Foraging habitat	478,251	101,068	21%

Table 3-2a. Extent of Existing and Protected Covered Species' Habitat Types within Conservation Zones 1-11 (acres) (continued)

Covered Species	*Total Extent*	*Total Existing Protected*	*Percent Existing Protected*
Giant garter snake			
Aquatic breeding, foraging and movement	19,824	5,725	29%
Upland aestivation and movement	190,805	31,954	17%
Western pond turtle			
Aquatic habitat	78,511	30,591	39%
Dispersal habitat	579,334	109,348	19%
Upland nesting and overwintering	54,880	19,738	36%
California red-legged frog			
Aquatic habitat	117	4	3%
Upland cover and dispersal habitat	4,984	640	13%
Dispersal habitat	19,572	151	0.8%
Western spadefoot toad			
Aquatic breeding habitat	6,791	4,256	63%
Terrestrial cover and aestivation habitat	14,352	5,071	35%
California tiger salamander			
Aquatic breeding habitat	6,772	4,255	63%
Terrestrial cover and aestivation habitat	14,352	5,071	35%
Valley elderberry longhorn beetle			
Riparian vegetation	17,130	5,310	31%
Non-riparian channels and grasslands	16,022	4,168	26%
Lange's metalmark butterfly	1,108	67	6%
Vernal pool shrimp species (*Vernal pool tadpole shrimp, conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, mid valley fairy shrimp, and California linderiella*)			
Vernal Pool Complex	6,821	4,319	63%
Degraded Vernal Pool Complex	2,493	683	39%
Vernal pool plant species (*Alkali milk-vetch, San Joaquin spearscale, Boggs Lake hedge-hyssop, Heckard's peppergrass, dwarf downingia, and legenere*)			
Vernal Pool Complex	6,958	4,380	63%
Degraded Vernal Pool Complex	2,493	683	39%
Heartscale and brittlescale	496	127	26%
Slough thistle	1,831	188	10%
Suisun thistle and soft bird's-beak	1,225	869	71%
Delta button celery	3,345	270	8%
Contra Costa Wallflower	20	17	85%
Carquinez goldenbush	1,032	391	38%
Delta tule pea and Suisun Marsh aster	5,948	3,699	62%
Mason's lilaeopsis and delta mudwort	6,931	1,717	25%
Antioch Dunes evening primrose	20	17	85%
Side-flowering skullcap	2,495	701	28%
Caper-fruited tropidocarpum	1,410	21	2%

Table 3-2b. Current Extent of Existing and Protected Covered Species' Habitat Types in BDCP Conservation Zones 1-5

Covered Species	*Conservation Zones (acres)*									
	1		**2**		**3**		**4**		**5**	
	Total Extent	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*
San Joaquin kit fox										
Breeding, foraging, and dispersal habitat	0	0	0	0	0	0	0	0	0	0
Foraging and dispersal habitat	0	0	0	0	0	0	0	0	0	0
Riparian woodrat	0	0	0	0	0	0	0	0	0	0
Salt marsh harvest mouse										
Wetland habitat	0	0	0	0	0	0	0	0	26	26
Upland habitat	0	0	0	0	0	0	0	0	12	12
Riparian brush rabbit	0	0	0	0	0	0	0	0	0	0
Townsend's western big-eared bat										
Roosting and primary foraging habitat	60	2	717	459	1,306	11	1,415	779	788	279
Primary foraging habitat	309	105	1,711	1,215	784	9	1,163	933	1,973	803
Secondary foraging habitat	53,693	4,336	66,509	38,023	81,156	439	46,254	18,302	120,918	29,837
Suisun shrew	0	0	0	0	0	0	0	0	2,648	2,004
Tricolored blackbird										
Nesting habitat	606	200	2,079	1,887	535	6	1,015	829	3,991	2,391
Foraging habitat: non-agriculture	10,455	2,083	18,462	15,969	5,646	17	7,180	5,538	6,902	2,918
Foraging habitat: agriculture	31,251	721	15,097	7,406	36,077	219	12,872	2,713	57,402	17,536
Suisun song sparrow	0	0	0	0	0	0	0	0	2,093	1,531
Yellow-breasted chat										
Primary nesting and migratory habitat[1]	219	47	1,753	1,219	890	8	1,309	911	1,048	378
Secondary nesting and migratory habitat	112	60	496	416	405	7	601	460	1,144	580
Least Bell's Vireo	320	102	2,248	1,634	1,293	15	1,900	1,366	2,183	954

Table 3-2b. Current Extent of Existing and Protected Covered Species' Habitat Types in BDCP Conservation Zones 1-5 (continued)

Covered Species	Conservation Zones (acres)									
	1		2		3		4		5	
	Total Extent	Total Existing Protected	Total Extent	Total Existing Protected	Total Extent	Total Existing Protected	Total Extent	Total Existing Protected	Total Extent	Total Existing Protected
Western burrowing owl										
High-value habitat	10,364	2,043	11,231	9,546	5,922	15	5,846	4,249	5,836	2,146
Moderate- value habitat	17,855	409	11,595	6,944	1,473	57	2,678	997	6,568	5,295
Low-value habitat	14,559	460	7,791	4,372	34,934	162	11,521	2,867	52,322	12,937
Western Yellow-Billed Cuckoo										
Breeding Habitat	99	63	1,623	1,178	527	3	886	724	939	461
Migratory Habitat	198	28	477	325	520	12	587	361	878	309
California Least Tern	1011	52	6,703	4,804	4,967	9	1,201	740	21,965	3,546
Greater sandhill crane										
Roosting/Foraging habitat	0	0	0	0	0	0	2,153	2,105	7,259	3,684
Foraging habitat	0	0	135	135	40,751	233	23,423	9,676	64,627	17,606
California black rail	515	157	1,782	1,658	169	4	647	545	3,488	2,188
California clapper rail	0	0	0	0	0	0	0	0	2,617	1,974
Swainson's hawk										
Foraging habitat	43,725	2,821	40,595	23,942	49,953	233	25,829	10,617	70,334	20,890
Nesting habitat	148	12	1,608	1,131	1,510	15	1,924	1,219	1,221	388
White-tailed kite										
Breeding habitat	297	90	2,096	1,498	1,744	18	2,209	1,421	1,970	776
Foraging habitat	43,959	2,825	48,467	24,075	50,333	234	26,104	10,724	70,907	21,070
Giant garter snake										
Aquatic breeding, foraging and movement	523	159	12,129	4,215	178	4	655	552	2,574	224
Upland aestivation and movement	17,583	1,430	11,630	7,168	27,267	157	13,660	4,620	38,913	13,026

Table 3-2b. Current Extent of Existing and Protected Covered Species' Habitat Types in BDCP Conservation Zones 1-5 (continued)

Covered Species	***Conservation Zones (acres)***									
	1		**2**		**3**		**4**		**5**	
	Total Extent	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*
Western pond turtle										
Aquatic habitat	1,818	234	9,131	6,779	3,891	12	2,494	1,795	10,987	1,718
Dispersal habitat	45,905	2,897	53,486	28,394	72,459	434	41,635	14,658	92,517	22,866
Upland nesting and overwintering	5,874	1,312	6,014	4,475	4,564	13	4,543	3,550	4,588	1,716
California red-legged frog										
Aquatic habitat	0	0	0	0	0	0	0	0	0	0
Upland cover and dispersal habitat	0	0	0	0	0	0	0	0	0	0
Dispersal habitat	0	0	0	0	0	0	0	0	0	0
Western spadefoot toad										
Aquatic breeding habitat	3,368	1,425	1,743	1,721	0	0	1,082	1,082	0	0
Terrestrial cover and aestivation habitat	4,659	477	2,536	2,202	0	0	1,879	1,760	0	0
California tiger salamander										
Aquatic breeding habitat	3,368	1,425	1,743	1,721	0	0	1,082	1,082	0	0
Terrestrial cover and aestivation habitat	4,659	477	2,536	2,202	0	0	1,879	1,760	0	0
Valley elderberry longhorn beetle										
Riparian vegetation	357	107	2,276	1,651	2,048	20	2,558	1,706	2,718	1,065
Non-riparian channels and grasslands	1,252	201	1,374	766	2,224	14	1,312	883	2,779	841
Lange's metalmark butterfly	0	0	0	0	0	0	0	0	0	0
Vernal pool shrimp species (*Vernal pool tadpole shrimp, conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, mid valley fairy shrimp, and California linderiella*)										
Vernal Pool Complex	3,355	1,425	1,738	1,716	0	0	1,082	1,082	0	0
Degraded Vernal Pool Complex	1,786	0	0	0	0	0	686	683	0	0

Table 3-2b. Current Extent of Existing and Protected Covered Species' Habitat Types in BDCP Conservation Zones 1-5 (continued)

Covered Species	*Conservation Zones (acres)*									
	1		**2**		**3**		**4**		**5**	
	Total Extent	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*
Vernal pool plant species (*Alkali milk-vetch, San Joaquin spearscale Boggs Lake hedge-hyssop, Heckard's peppergrass, dwarf downingia, and legenere*)										
Vernal Pool Complex	3,355	1,425	1,738	1,716	0	0	1,082	1,082	0	0
Degraded Vernal Pool Complex	1,786	0	0	0	0	0	686	683	0	0
Heartscale and brittlescale	190	69	0	0	0	0	0	0	0	0
Slough thistle	0	0	0	0	0	0	0	0	0	0
Suisun thistle and soft bird's-beak	0	0	0	0	0	0	0	0	37	37
Delta button celery	0	0	0	0	0	0	0	0	0	0
Contra Costa wallflower	0	0	0	0	0	0	0	0	0	0
Carquinez goldenbush	226	68	0	0	0	0	0	0	0	0
Delta tule pea and Suisun Marsh aster	49	14	81	72	39	0	85	68	187	79
Mason's lilaeopsis and delta mudwort	216	21	480	292	480	6	446	259	1,522	488
Antioch Dunes evening primrose	0	0	0	0	0	0	0	0	0	0
Side-flowering skullcap	139	19	200	123	253	5	183	127	743	323
Caper-fruited tropidocarpum	0	0	0	0	0	0	0	0	0	0

Table 3-2c. Current Extent of Existing and Protected Covered Species' Habitat Types in BDCP Conservation Zones 6-11

Covered Species	*Conservation Zones (acres)*											
	6		**7**		**8**		**9**		**10**		**11**	
	Total Extent	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*
San Joaquin kit fox												
Breeding, foraging, and dispersal habitat	0	0	356	0	3,873	618	594	19	394	0	0	0
Foraging and dispersal habitat	0	0	4,554	0	10,593	16	4,991	135	434	0	0	0
Riparian woodrat	10	0	1,487	94	40	3	1	0	0	0	0	0
Salt marsh harvest mouse												
Wetland habitat	0	0	0	0	0	0	0	0	0	0	11,098	9,574
Upland habitat	0	0	0	0	0	0	0	0	0	0	2,803	2,322
Riparian brush rabbit	26	0	2,626	120	238	18	4	0	0	0	0	0
Townsend's western big-eared bat												
Roosting and primary foraging habitat	610	97	1,628	70	36	2	58	1	29	15	245	160
Primary foraging habitat	3,156	409	1,066	50	234	21	137	9	255	58	92	30
Secondary foraging habitat	107,004	11,433	114,041	2,566	35,506	3,147	30,231	1,622	6,071	438	92,023	52,524
Suisun shrew	0	0	0	0	0	0	0	0	157	1	25,937	20,585
Tricolored blackbird												
Nesting habitat	2,945	433	468	26	268	20	247	29	518	179	11,365	8,371
Foraging habitat: non-agriculture	18,169	3,577	6,052	202	5,142	814	3,910	140	3,270	72	14,400	9,489
Foraging habitat: agriculture	46,958	2,480	47,872	781	17,731	9	10,396	1,183	39	0	243	50
Suisun song sparrow	0	0	0	0	0	0	0	0	86	1	24,779	19,645
Yellow-breasted chat												
Primary nesting and migratory habitat[1]	1,186	173	1,485	91	152	13	113	3	148	62	339	241
Secondary nesting and migratory habitat	1,978	312	568	24	62	5	63	7	64	9	39	16
Western Yellow-Billed Cuckoo												
Breeding Habitat	1,319	213	1,267	89	49	0	50	1	54	28	12	4
Migratory Habitat	1,218	213	633	22	121	13	107	4	130	28	21	12

Table 3-2c. Current Extent of Existing and Protected Covered Species' Habitat Types in BDCP Conservation Zones 6-11 (continued)

Covered Species	Conservation Zones (acres)											
	6		7		8		9		10		11	
	Total Extent	Total Existing Protected	Total Extent	Total Existing Protected	Total Extent	Total Existing Protected	Total Extent	Total Existing Protected	Total Extent	Total Existing Protected	Total Extent	Total Existing Protected
Western burrowing owl												
High-value habitat	13,600	1,709	5,972	194	4,717	765	3,815	100	1,701	70	9,442	5,425
Moderate- value habitat	3,554	604	3,244	1	1,311	6	739	3	0	0	3,784	1,898
Low-value habitat	47,876	3,557	45,675	806	16,689	34	9,832	1,215	43	0	1,886	1,423
Greater sandhill crane												
Roosting/Foraging habitat	327	0	0	0	0	0	2,091	953	0	0	0	0
Foraging habitat	52,141	5,319	0	0	0	0	3,180	291	0	0	0	0
California black rail	1,958	403	134	1	121	3	175	22	418	135	24,156	19,478
California clapper rail	0	0	0	0	0	0	0	0	157	1	5,121	3,039
White-tailed kite												
Breeding habitat	2,161	341	2,413	113	192	13	149	5	202	70	281	173
Foraging habitat	71,367	5,810	81,117	2,061	25,746	822	16,472	1,436	1,784	70	41,995	31,942
Swainson's hawk												
Foraging habitat	70,203	5,720	80,318	2,042	25,624	821	16,199	1,416	1,656	64	11,982	7,178
Nesting habitat	1,189	213	2,110	92	61	3	70	1	49	17	259	167
Least Bell's Vireo	3,163	485	2,052	116	214	18	175	10	211	71	378	237
California Least Tern	16,721	3,521	2,356	77	3,475	2,295	1,443	5	738	195	25,662	2,837
Giant garter snake												
Aquatic breeding, foraging and movement	3,049	409	144	1	131	3	178	22	264	135	0	0
Upland aestivation and movement	37,434	3,903	28,160	659	10,730	325	5,280	646	148	22	0	0
Western pond turtle												
Aquatic habitat	20,043	4,008	3,221	98	3,767	2,308	1,760	41	809	321	20,590	13,278
Dispersal habitat	79,041	6,133	100,381	2,396	28,021	100	24,545	1,371	2,551	87	38,794	30,011
Upland nesting and overwintering	11,130	1,677	3,150	191	3,716	763	1,475	81	748	68	9,080	5,891

Table 3-2c. Current Extent of Existing and Protected Covered Species' Habitat Types in BDCP Conservation Zones 6-11 (continued)

Covered Species	***Conservation Zones (acres)***											
	6		**7**		**8**		**9**		**10**		**11**	
	Total Extent	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*
California red-legged frog												
Aquatic habitat	0	0	13	0	86	4	19	0	0	0	0	0
Upland cover and dispersal habitat	0	0	341	0	3,830	619	462	21	351	0	0	0
Dispersal habitat	0	0	3,990	0	10,578	16	4,851	135	154	0	0	0
Western spadefoot toad												
Aquatic breeding habitat	0	0	0	0	381	27	122	0	0	0	94	1
Terrestrial cover and aestivation habitat	0	0	289	0	3,463	619	14	0	87	0	1,426	13
California tiger salamander												
Aquatic breeding habitat	0	0	0	0	381	27	122	0	0	0	76	1
Terrestrial cover and aestivation habitat	0	0	289	0	3,463	619	14	0	87	0	1,426	13
Valley elderberry longhorn beetle												
Riparian vegetation	3,702	506	2,656	120	256	23	185	10	279	73	95	30
Non-riparian channels and grasslands	3,281	562	1,524	99	1,097	294	487	69	92	15	601	422
Lange's metalmark butterfly	0	0	0	0	0	0	0	0	1,108	67	0	0
Vernal pool shrimp species (*Vernal pool tadpole shrimp, conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, mid valley fairy shrimp, and California linderiella*)												
Vernal Pool Complex	0	0	0	0	381	27	120	0	0	0	145	69
Degraded Vernal Pool Complex	0	0	0	0	22	0	0	0	0	0	0	0
Vernal pool plant species (*Alkali milk-vetch, San Joaquin spearscale Boggs Lake hedge-hyssop, Heckard's peppergrass, dwarf downingia, and legenere*)												
Vernal Pool Complex	0	0	0	0	381	27	120	0	0	0	282	130
Degraded Vernal Pool Complex	0	0	0	0	22	0	0	0	0	0	0	0
Heartscale and brittlescale	0	0	6	0	83	11	16	7	20	0	180	40
Slough thistle	0	0	1,831	188	0	0	0	0	0	0	0	0
Suisun thistle and soft bird's-beak	0	0	0	0	0	0	0	0	0	0	1,129	830

Table 3-2c. Current Extent of Existing and Protected Covered Species' Habitat Types in BDCP Conservation Zones 6-11 (continued)

Covered Species	*Conservation Zones (acres)*											
	6		**7**		**8**		**9**		**10**		**11**	
	Total Extent	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*	*Total Extent*	*Total Existing Protected*
Delta button celery	0	0	1,917	188	1,103	83	323	0	1	0	0	0
Contra Costa wallflower	0	0	0	0	0	0	0	0	20	17	0	0
Carquinez goldenbush	0	0	0	0	0	0	0	0	0	0	806	323
Delta tule pea and Suisun Marsh aster	245	40	31	0	23	2	22	1	35	9	5,151	3,415
Mason's lilaeopsis and delta mudwort	1,630	141	540	23	388	59	171	5	127	27	931	396
Antioch Dunes evening primrose	0	0	0	0	0	0	0	0	20	17	0	0
Side-flowering skullcap	841	95	77	2	8	0	35	2	15	4	1	0
Caper-fruited tropidocarpum	0	0	574	0	193	6	634	5	9	0	0	0

3.2.3 Development of the Aquatic Resources Component of the Conservation Strategy

The aquatic component of the BDCP Conservation Strategy is designed to support the restoration of ecological productivity of the Delta and adjacent areas to contribute to the conservation of covered fish species and the tidal natural communities upon which they depend, consistent with the water supply and reliability goals of the Plan. Over the course of the BDCP planning process, the Steering Committee convened independent scientists on several occasions to solicit their advice and recommendations regarding a number of concepts that were used to help guide the Conservation Strategy for aquatic resources, including:

- Land use changes within the Delta have reduced the quality and availability of aquatic habitat suitable for various life stages of covered fish – the conservation strategy should contribute to an increase in the quality, availability, spatial diversity, and complexity of aquatic habitat within the Delta.
- Achieving the goals of the BDCP will require more than manipulation of Delta flow patterns alone. A number of key ecosystem drivers are unrelated to freshwater flow patterns, and these drivers must also be addressed directly.
- The conservation strategy should improve connectivity among aquatic habitats, facilitate migration and movement of covered fish among habitats, and provide transport flows for the dispersal of planktonic material (organic carbon), phytoplankton, zooplankton, macroinvertebrates, and fish eggs and larvae.
- Synchrony between environmental cues and conditions and the life history of covered fish and their food resources within the upstream rivers, Delta, and Suisun Bay is important. The conservation strategy should consider hydrologic seasonal synchrony within the watershed, seasonal water temperature gradients, salinity gradients, turbidity, and other environmental cues.
- There are currently a number of stressors and sources of mortality affecting covered fish within the Delta – the conservation strategy should identify and implement actions to reduce sources of direct mortality and other stressors on the covered fish and the aquatic ecosystem within the Delta.
- Hydrology and SWP and CVP operations within the Delta are integrated with conditions both upstream and downstream of the Delta – the conservation strategy should consider effects on habitat conditions for covered fish in upstream river reaches, within the Delta, and downstream within the low salinity zone of the estuary in Suisun Bay.
- To the extent possible, the conservation strategy should rely on natural physical habitat and biological processes to support and maintain covered fish species and their habitat.

These concepts informed the development of the aquatic component of the Conservation Strategy. Underlying the BDCP Conservation Strategy is the widely-accepted assumption that the existing water conveyance system is fundamentally flawed and that continued reliance on the system as it currently exists is incompatible with the long-term restoration needs of the Delta. Given the inability of the existing conveyance system to meet ecological and water supply goals, and in light of the ongoing and anticipated changing conditions of the Delta brought on by climate change, anticipated seismic events, nonnative species, and other stressors, the BDCP provides for wholesale, systemic modifications to the Delta. Modifying the water conveyance infrastructure to allow for both north and south Delta diversions is essential to creating new opportunities to restore the ecological health of the Delta and to achieve improvements in water supply reliability. The BDCP provides for dual operations of north and south Delta intakes that allow for flexibility of operations to:

- Improve passage of fish within and through the Delta by improving hydrodynamic and water quality conditions that can create barriers to movement;
- Allow for restoration of tidal habitats in the east and south Delta by reducing the risk for entrainment of food produced in restored habitat and life stages of covered fish species using this habitat; and
- Reduce the risk of entrainment of covered fish species by conveying water from either the north or south Delta, depending on the seasonal distribution of their sensitive life stages.

The Conservation Strategy for aquatic resources identifies conservation actions to be implemented under both existing and future water conveyance facilities and operational regimes that can effectively reverse or reduce the adverse effects of environmental stressors on the aquatic ecosystem, covered fish species, and other native aquatic organisms. In addition to the water facilities and operations, the Conservation Strategy provides for habitat restoration actions to improve rearing, spawning, and migration habitat conditions for the covered fish species and to improve aquatic food web processes and actions to address specific stressors on the covered fish species, including impediments to fish passage, sources of unnatural mortality, and the adverse effects on the genetic integrity of covered fish species.

To improve habitat and food web conditions for the covered fish species, the Conservation Strategy provides for the restoration of 75,000 acres of tidal habitats, seasonally inundated floodplains, and adjacent transition uplands; 20 miles of channel margin habitat; and enhancement of seasonally inundated floodplain habitats of the Yolo Bypass through operation of a modified Fremont Weir. These restored natural communities will account for a substantial increase in the extent and quality of physical habitat available for covered fish species. For example, the ROAs described in Section 3.2.2, *Identifying Conservation Zones and Restoration Opportunity Areas*, (see Figure 3-2) were selected specifically to encompass areas most suitable for the restoration of tidal habitats and the most beneficial locations for covered fish species that use main channels, distributaries, and sloughs of the Sacramento, San Joaquin, and Mokelumne rivers and the channels and sloughs of Suisun Marsh. Prior to completion of the new conveyance facility, tidal habitat restoration actions will be focused on the Cache Slough and

Suisun Marsh ROAs, which are minimally affected by through-Delta conveyance operations. Expansion of tidal habitat in these ROAs will benefit delta smelt and longfin smelt. The expansion of tidal area will affect flows in the Sacramento River and its distributaries to the benefit of Sacramento River salmonids. Constructing the new north Delta diversions and isolated tunnel/pipeline facility will open up significant additional tidal habitat restoration opportunities that do not now exist. Accordingly, the long-term phase of the physical habitat restoration program will emphasize restoration of tidal and floodplain habitats in the northeast and south Delta to benefit San Joaquin, Mokelumne, and Cosumnes river salmonids as well as sturgeon, splittail, and lamprey. As described in Section 3.2.4, *Development of the Terrestrial Resources Component of the Conservation Strategy*, these restoration actions will also benefit covered wildlife and plant species that use tidal marsh and riparian habitats.

A third component of the aquatic strategy consists of actions to reduce the direct and indirect adverse effects of other stressors on the ecological functions of the Delta and the covered fish species. A number of factors have been identified that adversely affect covered fish species, either directly or by affecting food resources or habitat quality. Many of these conservation measures address other stressors that are not related directly to water operations or habitat restoration activities, but offer significant opportunities to reduce adverse impacts on covered species and otherwise improve productivity. These other stressors include poor water quality (e.g., low dissolved oxygen), nonnative predator species, illegal harvest activities, and the genetic effects of hatchery-raised fish. Implementation of conservation measures addressing these other stressors is expected to reduce adverse effects on covered species productivity.

Because there are some uncertainties regarding the likely responses of the aquatic ecosystem and covered fish species to some of the measures to address these other stressors, the monitoring and adaptive management programs will be used to ensure that such measures can be refined over time to improve their effectiveness.

3.2.3.1 Aquatic Resources Conservation Strategy Development Process

The process of developing the BDCP Conservation Strategy was complicated by the challenges associated with ecological requirements that vary among the covered fish species, the physical complexity of the Delta, and uncertainties about the nature and strength of certain cause-effect relationships operating in this aquatic ecosystem. Furthermore, the ecosystem experiences ongoing changes, some of which are relatively well understood (e.g., sea level rise), others incompletely understood (e.g., pelagic organism decline), and some that are entirely unknown. As part of the process of developing the Conservation Strategy, the linkages between key plan elements were identified in process referred to as the “logic chain,” which was used to help organize and address the elements of this complex system. Biological goals and objectives for the covered fish species were identified and monitoring metrics were assigned to assess the effectiveness of conservation actions toward achieving the biological goals and objectives.

The logic chain is intended to add specificity and clarity with respect to the relationships between stressors affecting covered fish species, biological goals and objectives, the assumptions underlying conservation approaches, the conservation measures and their projected outcomes, and the appropriate metrics to monitor the success of the Conservation Strategy. Understanding these key linkages helped to facilitate the evaluation of the Plan components and their likely effectiveness as they are implemented over time. As a result, the Conservation Strategy uses a comprehensive approach that accounts for the relationships between what the BDCP is trying to accomplish and how it intends to achieve its objectives.

3.2.3.2 Stressors Affecting Covered Fish Species

A key step in the development of the Conservation Strategy for aquatic resources was the identification of significant environmental stressors on each of the covered fish species. Biological objectives for the Conservation Strategy were developed on the basis of identified stressors on covered fish species and their habitats. Conservation measures were developed to address the biological goals and objectives. Table 3-3 identifies the primary stressors on covered fish species and indicates those stressors that will be addressed by BDCP conservation measures and those that will not.

Table 3-3. Stressors on Covered Fish Species and their Relationship to Biological Objectives

No.	*Applicable species*	*Stressors*	*Description*	*Biological objectives that Address the Stressor*[2]
Stressors on Covered Fish Species Addressed by BDCP Objectives				
1	CHSA STEE SASP GRST WHST RILA PALA	Habitat loss and modification	Changes in the extent access to and or quality of key natural in-Delta habitats for specific life history stages, including habitat variability and food.	CHSA1.1 CHSA1.2 STEE1.1 STEE1.2, SASP1.1 SASP1.2 GRST1.1 WHTST1.1 PALA1.1 RILA1.1
2	SASP	Food limitation	Food availability and food web disruptions due to altered co-occurrence with prey or due to effects of foraging by overbite clam.	SASP1.2
3	CHSA STEE GRST WHST RILA PALA	Altered flows	Altered distribution due to diversions and gate operations; modifications to Delta inflow and outflow rates and hydrodynamics resulting in deviations from migration pathways delays reduced survival and adult straying; rapid changes in flows and water levels affecting rearing habitat and outmigration success; directionality of flows thru the Delta (Note: It is not known to what extent altered flows are a stressor for splittail)	DESM1.4 CHSA1.5 STEE1.4 GRST1.1 WHST1.1 PALA1.4 RILA1.4

Table 3-3. Stressors on Covered Fish Species and their Relationship to Biological Objectives (continued)

No.	*Applicable species*[8]	*Stressors*	*Description*	*Biological objectives that Address the Stressor*[2]
4	CHSA STEE GRST WHST RILA PALA	Passage impediments/ barriers	Barriers to migration (upstream and downstream); factors within the Planning Area that reduce or eliminate access to key habitats.	CHSA1.4 STEE1.3 GRST1.5 WHST1.5 PALA1.3 RILA1.3
5	CHSA STEE SASP GRST WHST RILA PALA	Water quality (toxics DO temperature).	Effects of contaminants and toxic compounds on all life stages; effect of water temperature on productivity; effect of microcystis blooms on productivity; effect of water quality on distribution migration growth rate and reproductive success and survival (including predation).	DESM1.3 DESM1.4 LOSM1.2 CHSA1.6 STEE1.5 GRST1.3 GRST1.4 WHTST1.3 WHST1.4 PALA1.5 RILA1.5
6	CHSA SASP GRST WHST	Entrainment	Direct mortality due to entrainment or impingement at project and non-project diversions.	DESM1.4 DESM1.5 LOSM1.4 CHSA1.7 STEE1.6 SASP1.4 GRST1.6 WHST1.6
7	CHSA STEE SASP	Predators/non-native invasive species.	Predation losses including effects of structures and habitat alterations that promote predators including population effects from predation by introduced species (Note: this is a low impact stressor – little information available for splittail); Competition predation or alteration of habitat characteristics from nonnative invasive species.	DESM1.1 CHSA1.9 STEE1.8 SASP1.5
8	CHSA STEE SASP GRST WHST	Illegal harvest	Direct mortality due to illegal harvest; population effects from illegal harvest.	CHSA1.8 GRST1.7 STEE1.7 WHST1.7

[8] See note at the bottom of this table for species abbreviations

Table 3-3. Stressors on Covered Fish Species and their Relationship to Biological Objectives (continued)

No.	*Applicable species*[8]	*Stressors*	*Description*	*Biological objectives that Address the Stressor*[2]
9	SASP RILA PALA	Stranding	Effects on productivity and abundance from incidences of stranding associated with water management activities. Splittail are floodplain spawners. Design of the restored floodplain may influence potential for stranding.	PALA1.2 RILA1.2 SASP1.1 SASP1.3
10	GRST WHST	Dredging	Disturbance of benthos and direct and indirect effects of physical disturbances of substrates used for rearing from dredging activities associated with BDCP construction and maintenance activities.	GRST1.6 WHST1.6
11	CHSA STEE	Access to historical spawning habitat	Barriers to historical spawning habitat are predominately located outside of the BDCP planning area. In-delta migration and barriers addressed in Stressor # 4 above.	NA
12	CHSA STEE	Climate Change	Increases in ambient air temperatures resulting in increased water temperatures with negative effects on habitat suitability. Effects of climate change are considered but no specific objectives proposed. Changes in water temperature as applicable to BDCP covered activities are addressed under stressor # 5 above.	NA
13	RILA PALA	Disease	Disease may influence lamprey health with effects on reproduction and survival.	NA
14	RILA PALA	Ocean conditions	Reductions in the availability of host/food species may be affecting lamprey survival and growth.	NA

[1] Species abbreviations are defined as follows:
Note: objectives for Delta Smelt and Longfin Smelt are not included
CHSA = Chinook salmon all runs
STEE = Central Valley steelhead
SASP = Sacramento splittail
GRST = Green sturgeon
WHST = White sturgeon
RILA = River Lamprey
PALA = Pacific Lamprey
[2] Species-specific objectives are presented in Section 3.3, *Biological Goals and Objectives.*

3.2.3.3 Water Facilities and Operations

The BDCP Conservation Strategy includes conservation measures that provide for the development and operation of new water conveyance infrastructure and the establishment of operational parameters associated with both existing and new facilities. Central to the

[9] Stressors not addressed by BDCP objectives are associated with conditions outside the Plan Area and/or not under the control of BDCP Authorized Entities

Conservation Strategy is the development and operation of new north Delta facilities that will be located along the Sacramento River and divert water to the south Delta through an isolated tunnel/pipeline. The combination of moving freshwater via an isolated tunnel/pipeline facility in conjunctions with the existing south Delta facilities (referred to as "dual operations") is expected to provide flexibility sufficient to substantially improve conditions for covered fish species. The operation of these dual facilities as set out in the BDCP is expected to benefit different species at different times and under a variety of conditions. Dual operation of new and existing diversion facilities is expected to reduce levels of entrainment of native fish at the south Delta SWP/CVP facilities, particularly delta and longfin smelt.

To minimize the potential for entrainment of fish (particularly juvenile Sacramento River salmonids and splittail) at the new diversion facilities on the Sacramento River, state-of-the-art positive-barrier fish screens will be constructed at each of five intakes and flexible operational methods in the timing and rate of diversion will be coordinated among the intake facilities. Constructing state-of-the-art positive barrier fish screens on in-river and on-river intakes along the Sacramento River and employing flexible operational scenarios will ensure that fish mortality at the new north Delta diversion sites is minimized to the maximum extent practicable. The positive barrier fish screens will be designed and operated in accordance with design criteria (e.g., screen mesh size, approach velocity) currently used by CDFG, NMFS, and USFWS. These operational measures have been devised to ensure that any potential risks to migrating salmonids from the operation of the new north diversion facility will be avoided or otherwise minimized.

The water operations conservation measures establish parameters for water diversion rates and bypass flows in the Sacramento River at the diversions that reflect seasonal movement patterns of covered fish species, including specific responses during periods in which fish species are present in the vicinity of the diversions. These parameters have been developed to better reflect seasonal synchrony with hydrologic conditions within the river and upstream watersheds. Bypass criteria set out in the water operations conservation measures reflect the variation in the seasonal periods of hydrology. The criteria includes "pulse flow" operations, minimum river flow requirements, and flow requirements based on a percentage of the river flow that would pass by the diversions ("bypass flows"). Extensive hydrologic simulation modeling has been used to evaluate and develop the range of water diversion criteria included in the Conservation Strategy. Detailed information on the Sacramento River bypass and diversion operations criteria is presented in Section 3.4.2.1, *CM1 Water Facilities and Operation*.

Proposed water operations measures include actions to improve flows through the Yolo Bypass floodplain, ensure sufficient water for fish transport in the Sacramento River (i.e., north Delta diversion or Hood "bypass flows"), prevent fish from being drawn into the central Delta through the Delta Cross Channel, provide quality habitat for delta smelt and longfin smelt in the Delta and Suisun Bay, and minimize entrainment of fish at the south Delta SWP/CVP diversions. The flexibility associated with the operation of dual facilities in the north and south Delta is expected to allow for physical habitat restoration to be implemented in the western, eastern, and southern

Delta. Some of the enhanced production of carbon, zooplankton and phytoplankton generated from these restored habitats is expected to pass through the interior Delta, while some should also be consumed by fish within and adjacent to the marshes. The flexibility of this dual approach will also allow for substantial reductions in fish entrainment at the south Delta facilities, while meeting the water supply and reliability goals of the BDCP.

The BDCP conservation measures also include the modification of Fremont Weir (lowering a portion of the weir and installing an operable gate facility) and changes to its operations to improve the inundation regime in the Yolo Bypass. Research suggests that covered fish species, particularly splittail and Chinook salmon, would benefit significantly from optimizing the frequency, duration, and timing of seasonal inundation of the Yolo Bypass floodplain habitat (Sommer et al. 1997, 2001a, 2001b, 2004a, 2004b). In addition, the measures is also designed to increase levels of phytoplankton, zooplankton, and other organic material transported from the Yolo Bypass floodplain to Cache Slough, the lower Sacramento River, the western Delta, and Suisun Bay, which will increase the food supply for delta smelt and longfin smelt in those areas.

The BDCP also includes operational criteria that set seasonal limits based on Old and Middle River (OMR) reverse flows. To reduce the risk that south Delta SWP and CVP exports cause direct losses or salvage of covered fish or increases in the export of nutrients and food resources produced in restored southern and eastern Delta marshes, the water operations conservation measures provide for seasonally adjusted year-round limits on OMR reverse flows. Detailed information on OMR operations criteria is presented in CM1 *Water Facilities and Operations,* in Section 3.4, *Conservation Measures.*

The western Delta and Suisun Bay system functions as an estuarine mixing zone for freshwater passing downstream from the tributary rivers and saltwater intrusion from coastal waters through San Francisco Bay. Suisun Bay and the western Delta serve as the low salinity mixing area that has been found to be important rearing and foraging habitat for the covered fish species. The estuarine habitat is also important to the production of phytoplankton and zooplankton as well as many other fish that are the prey of covered fish. The dynamics of the estuarine zone are determined largely by tides and the balance of the magnitude of Delta inflow and Delta outflow. Habitat conditions and salinity gradients in the Suisun Bay and western Delta are most important to covered fish species during the winter and spring months. Consequently, the Conservation Strategy includes, as part of the water operations conservation measures, seasonally adjusted Delta flows designed to better maintain the functions of the estuarine habitat.

3.2.3.4 Physical Habitat Restoration

A second major component of the Conservation Strategy for aquatic resources is the protection, enhancement, and restoration of habitats and natural communities that support covered species. Habitat restoration actions will involve both the reestablishment of habitat in locations that historically supported such habitat and the creation of habitat on altered landscapes where no such habitat previously existed. Habitat enhancement refers to the improvement of ecological functions of existing habitat; habitat protection refers to the preservation of existing habitat susceptible to changes in use by human activity.

The habitat restoration conservation measures include commitments to restore natural habitats at a substantial scale. These actions will restore natural habitat mosaics and gradients to levels that have not been present in the Delta for at least 70 years. Specifically, these conservation measures provide for the restoration of 65,000 acres of tidal wetland and associated estuarine and upland habitats distributed across the Delta, but primarily located within Suisun Marsh and the north Delta Cache Slough complex; restoration of 10,000 acres of new floodplain habitat along major channels; and enhancement of floodplain in the Yolo bypass. ROAs have been identified within the Delta and Suisun Marsh that are characterized by physical conditions suitable for tidal marsh restoration (see Figure 3-2). The ROAs encompass potential restoration areas that could support covered fish species that use main channels, distributaries, and sloughs of the Sacramento, San Joaquin, and Mokelumne rivers in the Delta and the channels and sloughs of Suisun Marsh. Within the floodplain and tidal restoration areas, 5,000 acres of riparian habitat restoration will be implemented. These conservation actions will result in the restoration of large tracts of Delta tidal marsh, estuarine, and seasonal floodplain habitats of sufficient size to substantially increase the extent of physical habitat for covered species (including cover, rearing habitat, nesting habitat, and food resources) and improve overall food web productivity in the restoration areas and adjacent aquatic habitat.

3.2.3.5 Measures to Address Other Stressors

An important third component of the Conservation Strategy for aquatic resources consists of measures to reduce the direct and indirect adverse effects of other stressors on the ecological functions of the Delta and on covered species and natural communities. A number of factors have been identified that adversely affect covered fish species and their habitats. These other stressors include nonnative predators, localized low dissolved oxygen, and genetic issues in hatchery fish.

Specific other stressors conservation measures include actions to reduce predator levels through removal of predator habitat, such as submerged and floating aquatic vegetation and abandoned structures and vessels, particularly in reaches important to juvenile salmonid migration. New non-physical barriers are proposed to direct certain covered species away from areas that pose a higher risk of predation and entrainment. Other measures include actions to improve dissolved oxygen conditions in specific problem areas important to salmonid migration, and to develop new and expanded conservation hatcheries for delta smelt and longfin smelt for the purpose of establishing refugial populations.

3.2.4 Development of the Terrestrial Resources Component of the Conservation Strategy

The Conservation Strategy for terrestrial resources comprises a comprehensive program that provides for the protection of existing functioning natural communities, restoration of new areas of specific natural communities, enhancement of the function of natural communities for covered species habitat, establishment and long term management of geographically distributed conservation lands, and monitoring and adaptive management actions. The Conservation Strategy reflects well-established principles of conservation biology. The approach is designed to maximize opportunities to preserve and restore natural communities sufficient to achieve the goals and objectives for the terrestrial covered species. The natural community level measures include specific targets for habitat protection and restoration, including requirements relating to preserve size, habitat corridors and linkages, and preserve management. Where the goals and objectives for a covered species are may not be fully achieved through implementation of the natural community conservation measures, species-specific conservation measures have been included to ensure appropriate outcomes for species and habitats.

Because of the diverse species habitat requirements and highly altered nature of the Delta, the covered wildlife and plant species are distributed unevenly in the Plan Area, often in discrete, disconnected patches of habitat. A few of the wildlife and plant species are distributed broadly across the Plan Area, but many of the covered wildlife and plant species are found only at the margins of the Plan Area or in local parts of the Plan Area. For some of these species, the Plan Area includes only low-quality or marginal habitat and for others the Plan Area provides the key resources required for conservation. Hence, the conservation approaches for covered wildlife and plant species vary because of the large variation in the importance and quality of habitat in the Plan Area for these species.

Each natural community supports habitat for multiple covered wildlife and plant species, and the suite of species' habitats supported by some communities are similar. Conservation of each natural community is addressed based on the specific spatial, temporal and structural attributes of those communities.

The Conservation Strategy includes measures to provide connectivity between areas that are important for sustaining and improving ecosystem functions and providing for species conservation. For some species and natural communities this interconnection will be achieved through large-scale restoration of aquatic and wetland communities, such as tidal habitats concentrated in the Delta and Suisun Marsh and riparian forest and scrub. For covered species that occur in terrestrial natural communities along the periphery of the Plan Area (e.g., San Joaquin kit fox, California red-legged frog), opportunities for habitat interconnection will be mostly between existing and newly protected terrestrial habitat in the Plan Area and protected terrestrial habitat adjacent to the Plan Area (mostly associated with adjacent or surrounding HCPs and NCCPs).

The geographic pattern of habitat protection and restoration in the Plan Area will result in a system of core habitat patches linked by ribbons of habitat along channels, sloughs, and floodplains. This approach can be thought of as a "node and network" approach. In core species habitat areas, patches or "nodes" of protected and restored habitat will be established to address site-specific species needs. The Plan provides for large-scale preservation and restoration of habitat along the channels, floodplains, and sloughs of the Delta and Suisun Marsh that will provide a "network" of habitat connections among the nodes of protected and restored core habitats. Steps to establish a connectivity network for covered species within the Plan Area will be informed and guided by the California Essential Habitat Connectivity project (Spencer et al. 2010).

Many of the natural communities addressed by the BDCP share common characteristics that are related to spatial proximity on the landscape, shared ecosystem process (exchanges of nutrients through daily tidal cycles or seasonal flooding regimes), similarity of habitat structural characteristics (herbaceous versus woody vegetation), and some are dominated by human land use practices (managed wetlands or agricultural lands). For example, tidal freshwater emergent wetland, tidal mudflat, and tidal perennial aquatic communities are typically spatially contiguous along a tidal elevation gradient and are linked through ecosystem processes such as energy and nutrient flows. Another example is the spatial distribution of grassland, alkali seasonal wetland complex, and vernal pool complex communities that, within the Plan Area, are typically intermingled with each other to the extent that these communities form a complex mosaic on the landscape that defines the mapping of each community as discrete land cover units. While grassland in the Plan Area can occur in discrete patches that can be mapped, it often occurs intermixed with the alkali seasonal wetland complex and vernal pool complex natural communities. On fine spatial scales, the seasonal wetland communities are embedded as "islands" within a larger matrix of the grassland community, and for the BDCP development those areas were mapped as complexes of communities.

3.2.4.1 Conservation Targets

Conservation targets have been established for the natural communities and the covered wildlife and plant species habitats they support. Conservation targets represent the extent and distribution of habitat to be protected, enhanced, and restored/created to achieve the biological goals and objectives. Under the monitoring program, the effectiveness of habitat enhancement, restoration, and management actions will be assessed and potential adjustments to conservation actions can be identified to maintain or improve habitat functions over time (see Section 3.6, *Monitoring and Research Program*). The habitat conservation targets have been developed to satisfy mitigation requirements associated with the impacts of covered activities on covered species and provide for the conservation of those species.

The conservation targets for natural communities and the covered wildlife and plant species are presented in Table 3-4 and Table 3-5, respectively. The process used to develop conservation targets is presented in Figure 3-9. The information used to develop the conservation targets included the:

- Distribution and extent of each natural community within the Plan Area (Figure3-3 through Figure 3-8);
- Distribution and extent of each covered species' modeled habitat that is located within the Plan Area (Figure 3-14 through Figure 3-51 in Section 3.3.2.4, *Covered Wildlife and Plant Species Goals and Objectives*);
- Primary threats and stressors for each of the covered species (Appendix A, *Covered Species Accounts*);
- Location of habitat areas known to be occupied by each of the covered species (Appendix A, *Covered Species Accounts*);
- The distribution and extent of existing protected patches of each natural community and covered species habitat (Figures 3-3 through 3-8 and 3-14 through 4-51); and
- Potential for increasing connectivity with conserved habitat areas adjacent to the Plan Area (from documents of HCP/NCCPs approved or under development for lands that are adjacent to the Plan Area).

To establish the conservation targets, this information was evaluated for each of the following variables.

- The patch size and connectivity of each natural community with other protected and unprotected natural community patches and connectivity with existing protected natural communities was evaluated. The conservation targets were formulated to include large patches of connected natural communities and not small fragmented patches;
- The extent of modeled habitat for covered species that is supported by each natural community within each of the Conservation Zones was evaluated. The conservation targets were formulated to include natural communities in locations that support modeled habitat for multiple species and exclude areas that support modeled habitat for no or a relatively small number of species, except where patches are important for conserving a particular species;
- The habitat value of patches of natural communities for associated covered species and ability to maintain habitats into the future was evaluated. The conservation targets minimize protecting low value habitats (e.g., patches of grassland on levee slopes) and habitat areas at risk for future loss to natural events (e.g., habitats on subsided lands that may be lost to future levee failures associated with flood and seismic events);

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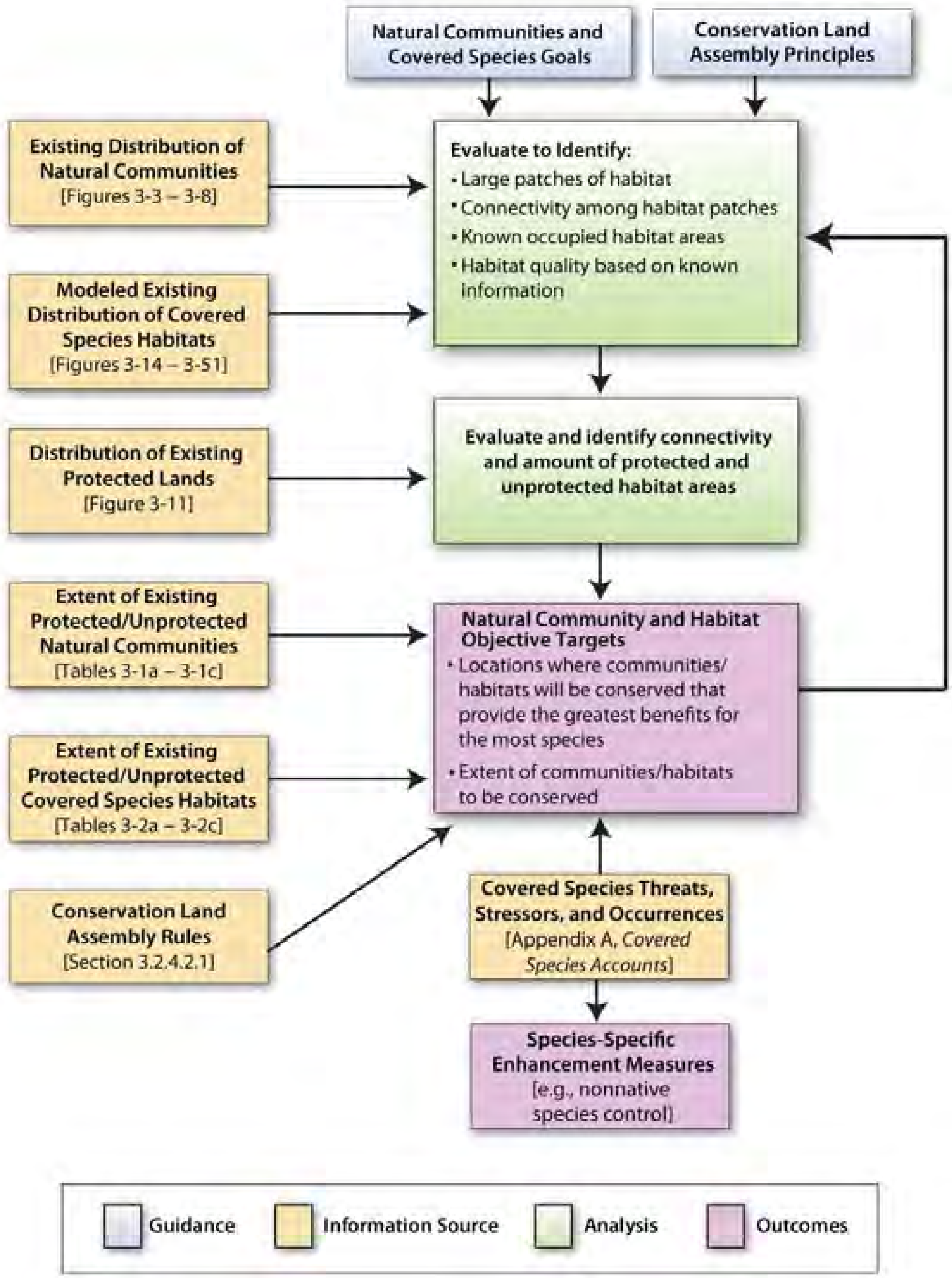

Figure 3-9. Process for Establishing Natural Community and Covered Species Habitat Targets and Species-Specific Measures

- The patch size and connectivity of each covered species' modeled habitat to other patches of modeled protected and unprotected species habitat within the Plan Area and habitat adjacent to the Plan Area was evaluated. The conservation targets were formulated to include large patches of connected modeled habitat for each of the covered species rather than small fragmented patches;
- Location of important known covered wildlife species population centers and covered plant species occurrences was evaluated. The conservation targets were formulated to protect a proportion of these habitat areas such that these populations and occurrences will be conserved;
- Proximity of modeled covered species habitats to known occupied habitats was evaluated. The conservation targets were formulated to protect occupied habitats and unoccupied habitat areas that are connected to known occupied habitat areas such that, with implementation of enhancement measures, unoccupied habitats can be occupied in the future; and
- Based on the evaluation of these variables for each natural community and covered wildlife and plant species, the conservation targets were established such that, once they are achieved, the largest and highest quality patches of natural communities and associated covered species habitats remaining in the Plan Area will be protected. The rationale for how the natural community conservation targets presented in Table 3-4 address the conservation needs for each of the covered species is presented in Section 3.3.2.4, *Covered Wildlife and Plant Species Goals and Objectives*.

Actions that provide for the conservation of the covered species and their habitats include habitat protection, enhancement, restoration, and management. Conservation actions also include targeted species-specific actions, some of which reflect approaches identified in approved recovery plans and approved conservation plans overlap with the Plan Area.

Table 3-4. Natural Community Conservation Targets by Conservation Zone

Natural Community	*Conservation Target (acres)* Restored	Protected/ Enhanced	*Total Conserved Land Base (acres)*	*Applicable Conservation Zones*	*Covered Species Habitats Supported by Conserved Natural Communities*
Tidal	65,000	0	65,000	1, 2, 4, 5, 6, 7, and 11	Chinook salmon (all runs), steelhead, delta smelt, longfin smelt, splittail, salt marsh harvest mouse, Townsend's western big-eared bat, Suisun shrew, tricolored blackbird, Suisun song sparrow, California black rail, California clapper rail, giant garter snake, western pond turtle, Suisun thistle, soft bird's-beak, delta tule pea, Mason's lilaeopsis, delta mudwort, and Suisun marsh aster.
Valley/foothill riparian	5,000	0	5,000	1-9 and/or 11	Chinook salmon (all runs), steelhead, splittail, riparian woodrat, riparian brush rabbit, Townsend's big-eared bat, yellow-breasted chat, white-tailed kite, Swainson's hawk, western pond turtle, and valley elderberry longhorn beetle.
Grassland	2,000	8,000	10,000	1, 8, and 11	San Joaquin kit fox, Townsend's big-eared bat, tricolored blackbird, western burrowing owl, white-tailed kite, Swainson's hawk, giant garter snake, western pond turtle, western spadefoot toad, California red-legged frog, and California tiger salamander.
Nontidal freshwater perennial emergent wetland and nontidal perennial aquatic	400	0	400	2 and 4	Townsend's big-eared bat, tricolored blackbird, giant garter snake, and western pond turtle
Alkali seasonal wetland complex	0	400	400	1, 8, and 11	San Joaquin kit fox, Townsend's big-eared bat, tricolored blackbird, western burrowing owl, white-tailed kite, Swainson's hawk, giant garter snake, western pond turtle, western spadefoot toad, California red-legged frog, and California tiger salamander.
Vernal pool complex	200	300	500	1, 8, and 11	San Joaquin kit fox, Townsend's big-eared bat, tricolored blackbird, western burrowing owl, white-tailed kite, Swainson's hawk, giant garter snake, western pond turtle, western spadefoot toad, and California red-legged frog.
Other natural seasonal wetlands	0	0	0	Not applicable.	None
Inland dune scrub	To be determined.	To be determined.	To be determined.	To be determined.	To be determined.
Agricultural habitats	0	16,620-32,640	16,620-32,640	1-9	San Joaquin kit fox, Townsend's western big-eared bat, Swainson's hawk, tricolored blackbird, greater sandhill crane, western burrowing owl, white-tailed kite, giant garter snake, and western pond turtle.
Total	**Up to 72,600**	**Up to 25,320-41,340**	**Up to 97,920-113,940**		

Table 3-5. Covered Species Habitat Conservation Targets

Covered species	*Conservation Provided by Conservation Zone (CZ)*	
	Preservation/ Enhancement (acres[2])	**Restoration (acres[2])**
San Joaquin kit fox		
Breeding habitat	1,000 CZ: 8	0
Riparian woodrat	0	300 CZ: 7
Salt marsh harvest mouse		
Wetland habitat	0	3,600-4,800 CZ: 11
Upland habitat	350-700 CZ: 11	350-700 CZ: 11
Riparian brush rabbit	0	300 CZ: 7, 8
Townsend's western big-eared bat		
Roosting and primary foraging habitat	0	5,000 CZ: 1, 2, 4-7, and/or 11
Suisun shrew	0	3,600-4,800 CZ: 11
Tricolored blackbird		
Nesting habitat	0	17,900-26,800 CZ 1, 2, 4- 7, and/or 11
Foraging habitat: non-agriculture	8,700 CZ1,2, or 4	0
Foraging habitat: agriculture	16,620-32,640 CZ 1-9	0
Suisun song sparrow	0	3,600-4,800 CZ:11
Yellow-breasted chat		
Primary nesting and migratory habitat[3]	0	≥2,000 CZ: 1, 2, 4- 7, and/or 11
Secondary nesting and migratory habitat	0	≤3,000 CZ: 1, 2, 4- 7, and/or 11
Least Bell's vireo	0	≥2,000 CZ: 1, 2, 4- 7, and 11
Western burrowing owl		
High-value habitat	8,000 CZ: 1, 8, and 11	2,000 CZ: 1, 8, and 11
Moderate- value habitat	>3,000 CZ: Any CZ	0
Western yellow-billed cuckoo	0	>1,000 CZ: 1, 2, 4-7
California least tern *Foraging habitat*	0	10,000-20,000 CZ: 1, 2, 4-7, and 11
Greater sandhill crane		
Roosting/Foraging Habitat	0	320 CZ: 3, 4, 5, 6
Foraging Habitat	>4,800 CZ: 3, 4, 5, 6	0
California black rail	0	17,500-26,400 CZ: 1, 2, 4- 7, and/or 11
California clapper rail	0	3,600-4,800 CZ: 11

Table 3-5. Covered Species Habitat Conservation Targets (continued)

Covered species	*Conservation Provided by Conservation Zone (CZ)*	
	Preservation/ Enhancement (acres[2])	**Restoration (acres[2])**
Swainson's hawk		
Foraging habitat	20,020 to 36,040 CZ 1-8, and/or 11	0
Nesting habitat	0	4,000 CZ: 1, 2, 4- 7, and/or 11
White-tailed kite		
Nesting habitat	0	4,000 CZ: 1, 2, 4- 7, and/or 11
Foraging habitat	24,620-46,040 CZ: Any CZ	0
Giant garter snake		
Primary Zone: Aquatic breeding, foraging and movement	≥6,900 CZ: 1, 2, 4, and/or 5	400 CZ: 2 and 4
Primary Zone; Upland aestivation and movement	7,100 CZ 1, 2, 4, and/or 5	0
Primary and Secondary Zone: Aquatic breeding, foraging	Not applicable.	13,290-21,640 CZ: 1, 2, 4,-7, and/or 11
Western pond turtle		
Aquatic habitat	0	27,900-46,800 CZ: 1, 2, 4-7, and/or 11
Dispersal habitat	4,000	0
Upland nesting and overwintering	≥5,230 CZ: Any CZ	5,000 CZ: 1, 2, 4-7, and/or 11
California red-legged frog		
Aquatic habitat	3 CZ: 8	0
Upland cover and dispersal habitat	1,000 (including encompassed stream aquatic habitat) CZ: 8	0
Western spadefoot toad		
Aquatic breeding habitat	300 CZ: 1, 8, and/or 11	200 CZ: 1, 8, and/or 11
Terrestrial cover and aestivation habitat	8,400 CZ: 1, 8, and/or 11	500 CZ: 1, 8, and/or 11
California tiger salamander		
Aquatic breeding habitat	300 CZ: 1, 8, and/or 11	200 CZ: 1, 8, and/or 11
Terrestrial cover and aestivation habitat	8,400 CZ: 1, 8, and/or 11	500 CZ: 1, 8, and/or 11
Valley elderberry longhorn beetle		
Riparian vegetation	0	5,000 CZ: 1, 2, 4- 7, and/or 11
Lange's metalmark butterfly	0	0
Vernal pool shrimp species (*vernal pool tadpole shrimp, conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, mid valley fairy shrimp, and California linderiella*)	300 CZ: 1, 8, and 11	200 CZ: 1, 8, and/or 11

Table 3-5. Covered Species Habitat Conservation Targets (continued)

Covered species	*Conservation Provided by Conservation Zone (CZ)*	
	Preservation/ Enhancement (acres[2])	**Restoration (acres[2])**
Vernal pool plant species (*Alkali milk-vetch, San Joaquin spearscale, Boggs Lake hedge-hyssop, Heckard's peppergrass, dwarf downingia, and legenere*)	300 CZ: 1, 8, and 11 Protect at least 3 alkali milkvetch and 2 Heckard's peppergrass unprotected occurrences CZ: 1, 8, and 11	200 CZ: 1, 8, and/or 11
Heartscale and brittlescale	150 CZ: 1, 8, and/or 11 Protect at least 3 heartscale and brittlescale unprotected occurrences CZ: 1, 8, and 11	0
Slough thistle	0	≥1,000 CZ: 7
Suisun thistle and soft bird's-beak	Protect at least 3 Suisun thistle and soft bird's-beak unprotected occurrences CZ: 11	3,600-4,800 CZ: 11
Delta button celery	≥100 CZ: 8	≥1,000 CZ: 7
Contra Costa wallflower	0	0
Carquinez goldenbush	300 CZ: 1 and/or 11 Protect at least 3 Carquinez goldenbush unprotected occurrences CZ: 1 and/or 11	0
Delta tule pea and Suisun Marsh aster	0	16,970-26,470 CZ: 1, 2, 5, 7, and 11
Mason's lilaeopsis and delta mudwort	0	16,980-26,560 CZ: 1, 2, 5, 7, and 11)
Antioch Dunes evening primrose	0	0
Side-flowering skullcap	0	0
Caper-fruited tropidocarpum	≥100 CZ: 8 Protect occurrences of caper-fruited tropidocarpum that reestablish on BDCP conservation areas CZ: 8	0

[1]Initial estimate prior to the full BDCP effects analysis.

[2]Values above 10 are rounded to the nearest 10 acres.

[3]Suisun Marsh/Upper Yolo Bypass Nest and Migratory Habitat acreage totals have been assumed to be equivalent to Primary Habitat and have been combined with the Primary Habitat acreage totals. For further definition of the Suisun Marsh/Upper Yolo Bypass Nest and Migratory Habitat, refer to Yellow-breasted Chat species account documented within Appendix A, *Covered Species Accounts*.

3.2.4.2 Assembly of Conservation Lands

Conservation lands include all areas of land and water included within BDCP protected, restored, and created natural communities in the Plan Area at full BDCP implementation. Upon full assembly of conservation lands over the term of BDCP implementation coupled with the continued operations of water facilities and management of habitats and other stressors conservation actions, all natural community and species goals and objectives are expected to be achieved. This section provides a discussion of the considerations associated with the assembly of conservation lands and guidance for selecting lands for conservation during implementation of the BDCP. Included are discussions of: (1) conservation land assembly principles; (2) existing protected lands and their relationship to conservation land assembly; (3) conservation actions that may occur outside the Plan Area; and (4) the relationship between other regional conservation planning programs and the BDCP Conservation Strategy.

3.2.4.2.1 Conservation Land Assembly Principles

The following conservation land assembly principles describe considerations used to distribute the conservation of natural communities and covered species habitats among the Conservation Zones to ensure the greatest biological benefits. These assembly principles provide guidance to the BDCP Implementation Office for selecting conservation lands.

1. Protect, enhance, and restore the full ecological diversity of natural communities and covered species habitats at the periphery of the Plan Area on lands most likely to accommodate future sea level rise and less likely to be flooded as a result of levee failures (i.e., terrestrial habitat conservation areas should be located where there is a low risk of future flooding).
2. Maintain a range of contiguous ecological gradients and provide connectivity between estuarine/wetland and upland communities inside and outside the Plan Area.
3. Design reserves to appropriately scale the ecological gradient and emphasize compatibility between restored native communities and working landscapes (e.g., agricultural lands).
4. Design reserves of sufficient size to ensure the intended conservation benefits for the target covered species.
5. Design reserves of sufficient size and configuration to ensure that they can be effectively managed given site constraints.
6. Maximize connections between preserve lands within and outside of the Plan Area.
7. Protect the highest quality natural communities and covered species' habitats available consistent with the BDCP implementation schedule.

The following are important implementation concepts that will be used by the BDCP Implementation Office to guide the design and timing of restoration actions and selection of sites for habitat protection and restoration.

1. During the BDCP near-term implementation period, focus restoration and enhancement of covered fish species habitats in north Delta locations to generate improvements in productivity consistent with continued operations of the south Delta SWP and CVP pumping facilities.
2. Identify restoration areas and design actions to accommodate and to integrate with BDCP water operations (see CM1 Water Facilities and Operation) to optimize primary and secondary productivity, spawning and rearing, and other aquatic functions that support covered species.
3. During the BDCP long-term implementation period, expand the restoration and enhancement of covered fish species habitats to include the Mokelumne and San Joaquin River deltas to provide benefits to covered fish species found in each of those areas.
4. Implement conservation measures for terrestrial and nontidal wetland communities and covered wildlife and plants in a manner that complements, as appropriate, the conservation strategies of approved and developing conservation plans for areas adjacent to and overlapping the Plan Area.
5. Restore habitat in large patches to increase the likelihood of providing the desired levels of ecological function and to support large numbers of covered species.
6. Distribute restored and enhanced habitats throughout the Delta to minimize the risk of loss of habitat benefits to catastrophic events in one part of the Delta.
7. Distribute and design restored habitats to withstand potential changes in Delta conditions associated with future sea level rise and changes in stream hydrographs.
8. Design tidal habitats to withstand effects that could be associated with Delta levee failures.
9. Restore habitat in patch sizes that are equal to or greater than the patch sizes required by the covered species that use the habitat.
10. Juxtapose restored habitats with existing habitats to improve and maintain habitat corridors and connectivity among covered species habitats.
11. Locate and design restored habitats to provide beneficial hydrodynamic effects on adjacent channel systems (e.g., increased tidal flows that may result in decreased bidirectional flow in upstream channels or provide greater mixing in adjacent channels).
12. Locate and design restored habitats to create natural gradients in the Delta that historically transitioned from shallow subtidal aquatic habitats, to riverine floodplain habitats, and to transitional upland habitats (seasonal wetland, riparian, grassland).

13. Design tidal marsh and seasonally inundated floodplain habitats to provide access and egress for covered fish species in a manner that avoids stranding or trapping of fish.

14. Locate and design restored habitats to minimize potential effects of other stressors that could degrade intended covered species benefits (e.g., effects of nearby diversions, discharges of low quality water).

3.2.4.2.2 Existing Protected Lands

An important consideration in the assembly of BDCP conservation lands is the extent and distribution of existing protected lands that conserve natural communities and covered species habitats. The BDCP Protected Lands GIS dataset identifies existing protected lands within the Plan Area. The dataset was compiled from various public sources. Ownership information was collected and organized into attributes which included: County, County Assessor's Parcel Number (APN), Management Level, Management Agency, Alias (if known), Type (type of ownership), and Data Source. Although the boundaries depicted within the data do not represent legal boundaries, they represent the best available information and were considered to be sufficient to guide development of the conservation measures for the system of conservation lands at a landscape level.

The public dataset sources used to generate the BDCP Protected Lands GIS data layer included:

- DFG Lands GIS data layer 2010;
- California Protected Areas Database March 2009;
- Central Valley Farmland Trust 2009;
- Yolo County Assessors Data 2009;
- Yolo County Natural Heritage Program 2009;
- Delta Parcels data created by DWR for SAIC 2008;
- Delta Wetlands Program website 2008;
- DWR ownership layer created for SAIC 2008;
- Sacramento Bee, 2008;
- Wildlife Conservation Board, 2008;
- GreenInfo 2007;
- Solano County Water Agency 2007;
- CaSIL Conservation Lands data layer 2005;
- USGS Oil & Gas Assessment Program 2003; and
- CA Public, Conservation and Trust Lands, v5.2.

The data layer was created by overlaying source data on top of county parcel boundary data. Parcels identified as protected lands via source datasets were then attributed with the appropriate information.

Based on the ownership information derived from the above sources, the data was evaluated and grouped into three primary categories defined as follows.

- **Category 1 protected lands:** Lands that are subject to irrevocable protection against a change in primary land use through local, state, or federal authority and with a primary management goal related to ecological protection.
- **Category 2 protected lands:** Lands that are subject to irrevocable protection against a change in primary land use through local, state, or federal authority with a primary land management goal assessed to be that of open space for mixed use in a manner that maintains ecological value.
- **Category 3 protected lands:** Lands that are subject to irrevocable protection against a change in primary land use through local, state, or federal authority. However, these lands are not managed primarily for ecological protection nor are they managed as open space for mixed use in a way that maintains ecological value.

Properties excluded from consideration included those owned by the Department of Defense and city parks. Figure 3-10 illustrates a decision matrix that was applied to assign protection categories.

The distribution of existing protected lands by Conservation Zone is presented in Figure 3-11. The extent of each natural community and covered species habitat in each of the Conservation Zones is presented in Table 3-1a-c and Table 3-2-c, respectively.

3.2.4.2.3 Conservation Actions that May Occur Outside the Plan Area

Initially, the Plan Area will encompass the Sacramento-San Joaquin Delta, Suisun Marsh, and the upper Yolo Bypass. However, additional areas may be incorporated into the Plan Area during plan implementation to accommodate conservation actions that advance the biological goals and objectives of the BDCP. Such conservation actions are limited to the preservation and/or restoration of habitat for terrestrial species located within any of the six Delta counties.[10] In particular, BDCP conservation actions will likely be directed to areas that would support both the BDCP Conservation Strategy and regional conservation planning efforts underway in the Delta counties.

[10] The Delta counties are: Sacramento, San Joaquin, Yolo, Solano, Contra Costa, and Alameda.

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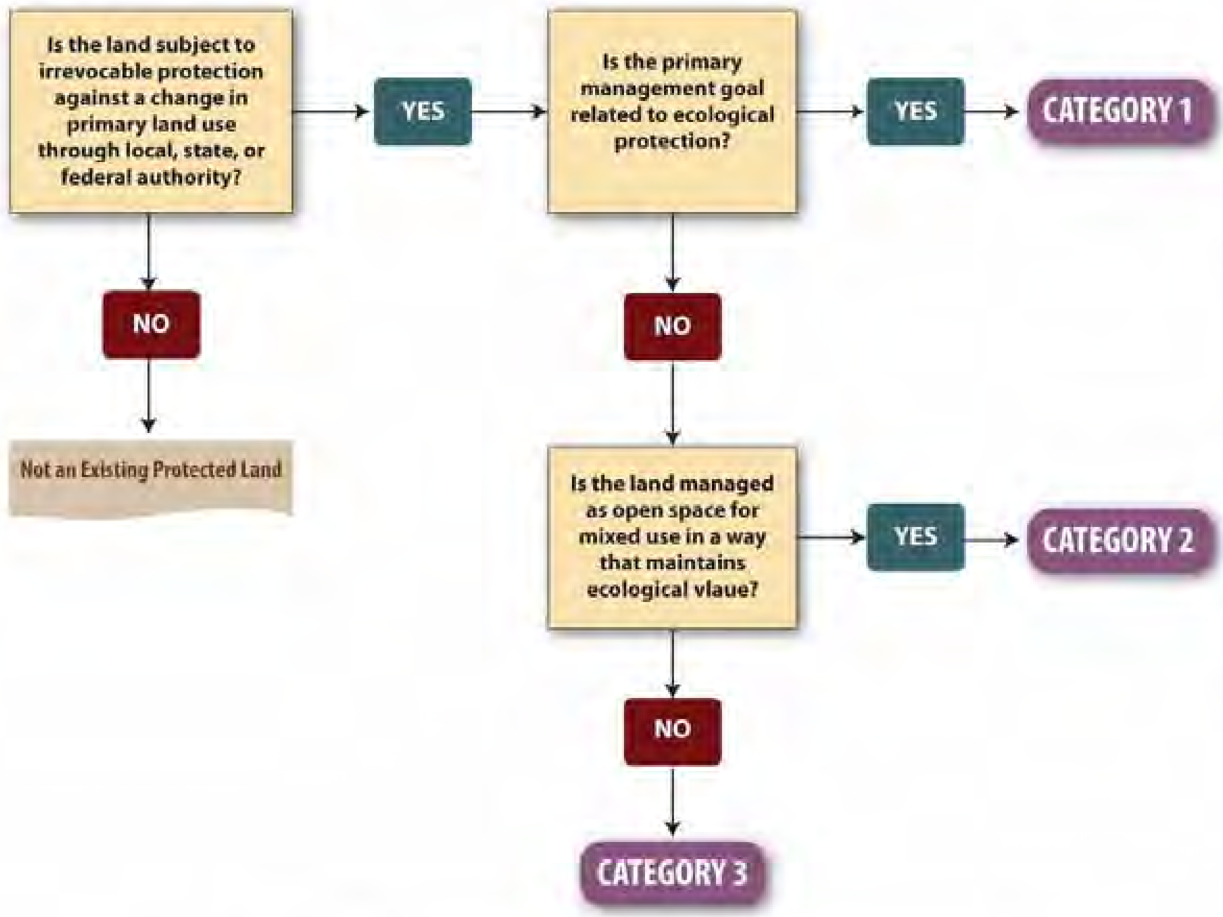

PROTECTED LANDS	
CATEGORY 1	Land use is protected with a primary management goal related to ecological protection.
CATEGORY 2	Land use is protected with a primary management goal related to maintaining open space for mixed use in a manner that maintains ecological value.
CATEGORY 3	Land use is protected, but not managed as open space for mixed use in a way that maintains ecological value.

Figure 3-10. Decision Matrix for Assigning Protection Status Categories for Compiled Protected Lands Database

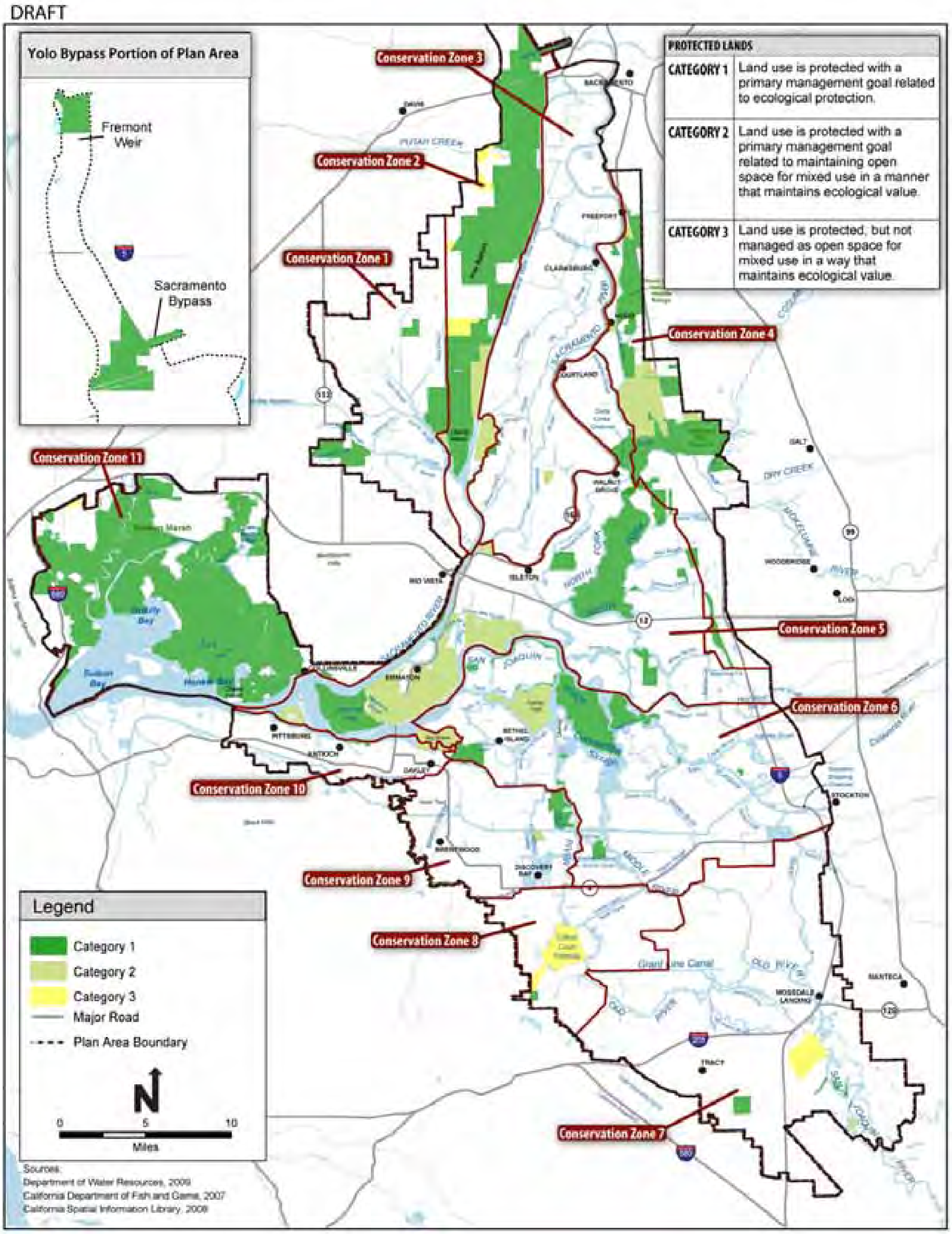

Figure 3-11. Distribution of Protected Lands and Conservation Zones 1-11

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Most of the habitat for covered wildlife and plant species is found at the margins of the Plan Area or in distinct portions of the Plan Area. For some species, the Plan Area includes only low functioning habitat. The approach to conservation for these species varies reflecting the fragmented distribution of their habitats within the Plan Area, the extent and connectivity of those habitats within and adjacent to the Plan Area, and the distribution and abundance of each of the species. Conservation measures to address species such as giant garter snake, San Joaquin kit fox, and vernal pool invertebrates may more effectively be implemented on lands just outside of the Plan Area in the Delta counties.

3.2.4.2.4 Relationship between other Regional Conservation Planning Programs and the BDCP Conservation Strategy

Several regional conservation plans have been approved in the vicinity of the Delta and others are in the process of being developed. These plans are generally sponsored by local governments and special districts to address the mitigation and conservation needs of terrestrial and wetland wildlife and plant species. The regional conservation plans that overlap with BDCP, listed in rank order of amount of physical overlap, are:

- San Joaquin County HCP (approved);
- East Contra Costa County HCP/NCCP (approved);
- Solano County HCP (in development);
- Yolo County HCP/NCCP (in development);
- Suisun Marsh Habitat Restoration and Management Plan (in development);
- South Sacramento County HCP (in development); and
- East Alameda County Conservation Strategy (in development).

The San Joaquin County HCP has the largest amount of overlap with the BDCP Plan Area with more than 300,000 acres of land in common. The East Alameda County Conservation Strategy has the least amount of overlap with the BDCP Plan Area with less than 5,000 acres of land in common. An additional plan, the approved Natomas Basin HCP in Sacramento County, is adjacent to the Upper Yolo Bypass area that is included in the BDCP Conservation Strategy. Most of the BDCP wildlife and plant covered species are also covered or proposed for coverage by at least one of these other plans (Table 3-6). There are BDCP covered species that occur in surrounding plan areas that are not covered by those plans and species covered in these other plans that are not covered under the BDCP. The geographic and species overlap with surrounding plans provides an opportunity for collaboration and partnership in the implementation of conservation actions common to these plans and the BDCP.

Table 3-6. BDCP Covered Species that are Covered or Proposed for Coverage under Overlapping and Adjacent HCPs and NCCPs

BDCP Covered Species	*Species Covered or Currently Proposed for Coverage in Adjacent and Overlapping HCPs and NCCPs*					
	San Joaquin County HCP	**East Contra Costa HCP/NCCP**	**Natomas Basin HCP**	**Solano County HCP[11]**	**South Sacramento HCP[12]**	**Yolo County HCP/NCCP**
Mammals						
San Joaquin kit fox *Vulpes macrotis mutica*	X	X				
Riparian woodrat *Neotoma fuscipes riparia*	X					
Salt marsh harvest mouse *Reithrodontomys raviventris*				X		
Riparian brush rabbit *Sylvilagus bachmani riparius*	X					
Townsend's western big-eared bat *Corynorhinus townsendii*		X				X
Suisun shrew *Sorex ornatus sinuosus*				X		
Birds						
Tricolored blackbird *Agelaius tricolor*	X	X	X	X	X	X
Suisun song sparrow *Melospiza melodia maxillaries*				X		
Yellow breasted chat *Icteria viriens*				X	X	X
Least Bell's vireo *Vireo bellii pusillus*						X
Western burrowing owl *Athene cunicularia*	X	X	X	X	X	X
Western yellow-billed cuckoo *Coccyzus americanus occidentalis*	X					X

[11] Per version of covered species on website, last updated February 2007.

[12] Per version of covered species on, last updated June 23, 2008.

Table 3-6. BDCP Covered Species that are Covered or Proposed for Coverage under Overlapping and Adjacent HCPs and NCCPs (continued)

BDCP Covered Species	***Species Covered or Currently Proposed for Coverage in Adjacent and Overlapping HCPs and NCCPs***					
	San Joaquin County HCP	**East Contra Costa HCP/NCCP**	**Natomas Basin HCP**	**Solano County HCP**[13]	**South Sacramento HCP**[14]	**Yolo County HCP/NCCP**
Birds						
California least tern *Sternula antillarum browni*						
Greater sandhill crane *Grus canadensis tabida*	X				X	
California black rail *Laterallus jamaicensis coturniculus*				X		
California clapper rail *Rallus longirostris obsoletus*				X		
Swainson's hawk *Buteo swainsoni*	X	X	X	X	X	X
White-tailed kite *Elanus leucurus*					X	X
Reptiles						
Giant garter snake *Thamnophis gigas*	X	X	X	X	X	X
Western pond turtle *Emys marmorata*	X	X	X	X	X	X
Amphibians						
California red-legged frog *Rana aurora draytonii*	X	X		X		X
Western spadefoot toad *Spea hammondii*	X				X	X
California tiger salamander *Ambystoma californiense*	X	X	X	X	X	X

X

[13] Per version of covered species on website, last updated February 2007.

[14] Per version of covered species on, last updated June 23, 2008.

Table 3-6. BDCP Covered Species that are Covered or Proposed for Coverage under Overlapping and Adjacent HCPs and NCCPs (continued)

BDCP Covered Species	***Species Covered or Currently Proposed for Coverage in Adjacent and Overlapping HCPs and NCCPs***					
	San Joaquin County HCP	**East Contra Costa HCP/NCCP**	**Natomas Basin HCP**	**Solano County HCP[13]**	**South Sacramento HCP[14]**	**Yolo County HCP/NCCP**
Fish						
Central Valley steelhead *Oncorhynchus mykiss*				X		
Sacramento River winter-run Chinook salmon *Oncorhynchus tshawytscha*				X		
Central Valley spring-run Chinook salmon *Oncorhynchus tshawytscha*				X		
Central Valley fall- and late fall-run Chinook salmon *Oncorhynchus tshawytscha*				X		
Longfin smelt *Spirinchus thaleichthys*						
Delta smelt *Hypomesus transpacificus*	X					
Sacramento splittail *Pogonichthys macrolepidotus*	X					
White sturgeon *Acipenser transmontanus*						
North American green sturgeon *Acipenser medirostris*			X			
Pacific lamprey *Lampetra tridentata*			X			
River lamprey *Lampetra ayresii*						
Invertebrates						
Lange's metalmark butterfly *Apodemia mormo langei*						
Valley elderberry longhorn beetle *Desmocerus californicus dimorphus*	X		X	X	X	X

Table 3-6. BDCP Covered Species that are Covered or Proposed for Coverage under Overlapping and Adjacent HCPs and NCCPs (continued)

BDCP Covered Species	***Species Covered or Currently Proposed for Coverage in Adjacent and Overlapping HCPs and NCCPs***					
	San Joaquin County HCP	**East Contra Costa HCP/NCCP**	**Natomas Basin HCP**	**Solano County HCP[13]**	**South Sacramento HCP[14]**	**Yolo County HCP/NCCP**
Invertebrates						
Vernal pool tadpole shrimp *Lepidurus packardi*	X	X	X	X	X	X
Conservancy fairy shrimp *Branchinecta conservation*	X					X
Longhorn fairy shrimp *Branchinecta longiantenna*	X	X				
Vernal pool fairy shrimp *Branchinecta lynchi*	X	X	X	X	X	X
Midvalley fairy shrimp *Branchinecta mesovalleyensis*		X	X X	X	X	X
California linderiella *Linderiella occidentalis*				X		X
Plants						
Alkali milk-vetch *Astragalus tener* var. *tener*				X		X
Heartscale *Atriplex cordulata*				X		
Brittlescale *Atriplex depressa*		X		X		X
San Joaquin spearscale *Atriplex joaquiniana*		X		X		X
Slough thistle *Cirsium crassicaule*	X					
Suisun thistle *Cirsium hydrophilum* var. *hydrophilum*				X		
Soft bird's-beak *Cordylanthus mollis* ssp. *mollis*				X		

Table 3-6. BDCP Covered Species that are Covered or Proposed for Coverage under Overlapping and Adjacent HCPs and NCCPs (continued)

BDCP Covered Species	***Species Covered or Currently Proposed for Coverage in Adjacent and Overlapping HCPs and NCCPs***					
	San Joaquin County HCP	**East Contra Costa HCP/NCCP**	**Natomas Basin HCP**	**Solano County HCP**[13]	**South Sacramento HCP**[14]	**Yolo County HCP/NCCP**
Plants						
Dwarf downingia *Downingia pusilla*				X	X	
Delta button-celery *Eryngium racemosum*	X					
Contra Costa wallflower *Erysimum capitatum* var. *angustatum*						
Boggs Lake hedge-hyssop *Gratiola heterosepala*	X		X	X	X	
Carquinez goldenbush *Isocoma arguta*				X		
Delta tule pea *Lathyrus jepsonii* var. *jepsonii*	X			X		X
Legenere *Legenere limosa*	X		X	X	X	
Heckard's peppergrass *Lepidium latipes* var. *heckardii*				X		X
Mason's lilaeopsis *Lilaeopsis masonii*	X	X				X
Delta mudwort *Limosella subulata*	X					
Antioch Dunes evening-primrose *Oenothera deltoides* ssp. *howellii*						
Side-flowering skullcap *Scutellaria lateriflora*	X		X			
Suisun Marsh aster *Symphyotrichum lentum* (formerly *Aster lentus*)	X		X			
Caper-fruited tropidocarpum *Tropidocarpum capparideum*						

Opportunities exist for joint implementation of conservation actions for covered species and natural communities both inside and outside of the BDCP Plan Area. The BDCP Implementation Office may partner with willing regional conservation planning sponsors to jointly implement conservation actions that complement each plan and provide economies of scale and efficiencies. These partnerships would be guided by the following criteria.

- BDCP is responsible for the mitigation of its impacts; and the mitigation actions and the mitigation requirements of the BDCP must be additive to the mitigation obligations of other plans (i.e., BDCP mitigation cannot supplant the mitigation obligations of other plans); and

Conservation actions implemented by another conservation program within the BDCP Plan Area on behalf of the BDCP could be funded by the BDCP to cover the costs of initial implementation, long-term management, long-term monitoring, and remedial actions.

3.3 BIOLOGICAL GOALS AND OBJECTIVES

This section describes the biological goals and objectives of the BDCP. Biological goals are defined as broad guiding principles for development of the Conservation Strategy that can be parsed into more manageable subsets of biological objectives. These objectives, in turn, provide measurable metrics by which to measure progress in meeting plan goals and help inform the adaptive management process. The BDCP biological goals and objectives are consistent with the guidance provided in the federal Five-Point Policy for Habitat Conservation Plans[15] and with the BDCP Planning Agreement conservation goals and objectives. BDCP biological goals are intended to be broad principles designed to guide the conservation strategy to meet the statutory criteria of the NCCPA and Sections 7 and 10 of the ESA. BDCP objectives may be either habitat or species based, and they are described as specific, measurable objectives.[16] Specific biological goals and objectives set parameters and benchmarks for the development and implementation of BDCP conservation measures and help frame the monitoring and adaptive management programs.

The biological goals and objectives are purposefully framed to reflect and respond to the significant ecological complexity of the Delta and associated scientific uncertainties. They are designed to serve several important functions in the Conservation Strategy. The first is to describe the desired biological outcomes of the Conservation Strategy, and how those outcomes will contribute to the long-term conservation of covered species and their habitats. The second is to serve as important yardsticks by which to measure progress in achieving those outcomes across multiple temporal and spatial scales. A third, closely related function, is to provide the context and framework for the monitoring program and monitoring metrics by which to evaluate the effectiveness of the conservation measures themselves, and to inform the adaptive

[15] See 65 FR No. 106 at 35242 (June 1, 2000)

[16] According to the federal Five Point HCP Policy, "the Services and the applicants must determine the appropriate unit of measure such as numbers of individuals at a particular life stage, all life stages, or quantity or quality of habitat." 65 Fed. Reg. 35242, 35244 (June 1, 2000).

management program through which adjustments to the Conservation Strategy may occur over the course of its implementation.

As is standard practice in conservation planning, these biological goals and objectives are themselves not intended to constitute permit conditions or otherwise serve as required regulatory targets for the permittees/authorized entities. Rather, the purpose of biological goals and objectives is to guide the development and implementation of the conservation strategy. As long as permittees/authorized entities properly implement the Conservation Strategy elements, they will be fulfilling their plan obligations in compliance with their Section 10 and Section 2835 permits.[17]

The ecological complexity of the Delta and the extent of scientific uncertainty associated with this complexity require a conservation strategy that is flexible, testable, and scientifically grounded. A rationale that identifies the general underlying problems is provided with each of the biological goals and objectives statements. The BDCP Conservation Strategy is built on a set of core hypotheses about how to restore the ecological processes and functions necessary to achieve biological goals and objectives over time. Core hypotheses are articulated as problem statements that are associated with each of the conservation measures and are intended to provide an orderly, scientifically-disciplined approach to managing complexity and uncertainty. These core hypotheses will be tested and evaluated, verified or adjusted during BDCP implementation through an adaptive management process. The biological goals and objectives are part of this overall approach. They are designed in a conceptual hierarchy, the components of which are measurable, transparent and verifiable. They are intended to be consistent with the goals and objectives of existing recovery plans and other regional species plans goals that have been established for the covered species, so that implementation of the BDCP contributes to the long-term conservation of covered species and their habitats.

The biological goals and objectives are organized hierarchically on the basis of the following ecological scale:

- **Ecosystem Goals and Objectives.** Ecosystem goals and objectives are focused on the extent, distribution, and connectivity among habitats and improvements to the overall condition of hydrological, physical, chemical, and biological processes in the Plan Area in support of achieving goals and objectives for natural communities and covered species.
- **Natural Community Goals and Objectives.** Natural community goals and objectives are focused on maintaining or enhancing ecological functions and values of natural communities. Achieving natural community goals and objectives also serve to conserve habitat of associated covered species and other native species.
- **Species-Specific Goals and Objectives.** Species-specific goals and objectives address species-specific stressors and habitat needs that are not addressed under the higher order

[17] As the federal fish and wildlife agencies have stated, "[w]hether the HCP is based on prescriptions, results, or both, the permittee's obligation for meeting the biological goals and objectives is proper implementation of the operating conservation program. In other words, under the No Surprises assurances, a permittee is required only to implement the HCP, IA, if any, and terms and conditions of the permit." 65 Fed. Reg. at 35251.

ecosystem and natural community goals and objectives. For covered fish species, goals and objectives may be life stage specific.

These goals and objectives are intended to encompass the ecological functions within the Plan Area that are important for covered species. They thus relate directly to the functions of habitats within the Plan Area that have been designated as "critical habitats" for covered species by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service. Table 3-7 correlates these goals and objectives to the elements of critical habitats within the Plan Area deemed important by both agencies for species proposed to be covered by the BDCP.

Table 3-7. Goals and Objectives that Address Primary Constituent Elements of Critical Habitat Designated for Covered Species

Primary Constituent Element of Critical Habitat	*Goals and Objectives that Address Primary Constituent Elements*	
	Goals	**Objectives**
California tiger salamander critical habitat[7]		
Standing bodies of fresh water (including natural and manmade (e.g., stock)) ponds, vernal pools, and other ephemeral or permanent water bodies which typically support inundation during winter rains and hold water for a minimum of 12 weeks in a year of average rainfall.	VPNC1; VPNC2; ONSW1	VPNC1.1; VPNC2.1; ONSW1.1
Upland habitats adjacent and accessible to and from breeding ponds that contain small mammal burrows or other underground habitat that California tiger salamander depend upon for food, shelter, and protection from the elements and predation.	GRNC1; GRNC2; ONSW1	GRNC1.1; GRNC1.2; GRNC2.2; GRNC2.3; GRNC2.4; ONSW1.1
Accessible upland dispersal habitat between occupied locations that allow for movement between such sites.	GRNC1; GRNC2	GRNC1.1; GRNC1.2; GRNC2.1; GRNC2.2; GRNC2.3; GRNC2.4
Vernal pool tadpole shrimp, Conservancy fairy shrimp, and vernal pool fairy shrimp critical habitat[8]		
Topographic features characterized by mounds and swales, and depressions within a matrix of surrounding uplands that result in complexes of continuously, or intermittently, flowing surface water in the swales connecting the pools described in PCE (ii), providing for dispersal and promoting hydroperiods of adequate length in the pools.	VPNC1; VPNC2; GRNC1	VPNC1.1; VPNC2.1; GRNC1.1; GRNC1.2
Depressional features including isolated vernal pools with underlying restrictive soil layers that become inundated during winter rains and that continuously hold water for a minimum of 41 days (vernal pool tadpole shrimp), 19 days (Conservancy fairy shrimp, and 18 days for vernal pool fairy shrimp (Helm 1998), in all but the driest years; thereby providing adequate water for incubation, maturation, and reproduction. As these features are inundated on a seasonal basis, they do not promote the development of obligate wetland vegetation habitats typical of permanently flooded emergent wetlands.	VPNC1; VPNC2; GRNC1	VPNC1.1; VPNC2.1; GRNC1.1; GRNC1.2
Sources of food, expected to be detritus occurring in the pools, contributed by overland flow from the pools' watershed, or the results of biological processes within the pools themselves, such as single-celled bacteria, algae, and dead organic matter, to provide for feeding.	VPNC1; VPNC2; GRNC1	VPNC1.1; VPNC2.1; VPNC2.2; GRNC1.1; GRNC1.2

Table 3-7. Goals and Objectives that Address Primary Constituent Elements of Critical Habitat Designated for Covered Species (continued)

Primary Constituent Element of Critical Habitat	*Goals and Objectives that Address Primary Constituent Elements*	
	Goals	**Objectives**
Structure within the pools described in PCE (ii), consisting of organic and inorganic materials, such as living and dead plants from plant species adapted to seasonally inundated environments, rocks, and other inorganic debris that may be washed, blown, or otherwise transported into the pools, that provide shelter.	VPNC1; VPNC2; GRNC1	VPNC1.1; VPNC2.1; VPNC2.2; GRNC1.1; GRNC1.2
Suisun thistle[9]		
Persistent emergent, intertidal, estuarine wetland at or above the mean high-water line (as extended directly across any intersecting channels).	BMNC1	BMNC1.1
Open channels that periodically contain moving water with ocean-derived salts in excess of 0.5 percent.	BMNC1	BMNC1.1
Gaps in surrounding vegetation to allow for seed germination and growth.	BMNC1; BMNC2; SUTH1	BMNC1.1; BMNC2.1; SUTH1.2
Soft bird's-beak[9]		
Persistent emergent, intertidal, estuarine wetland at or above the mean high-water line (as extended directly across any intersecting channels).	BMNC1	BMNC1.1
Rarity or absence of plants that naturally die in late spring (winter annuals)	BMNC1; BMNC2	BMNC1.1; BMNC2.1
Partially open spring canopy cover (approximately 790 nMol/m2/s) at ground level, with many small openings to facilitate seedling germination.	BMNC1; BMNC2; SOBB1	BMNC1.1; BMNC2.1; SOBB1.2

[7]From Final Rule, Federal Register, Vol. 70, No. 154, August 11, 2005. pp. 46923-46999.
[8]From Final Rule, Federal Register, Vol. 72, No. 70, April 12, 2007. pp. 18517-18553.
[9]From Final Rule, Federal Register, Vol. 72, No. 70, April 12, 2007. pp. 18518-18553.

Monitoring metrics and metric values or targets that may be associated with these monitoring metrics accompany objectives and are described in Section 3.6, *Monitoring and Research Program*. The purpose of the metrics and targets is to describe how progress will be measured towards or away from these goals and objectives over the course of BDCP implementation. They are intended to enable the BDCP Implementation Office and other interested parties to track how the implementation of the conservation measures may be effectuating improvements in the system as a whole at the larger scale of these objectives. In some cases, these metrics may be identical to those used to track the effectiveness of individual conservation measures; in other cases, the metrics may be broader than those established for conservation measures.

The metrics for these biological objectives are described in Section 3.6, *Monitoring and Research Program*. These metrics will likely change over the term of the BDCP as new capabilities emerge to track performance in achieving the objectives and as the scientific understanding of the ecological and biological functions of the Bay Delta evolve. They are intended to serve as an essential component of the monitoring and adaptive management program for the Plan, and may be changed through the BDCP adaptive management decision making process (Section 3.7, *Adaptive Management Program*).

3.3.1 Framework for the Goals and Objectives

To address the many uncertainties associated with conserving covered fish species, the aquatic biological goals and objectives were shaped within the framework of the "logic chain" architecture as described in Section 3.2.3.1, *Aquatic Resources Conservation Strategy Development Process*. The logic chain captures the underlying rationale and assumptions for the conservation measures and establishes benchmarks against which progress can be measured. This clear articulation of hypotheses and expected outcomes of implementing the conservation measures facilitates the effective assessment of progress towards achieving the goals and objectives and the effectiveness of the conservation measures during Plan implementation.

Figure 3-12 and Figure 3-13 illustrate these hierarchical relationships between broad, general goals at the species and ecosystem levels, BDCP biological goals and objectives, conservation measures that are designed to achieve the biological goals and objectives (see Section 3.4, *Conservation Measures*), and the monitoring and adaptive management components of the Conservation Strategy (Section 3.6, *Monitoring and Research Program*, and Section 3.7, *Adaptive Management Program*). Figure 3-12 depicts the relationship among the different tiers of the BDCP goals and objectives themselves, and how these tiers tie back into the viability attributes. Figure 3-13 depicts the relationship between overall general species conservation and recovery goals – at the top of the pyramid – and the key substantive components of the BDCP plan itself: the biological goals and objectives for the BDCP, the conservation measures of the BDCP, and the monitoring and adaptive management actions for the BDCP. It also describes the key attributes of long-term species viability in terms of abundance, diversity, spatial distribution and growth rates so as to demonstrate graphically how the BDCP goals and objectives and its conservation measures are intended to contribute to the achieving of these attributes. Together, these two figures are intended to illustrate the tiered conceptual hierarchy both within the BDCP itself and how it will contribute to the larger conservation goals for those species covered by the plan.

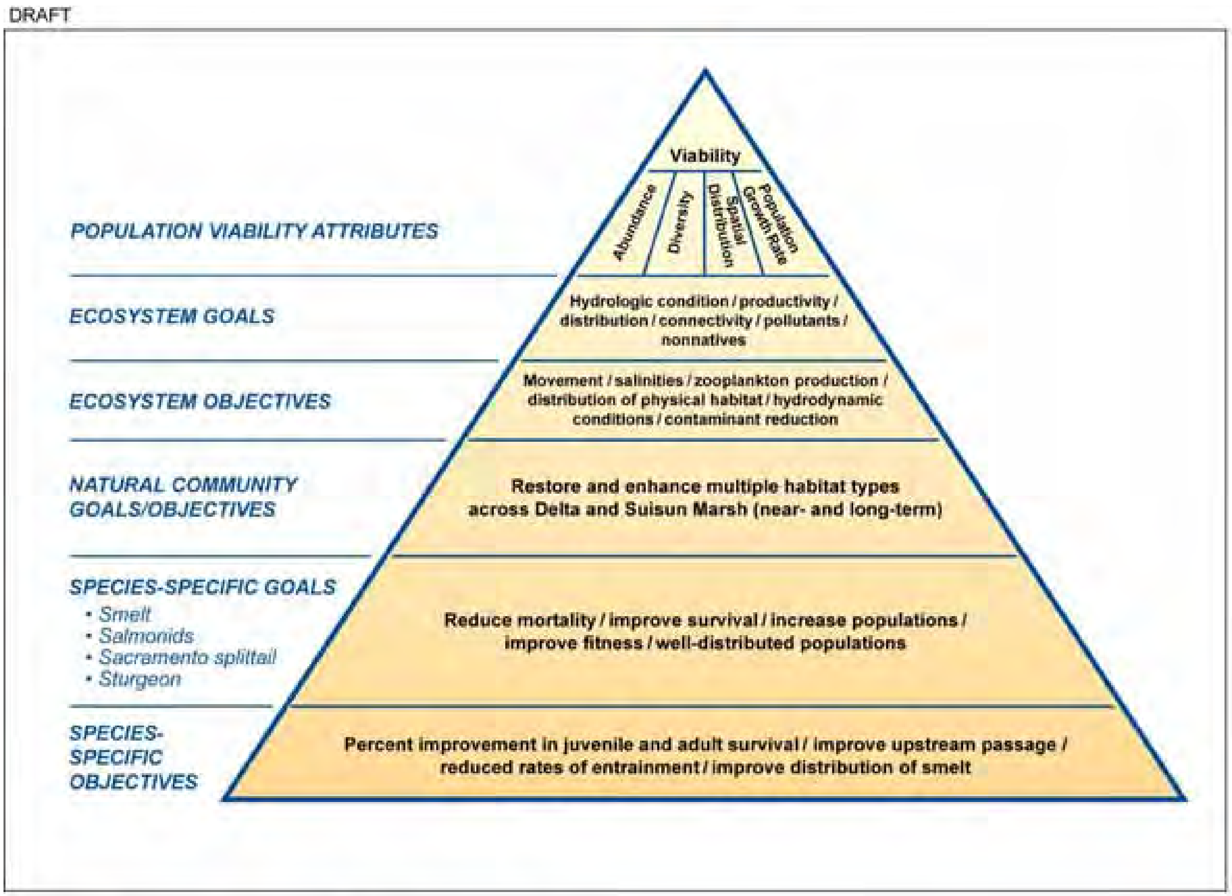

Figure 3-12. Relationships Among Goals and Objectives Tiers

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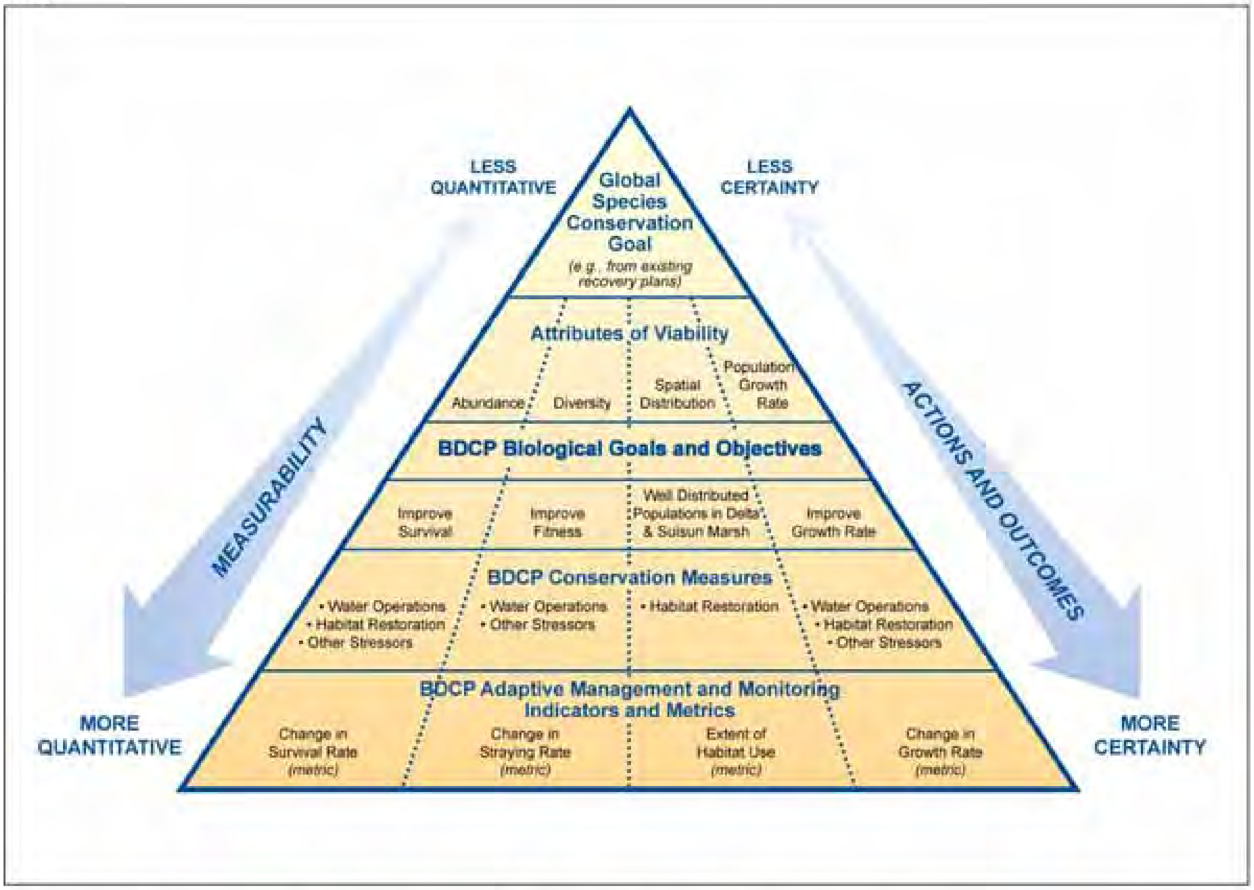

Figure 3-13. Biological Goals and Objectives: Relationships with Broader Goals, Conservation Measures, Adaptive Management, and Monitoring

There is generally greater certainty associated with conservation approaches to covered wildlife and plant species than for covered fish species. The development of goals and objectives for natural communities and covered wildlife and plant species followed a well established approach based on the frameworks used in other HCP/NCCPs and USFWS recovery plans that address the same species and communities. HCP and NCCP programs with plan areas that overlap with the BDCP Plan Area were used as sources of information in developing goals and objectives for the BDCP natural communities and covered wildlife and plants. Based on guidance from and in collaboration with the USFWS and DFG, the biological goals and objectives were developed. The goals and objectives are intended to guide the conservation strategy and meet the statutory criteria for the NCCPA and Sections 7 and 10 of the ESA. Through a collaborative and iterative process, goals and objectives for each covered natural community and covered species were formulated on the basis of specific biological rationale based on the ecological setting, species biology, threats to communities and species, and the potential effects of covered activities. Conservation measures and avoidance and minimization measures were designed to achieve the broad-based goals and the more specific or measureable objectives. The monitoring, research, and adaptive management programs will provide new information and program flexibility to improve the conservation actions to meet goals and objectives during Plan implementation.

3.3.2 Goal and Objective Statements

This section presents the ecosystem, natural community, and species-specific biological goals and objectives. Each goal and objective is assigned a unique alpha-numeric code that is used throughout the BDCP document and that will assist with monitoring of implementation of the BDCP Conservation Strategy. A rationale is associated with each of the biological goals and objectives statements. These rationales identify the general underlying problems that the conservation measures (that are designed to achieve each of the biological objectives) are intended to address.

3.3.2.1 Ecosystem Goals and Objectives

Ecosystem goals and objectives were developed to follow the principles of conservation biology and the requirements of NCCPA. For the covered fish species, the ecosystem goals and objectives are designed to address major stressors of ecosystem processes and functions that support the covered species. These goals and objectives address the hydrodynamic and water quality functions of habitat, movement, and food production for each of the life stages of the covered fish species using the Plan Area, as well as the effects of nonnative predator and competitor species. For the covered wildlife and plant species, these goals and objectives address the desired extent, distribution, connectivity, and ecological function of ecosystems supporting their habitats and life requirements within the BDCP landscape.

3.3.2.1.1 Landscapes and Ecological Gradients

Goal ECSY1: Protect and restore large landscapes representing a range of physical and biological attributes (e.g., hydrology, soil, and plant associations) necessary to sustain viable populations of covered species and to preserve native species biodiversity.

> **Objective ECSY1.1:** Protect 25,000-41,000 acres of existing natural communities that support covered species.

> **Objective ECSY1.2:** Protect a range of environmental gradients (e.g., hydrology, elevation, and soils) across a diversity of natural communities.

> **Objective ECSY1.3:** Restore or create up to 65,000 acres of tidally influenced habitat consisting of subtidal, mudflat, tidal marsh, and transitional upland habitat for sea level rise accommodation that supports a gradient of natural communities and habitat for covered species.

> **Objective ECSY1.4:** Restore or create up to 10,000 acres of seasonally inundated floodplain and 20 miles of channel margin habitat.

> **Objective ECSY1.5:** Manage protected and restored or created habitats to enhance habitat functions for associated covered and other native species over the term of the BDCP.

Goal ECSY2: Provide hydrodynamic conditions within Delta waterways that are more reflective of natural patterns of flow within the BDCP Plan Area and Suisun Marsh.

> **Objective ECSY2.1:** Support the movement of larval and juvenile life stages of native fish species to downstream rearing habitats.

> **Objective ECSY2.2:** Support the movement of adult life stages of native fish species to natal spawning habitats.

> **Objective ECSY 2.3:** Promote water quality conditions within the Delta that help restore native fish habitat.

> **Objective ECSY2.4:** Maintain or increase life history diversity of native fishes and a diversity of rearing conditions for native fishes over time.

> **Objective ECSY 2.5:** Promote greater connectivity between low salinity zone habitats and upstream freshwater habitats, and availability of spawning habitats for native pelagic species.

Rationale

Habitat loss, fragmentation, and degradation within and outside of the Plan Area have disrupted the ecosystem function and large-scale habitat connectivity that are necessary for sustaining covered and other native species and maintaining biodiversity. Protecting and restoring large swaths of connected habitat will enhance ecosystem processes and connectivity and help increase the abundance, distribution, and diversity of covered and other native species.

3.3.2.1.2 Connectivity

Goal ECSY3: Provide for connectivity among protected lands to provide for the movement of native organisms among habitat areas and to facilitate genetic exchange among populations.

> **Objective ECSY3.1:** Protect corridors of habitat that provide linkages among protected habitat areas within and adjacent to the Plan Area.

> **Objective ECSY3.2:** Improve habitat corridors that allow covered and other native species to move into protected habitats from adjacent areas and to move among habitat areas within protected lands.

Rationale

The destruction of habitat for native species has both reduced the extent of habitat and fragmented more extensive areas of habitat into isolated patches of habitat. These impacts to habitat have disrupted the historical movement and dispersal patterns of individuals and their genetics and threaten the health and existence of the species. Maintaining habitat connectivity also makes it more likely that individuals can disperse into and colonize new habitat or territories as those areas become available. Achievement of this goal will benefit all covered and other native species within the Plan Area.

3.3.2.1.3 Ecosystem Processes

Goal ECSY4: Promote ecosystem processes that support natural communities, covered species, other native species, and the habitats of those species.

> **Objective ECSY4.1**: Maintain and improve disturbance regimes and other processes that support functioning natural communities.

Goal ECSY5: Increase aquatic primary and secondary production in the Delta, Yolo Bypass and Suisun Marsh to increase the abundance and availability of food for native aquatic organisms.

> **Objective ECSY5.1:** Over the term of the BDCP, increase the abundance and productivity of zooplankton that provide food and support food production for covered fish species in Delta waterways.

Objective ECSY5.2: Over the term of the BDCP, increase the abundance and productivity of aquatic invertebrate species that provide food and support food production for covered fish species in Delta waterways.

Goal ECSY6: Reduce the adverse predation effects of nonnative species on covered fish species.

Objective ECSY6.1: Manage the distribution and abundance of established nonnative predators in the Delta to reduce predation on native covered fishes.

Objective ECSY6.2: Manage the distribution of covered fish species to minimize movements into high predation risk areas of the Delta.

Rationale

The variability and range of ecosystem characteristics such as disturbance regimes and dynamic ecosystem physical and chemical processes such as tidal and nontidal inundation dynamics, seasonal fluvial flooding and low flow dynamics, and nutrient flows have been drastically altered or eliminated in the Plan Area due to the modification of ecosystem hydrology, the conversion of natural habitat to agricultural systems, residential and commercial development, and other anthropogenic effects. These ecosystem physical and chemical processes drive many biological processes and contribute towards sustaining viable populations of covered and other native species. Maintaining and restoring these ecosystem processes will sustain and increase the extent of natural communities which support the abundance, distribution, and diversity of covered and other native species, which are expected to increase or maintain as described in this Plan. .

3.3.2.1.4 Climate Change

Goal ECSY7: Protect lands with a sufficient range of habitat conditions to accommodate anticipated shifts in the distributions of covered species and natural communities in response to climate change.

Objective ECSY7.1: Protect sufficient upland transitional habitat area adjacent to restored brackish and freshwater tidal emergent wetland to permit the future upslope natural establishment of tidal emergent wetland communities with sea level rise.

Rationale

The effects of climate change on the Plan Area are expected to have far-reaching and potentially dramatic impacts on native species and natural communities. Sea level rise will inundate some subsided and low-lying terrestrial areas, while other effects of climate change are expected to be more complex. For example, changes in temperature range and precipitation patterns may cause some areas of suitable habitat to become unsuitable for some species; while other areas of currently unsuitable habitats may become suitable for other species. Many habitats and species are expected to be affected and their temporal dynamics and spatial distributions will change in unpredictable ways. Faced with such large, uncertain, and dynamic responses, it is important that a broad range of elevation, connectivity, and other habitat characteristics be protected to ensure that while some current habitat may be lost to species due to global climate change, sufficient suitable habitat will remain available to sustain both covered and non-covered species. Achievement of this goal will benefit all covered and other native species within the Plan Area.

3.3.2.2 Natural Community Goals and Objectives

Natural community goals and objectives were developed following the principles of conservation biology and the requirements of the NCCPA. Natural community goals and objectives were developed to address:

- Protecting each natural community in quantities and locations that contribute to the conservation of associated covered and other native species;
- Maintaining and enhancing the habitat functions supported by preserved habitats to provide for sustaining and increasing the abundance and distribution of associated covered and other native species; and
- Restoring or creating natural communities to increase the extent and availability of covered and other native species habitats to accommodate increases in abundance and distribution.

Information used to develop the natural community goals and objectives included:

- Current spatial distribution and extent of each natural community within the Conservation Zones (Figure 3-3 through Figure 3-8);
- Preliminary estimates of the extent of each natural community that could be affected by the implementation of BDCP covered activities and conservation measures;
- Condition of habitat functions supported by existing patches of natural communities;
- Function of existing patches of natural communities as habitat corridors supporting the movement of covered and other native species among habitat areas inside and outside of the Conservation Zones;
- Spatial distribution of patches of natural communities relative to existing preserved areas;
- The spatial distribution of covered species habitats within Conservation Zones and the distribution of known occurrences of covered species; and
- The habitat-related conservation needs of covered and other native species within and adjacent to the Conservation Zones.

Each natural community supports habitat for multiple covered species and multiple natural communities may provide habitat functions for a particular covered species. Table 3-8 describes the habitat functions that are provided by each of the natural communities that primarily support each species in the Plan Area. Table 3-9 identifies all of the natural communities that support habitat for each of the covered species as described in each species' habitat model (see Appendix A, *Covered Species Accounts*). For example, grassland supports foraging habitat for the Swainson's hawk and breeding and foraging habitat for the western burrowing owl. Agricultural lands also support foraging habitat for both of these species. Consequently, conservation of foraging habitat for these species can be accomplished by preserving, enhancing, and/or restoring a specified quantity of either grassland or agricultural land or a combination of both. The strategy for the conservation of natural communities is based on the need to provide a distributed and heterogeneous spatial arrangement of habitat for each covered species.

Natural community goals and objectives are outlined below. The approach and rationale used to establish each objective follows for each natural community. Conservation measures designed to meet all objectives are found in Section 3.4. Table 3-10 presents the expected extent of each natural community that will be protected and restored in the Plan Area with full BDCP implementation.

3.3.2.2.1 Tidal Perennial Aquatic

Tidal perennial aquatic natural community includes both deep and shallow aquatic environments (deep is greater than 10 ft [approximately 3 m] depth from mean lower low tide [lowest of the low tide in a day]; shallow is from mean lower low tide to 10 ft [3 m] depth) (CALFED 2000). Under current water operation conditions in the Plan Area, the tidal perennial aquatic natural community is predominantly fresh water with brackish conditions occurring in Suisun Bay at times of high tides and low river flows.

The tidal perennial aquatic natural community is an important link between upstream and downstream ecosystems. Much of the productivity, organic matter, and inorganic sediment from upstream waterways and marshes eventually moves into the tidal perennial aquatic community and subsequently moves downstream to the Pacific Ocean. In the Plan Area, saline oceanic water mixes with freshwater from rivers in the western region of the tidal perennial aquatic natural community. This mixing establishes a salinity gradient, which varies by area and location with seasonal variations in freshwater outflow and tidal action and which drives the location of species that require specific salinity ranges. Historically, in most seasons, the salinity gradient was generally farther downstream than it now occurs under similar precipitation and unimpaired flow conditions (Contra Costa Water District 2010). See Section 2.3.4.1, *Tidal Perennial Aquatic* in Chapter 2, *Existing Ecological Conditions*, for more detail on the current state of the tidal perennial aquatic natural community.

The historical functions of the tidal perennial aquatic natural community in the Delta have been substantially reduced through the destruction of tidal communities and the loss and fragmentation of aquatic habitats, and the alteration of natural tidal regimes.

Table 3-8. Habitat Function of BDCP Natural Communities that Support Primary Habitats for Covered Wildlife and Plant Species[18]

Covered Species	*Natural Community*													
	Tidal perennial aquatic	**Tidal mudflat**	**Tidal brackish emergent wetland**	**Tidal freshwater emergent wetland**	**Valley/ foothill riparian**	**Grassland**	**Inland dune scrub**	**Alkali seasonal wetland complex**	**Vernal pool complex**	**Other natural seasonal wetland**	**Nontidal freshwater perennial emergent wetland**	**Nontidal perennial aquatic**	**Managed wetland**	**Agricultural habitats**
Mammals														
San Joaquin kit fox						All life history require-ments								Foraging and movement
Riparian woodrat					All life history require-ments									
Salt marsh harvest mouse			All life history require-ments			Upland refugia during high tides								
Riparian brush rabbit					All life history require-ments									
Townsend's big-eared bat	Foraging	Foraging	Foraging	Foraging	Roosting and Foraging	Foraging		Foraging	Foraging	Foraging	Foraging	Foraging	Foraging	Foraging
Suisun shrew			All life history require-ments			Upland refugia during high tides							All life history require-ments	
Birds														
Tricolored blackbird				Breeding	Breeding	Foraging		Foraging	Foraging	Foraging	Breeding		Breeding and Foraging	Foraging
Suisun song sparrow			All life history require-ments	All life history require-ments									All life history require-ments	
Yellow-breasted chat					All life history require-ments									
Least Bell's vireo					All life history require-ments.									
Western burrowing owl						Breeding and foraging		Foraging	Foraging	Foraging			Foraging	Breeding and foraging
Western yellow-billed cuckoo					All life history require-ements									
California least tern	Foraging													

[18] This table represents primary habitats for covered species and species groups, not all the natural communities that may support some habitat functions included in each species' habitat models presented in Appendix A, Covered Species Accounts.

Table 3-8. Habitat Function of BDCP Natural Communities that Support Primary Habitats for Covered Wildlife and Plant Species[19] (continued)

Covered Species	*Natural Community*													
	Tidal perennial aquatic	**Tidal mudflat**	**Tidal brackish emergent wetland**	**Tidal freshwater emergent wetland**	**Valley/ foothill riparian**	**Grassland**	**Inland dune scrub**	**Alkali seasonal wetland complex**	**Vernal pool complex**	**Other natural seasonal wetland**	**Nontidal freshwater perennial emergent wetland**	**Nontidal perennial aquatic**	**Managed wetland**	**Agricultural habitats**
Birds														
Greater sandhill crane						Foraging		Foraging	Foraging	Foraging			Foraging and roosting	Roosting and foraging
California black rail			All life history require-ments	All life history require-ments							All life history require-ments			
California clapper rail			All life history require-ments											
Swainson's hawk					Breeding	Foraging		Foraging	Foraging	Foraging			Foraging	Foraging
White-tailed kite					Breeding	Foraging		Foraging	Foraging	Foraging			Foraging	Foraging
Reptiles														
Giant Garter Snake	Breeding, foraging, and move-ment			Breeding, foraging, and movement		Aestiva-tion and movement		Aestiva-tion and movement	Aestiva-tion and movement	Breeding, foraging, and move-ment	Breeding, foraging, and movement	Breeding, foraging, and movement	Aestiva-tion and movement	Breeding (rice), foraging, aestivation, and movement
Western pond turtle	Foraging and move-ment		Foraging and movement	Foraging and movement	Breeding, foraging, aestivation, and movement	Breeding, foraging, aestivation, and movement		Foraging and movement	Foraging and movement	Foraging and move-ment	Foraging and movement	Foraging and move-ment	Foraging and movement	Foraging, and movement
Amphibians														
California red-legged frog				Breeding, foraging and movement	Foraging, aestivation, and movement	Foraging, aestivation, and movement			Foraging, aestivation, and movement		Breeding, foraging and movement	Breeding, foraging	Foraging and movement	Foraging and movement
Western spadefoot toad						Foraging, aestivation, and movement		Foraging, aestivation, and movement	Breeding and foraging	Foraging, and breeding		Breeding		
California tiger salamander						Foraging, cover, and movement		Foraging and movement	Breeding and foraging					

[19] This table represents primary habitats for covered species and species groups, not all the natural communities that may support some habitat functions included in each species' habitat models presented in Appendix A, Covered Species Accounts.

Table 3-8. Habitat Function of BDCP Natural Communities that Support Primary Habitats for Covered Wildlife and Plant Species[19] (continued)

Covered Species	*Natural Community*													
	Tidal perennial aquatic	**Tidal mudflat**	**Tidal brackish emergent wetland**	**Tidal freshwater emergent wetland**	**Valley/ foothill riparian**	**Grassland**	**Inland dune scrub**	**Alkali seasonal wetland complex**	**Vernal pool complex**	**Other natural seasonal wetland**	**Nontidal freshwater perennial emergent wetland**	**Nontidal perennial aquatic**	**Managed wetland**	**Agricultural habitats**
Invertebrates														
Lange's metalmark butterfly							All life history require-ments							
Valley elderberry longhorn beetle					All life history require-ments									
Vernal pool tadpole shrimp									All life history require-ments					
Conservancy fairy shrimp									All life history require-ments					
Longhorn fairy shrimp									All life history require-ments					
Vernal pool fairy shrimp									All life history require-ments					
Mid Valley fairy shrimp									All life history require-ments					
California linderiella									All life history require-ments					

Table 3-8. Habitat Function of BDCP Natural Communities that Support Primary Habitats for Covered Wildlife and Plant Species[19] (continued)

Covered Species	*Natural Community*													
	Tidal perennial aquatic	**Tidal mudflat**	**Tidal brackish emergent wetland**	**Tidal freshwater emergent wetland**	**Valley/ foothill riparian**	**Grassland**	**Inland dune scrub**	**Alkali seasonal wetland complex**	**Vernal pool complex**	**Other natural seasonal wetland**	**Nontidal freshwater perennial emergent wetland**	**Nontidal perennial aquatic**	**Managed wetland**	**Agricultural habitats**
Plants														
Alkali milk-vetch[2]									All life history require-ments					
Heartscale[3]						All life history require-ments		All life history require-ments	All life history require-ments					
Brittlescale[3]						All life history require-ments		All life history require-ments	All life history require-ments					
San Joaquin spearscale[4]						All life history require-ments		All life history require-ments	All life history require-ments					
Slough thistle[6]					All life history require-ments									
Suisun thistle[7]			All life history require-ments											
Soft bird's-beak[8]			All life history require-ments											
Dwarf downingia									All life history require-ments					
Delta button celery[9]					All life history require-ments	All life history require-ments		All life history require-ments	All life history require-ments					
Contra Costa wallflower							All life history require-ments							

Table 3-8. Habitat Function of BDCP Natural Communities that Support Primary Habitats for Covered Wildlife and Plant Species[19] (continued)

Covered Species	*Natural Community*													
	Tidal perennial aquatic	**Tidal mudflat**	**Tidal brackish emergent wetland**	**Tidal freshwater emergent wetland**	**Valley/ foothill riparian**	**Grassland**	**Inland dune scrub**	**Alkali seasonal wetland complex**	**Vernal pool complex**	**Other natural seasonal wetland**	**Nontidal freshwater perennial emergent wetland**	**Nontidal perennial aquatic**	**Managed wetland**	**Agricultural habitats**
Plants														
Boggs Lake hedge-hyssop									All life history require-ments					
Carquinez goldenbush[10]						All life history require-ments		All life history require-ments						
Delta tule pea[11]			All life history require-ments	All life history require-ments	All life history require-ments									
Legenere									All life history require-ments					
Heckard's peppergrass[12]									All life history require-ments					
Mason's lilaeopsis[13]		All life history require-ments	All life history require-ments	All life history require-ments	All life history require-ments									
Delta mudwort[13]		All life history require-ments	All life history require-ments	All life history require-ments	All life history require-ments									
Antioch Dunes evening-primrose							All life history require-ments							
Side-flowering skullcap					All life history require-ments									
Suisun Marsh aster[14]			All life history require-ments	All life history require-ments	All life history require-ments									

Table 3-8. Habitat Function of BDCP Natural Communities that Support Primary Habitats for Covered Wildlife and Plant Species[19] (continued)

Covered Species	*Natural Community*													
	Tidal perennial aquatic	**Tidal mudflat**	**Tidal brackish emergent wetland**	**Tidal freshwater emergent wetland**	**Valley/ foothill riparian**	**Grassland**	**Inland dune scrub**	**Alkali seasonal wetland complex**	**Vernal pool complex**	**Other natural seasonal wetland**	**Nontidal freshwater perennial emergent wetland**	**Nontidal perennial aquatic**	**Managed wetland**	**Agricultural habitats**
Plants														
Caper-fruited tropidocarpum						All life history require-ments								
Other Species Groups														
Wintering Waterfowl	Foraging and resting	Foraging and resting	Foraging and resting	Foraging and resting		Foraging and resting		Foraging and resting	Foraging and resting	Foraging and resting	Foraging and resting	Foraging and resting	Foraging and resting	Foraging and resting
Resident Waterfowl	Foraging, resting, and brooding	Foraging and resting	Foraging and resting	Foraging and resting		Foraging, nesting, and resting		Foraging, nesting, and resting	Foraging, nesting, and resting	Foraging and resting	Foraging and resting	Foraging, resting, and brooding	Foraging and resting	Foraging, nesting, brooding, and resting
Migrant Shorebirds	Foraging and resting	Foraging and resting	Foraging and resting	Foraging and resting		Foraging and resting		Foraging and resting	Foraging and resting	Foraging and resting	Foraging and resting	Foraging and resting		Foraging and resting
Wading birds	Foraging	Foraging	Foraging and roosting	Foraging, breeding, and roosting	Roosting	Foraging		Foraging	Foraging	Foraging	Foraging and breeding	Foraging	Foraging	Foraging

[1] Riparian brush rabbits will also use small grassland and seasonal wetlands that occur immediately adjacent to or as openings within riparian communities.

[2] Occurs along the upper margins of vernal pools, playa pools, and in swales in the clay alluvium vernal pools and playas, Montezuma Block vernal pools and playas, and alkaline sink/meadow vernal pools in the BDCP vernal pool complex regions.

[3] Occurs along intermittent and perennial drainages and along the borders of playa pools in the clay alluvium vernal pools and playas, Montezuma Block vernal pools and playas, and alkaline sink/meadow vernal pools in the BDCP vernal pool complex regions. Also occurs in alkali seasonal wetland complex in the same areas.

[4] Occurs in more saline or disturbed areas in the clay alluvium vernal pools and playas, Montezuma Block vernal pools and playas, and alkaline sink/meadow vernal pools in the BDCP vernal pool complex regions. Also occurs in grassland and alkali seasonal wetland complex in the same areas.

[5] Not known to occur in the Plan Area or ROAs.

[6] In the southern San Joaquin Valley it occurs in the scoured and overflow areas of stream channels on alkaline soils. In the northern San Joaquin Valley the historical occurrences have been along tidal river channels or in wetland inclusions in agricultural fields.

[7] Endemic to the Suisun Marsh where it occurs adjacent to first-order channels or mosquito control ditches that link to first-order channels.

[8] In Suisun Marsh soft bird's-beak is distributed in bands at the lower margin of the brackish high marsh that are not correlated with elevation, but with soil pore water salinity during the dry season which is determined by distance to channel and varies from season to season depending on freshwater flows from creeks draining into the marsh. Where the topography is more complex, such as areas with ridges or mounds and on levee banks, soft bird's-beak can be found in a variety of patch shapes.

[9] Delta button celery occurs in two habitat types. One habitat type is seasonally scoured and inundated swales, depressions, and clay flats in the floodplain of the San Joaquin River and the other alkaline clay deltas of Coast Range tributaries that are deposited immediately above the flood basin of the San Joaquin River where plant cover is typical alkaline sink vegetation.

[10] Carquinez goldenbush occurs along seasonal drainages, adjacent to the margins of alkaline playa pools, and in association with vegetation that is transitional between the brackish marsh and the grasslands within the 3.4-4.3 meter NAVD88 elevation band along the eastern border of Suisun Marsh.

[11] Occurrences in open vegetation in freshwater areas are on the landward side of the landward boundary of Tidal Freshwater Emergent Wetland and in brackish water areas in and near Suisun Marsh, within a range of tidal elevations that are generally near drainages.

[12] Occurs in all BDCP vernal pool complex regions on alkaline clays soils in areas that are not deeply inundated.

[13] Occurs on open areas of tidal mudflats that are susceptible to scour and deposition and it colonizes new areas through water transported seed and vegetative parts.

[14] Occurrences in open vegetation in freshwater areas are on the landward side of the landward boundary of Tidal Freshwater Emergent Wetland and in brackish water areas in and near Suisun Marsh, within a range of tidal elevations that are generally near drainages. It is also found in less densely vegetated areas of valley/foothill riparian vegetation.

Table 3-9. Natural Communities Supporting Modeled Covered Species' Habitats

Covered Species	*Natural Communities Supporting Species Habitat*
San Joaquin kit fox	
Breeding, foraging, and dispersal habitat	Grassland, Vernal Pool Complex
Foraging and dispersal habitat	Agricultural Habitats
Riparian woodrat	Valley/Foothill Riparian
Salt marsh harvest mouse	
Wetland habitat	Tidal Brackish Emergent Wetland, Managed Wetland
Upland habitat	Grassland, Alkali Seasonal Wetland Complex, Vernal Pool Complex
Riparian brush rabbit	Valley/Foothill Riparian
Townsend's big-eared bat	
Roosting and primary foraging habitat	Valley/Foothill Riparian
Primary foraging habitat	Valley/Foothill Riparian
Secondary foraging habitat	Tidal Perennial Aquatic, Tidal Mudflat, Tidal Brackish Emergent Wetland, Tidal Freshwater Emergent Wetland, Grassland, Alkali Seasonal Wetland Complex, Vernal Pool Complex, Other Natural Seasonal Wetland, Nontidal Freshwater Perennial Emergent Wetland, Nontidal Perennial Aquatic, Managed Wetland, Agricultural Habitats
Suisun shrew	Tidal Brackish Emergent Wetland, Tidal Freshwater Emergent Wetland, Alkali Seasonal Wetland Complex, Nontidal Freshwater Perennial Emergent Wetland, Managed Wetland
Tricolored blackbird	
Nesting habitat	Tidal Brackish Emergent Wetland, Tidal Freshwater Emergent Wetland, Valley/Foothill Riparian, Nontidal Freshwater Perennial Emergent Wetland, Managed Wetland
Foraging habitat: non-agriculture	Grassland, Alkali Seasonal Wetland Complex, Vernal Pool Complex, Other Natural Seasonal Wetland, Managed Wetland
Foraging habitat: agriculture	Agricultural Habitats
Suisun song sparrow	Tidal Brackish Emergent Wetland, Tidal Freshwater Emergent Wetland, Alkali Seasonal Wetland Complex, Nontidal Freshwater Perennial Emergent Wetland, Managed Wetland
Yellow-breasted Chat	
Primary nesting and migratory habitat[2]	Valley/Foothill Riparian
Secondary nesting and migratory habitat	Valley/Foothill Riparian
Least Bell's vireo	Valley/Foothill Riparian
Western burrowing owl	
High-value habitat	Grassland, Vernal Pool complex
Moderate-value habitat	Grassland, Alkali Seasonal Wetland Complex, Vernal Pool Complex
Low-value habitat	Alkali Seasonal Wetland Complex, Vernal Pool Complex, Other Natural Seasonal Wetland, Managed Wetland, Agricultural Habitats
Western yellow-billed cuckoo	Valley/Foothill Riparian
California least tern	Tidal Perennial Aquatic
Greater sandhill crane	Grassland, Alkali Seasonal Wetland Complex, Vernal Pool Complex, Managed Wetland, Agricultural Habitats

Table 3-9. Natural Communities Supporting Modeled Covered Species' Habitats (continued)

Covered Species	*Natural Communities Supporting Species Habitat*
California black rail	Tidal Brackish Emergent Wetland, Tidal Freshwater Emergent Wetland, Alkali Seasonal Wetland Complex, Nontidal Freshwater Perennial Emergent Wetland, , Managed Wetland
California clapper rail	Tidal Brackish Emergent Wetland, Tidal Freshwater Emergent Wetland,
Swainson's hawk	
Nesting habitat	Valley/Foothill Riparian
Foraging habitat	Grassland, Alkali Seasonal Wetland Complex, Other Natural Seasonal Wetland, Managed Wetland, Agricultural Habitats
White-tailed kite	
Breeding habitat	Valley/Foothill Riparian
Foraging habitat	Grassland, Alkali Seasonal Wetland Complex, Vernal Pool Complex, Other Natural Seasonal Wetland, Managed Wetland, Agricultural Habitats
Giant garter snake	
Primary Zone: Aquatic breeding, foraging, and movement	Tidal Perennial Aquatic, Tidal Freshwater Emergent Wetland, Other Natural Seasonal Wetland, Nontidal Freshwater Perennial Emergent Wetland, Agricultural Habitats
Primary zone: Upland aestivation and movement	Grassland, Alkali Seasonal Wetland Complex, Vernal Pool Complex, Other Natural Seasonal Wetland, Managed Wetland, Agricultural Habitats
Western pond turtle	
Aquatic habitat	Tidal Perennial Aquatic, Tidal Brackish Emergent Wetland, Tidal Freshwater Emergent Wetland, Nontidal freshwater perennial emergent wetland, Nontidal perennial aquatic
Dispersal habitat	Valley/Foothill Riparian, Alkali Seasonal Wetland Complex, Vernal Pool Complex, Other Natural Seasonal Wetland, Managed Wetland, Agricultural Habitats
Upland nesting and overwintering	Valley/Foothill Riparian, Grassland, Vernal Pool Complex
California red-legged frog	
Aquatic habitat	Tidal Freshwater Emergent Wetland, Nontidal Freshwater Perennial Emergent Wetland, Nontidal Perennial Aquatic, Managed Wetland
Upland cover and dispersal habitat	Valley/Foothill Riparian, Grassland, Vernal Pool Complex
Dispersal habitat	Agricultural Habitats
Western spadefoot toad	
Aquatic breeding habitat	Vernal Pool Complex, Other Natural Seasonal Wetland, Nontidal Perennial Aquatic,
Terrestrial cover and aestivation habitat	Grassland, Alkali Seasonal Wetland Complex
California tiger salamander	
Aquatic breeding habitat	Vernal Pool Complex
Terrestrial cover and aestivation habitat	Grassland, Alkali Seasonal Wetland Complex
Lange's metalmark butterfly	Inland Dune Scrub
Valley elderberry longhorn beetle	
Riparian vegetation	Valley/Foothill Riparian
Non-riparian channels and grasslands	Grassland, Vernal Pool Complex

Table 3-9. Natural Communities Supporting Modeled Covered Species' Habitats (continued)

Covered Species	*Natural Communities Supporting Species Habitat*
Vernal pool shrimp species (vernal pool tadpole shrimp, conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, midvalley fairy shrimp, California linderiella)	Vernal Pool Complex
Vernal pool plant species (Alkali milk-vetch, San Joaquin spearscale, Boggs Lake hedge-hyssop, Heckard's peppergrass, legenere)	Vernal Pool Complex
Heartscale and brittlescale	Alkali Seasonal Wetland Complex, Vernal Pool Complex, Grassland
Slough thistle	Valley/Foothill Riparian
Suisun thistle and soft bird's-beak	Tidal Brackish Emergent Wetland
Delta button-celery	Valley/Foothill Riparian, Grassland, Alkali Seasonal Wetland Complex, Vernal Pool Complex
Dwarf downingia	Venal Pool Complex
Contra Costa wallflower	Inland Dune Scrub
Carquinez goldenbush	Grassland, Alkali Seasonal Wetland Complex, Vernal Pool Complex
Delta tule pea and Suisun marsh aster	Tidal Brackish Emergent Wetland, Tidal Freshwater Emergent Wetland, Valley/Foothill Riparian
Mason's lilaeopsis and delta mudwort	Tidal Mudflat
Antioch Dunes evening-primrose	Inland Dune Scrub
Side-flowering skullcap	Valley/Foothill Riparian
Caper-fruited tropidocarpum	Grassland

Table 3-10. Expected Extent of Conserved Natural Communities in Conservation Zones 1-11 with BDCP Implementation

Natural Communities	*Total Extent (acres)*	*Total Existing Protected (acres)*	*Percent Existing Protected (acres)*	*BDCP Protected (acres)* **A**	*BDCP Restored (acres)* **B**	*BDCP Conserved (acres)* **A+B**	*Total Conserved with BDCP Implement-ation* **(Existing +BDCP)**	*Percent Conserved with BDCP Implement-ation*
Tidal perennial aquatic	86,240	18,080	21%	0	24,913-31,622[2]	24,913-31,622	42,963-49,672	39-42%
Tidal mudflat[1]	Not available.	Not available.	Not available.	0	Not available.	Not available.	Not available.	Not available.
Tidal brackish emergent wetland	8,351	5,102	61%	0	3,676-4,826[2]	3,676-4,826	8,292-9,442	72-75%
Tidal freshwater emergent wetland	8,947	4,990	56%	0	13,924-21,644[2]	13,924-21,644	18,897-26,617	83-87%
Valley foothill riparian	17,337	5,338	31%	0	5,000	5,000	9,608	45%
Grassland	62,880	14,984	24%	8,000	2,000	10,000	23,974	39%
Alkali seasonal wetland complex	3,723	2,769	74%	400	0	400	3,111	87%
Vernal pool complex	6,958	4,379	63%	300	200	500	4,849	69%
Other natural seasonal wetland	265	205	77%	0	0	0	205	77%
Nontidal freshwater perennial emergent wetland	1,134	408	36%	0	400	400	1,948	30%
Nontidal perennial aquatic	5,341	1,239	23%	0				
Managed wetlands	64,844	52,676	81%	To come.	To come.	To come.	To come.	To come.
Agricultural lands	503,779	57,168	11%	To come.	0	To come.	To come.	To come.
Alfalfa	82,283	3,665	5%	Not available.	0	Not available.	Not available	Not available.
Irrigate Pasture	49,693	12,748	26%	Not available.	0	Not available.	Not available.	Not available.
Vineyard	28,901	2,476	9%	0	0	0	2,266	8%
Orchard	18,020	343	2%	0	0	0	278	2%
Rice	12,637	2,202	17%	4,600	0	4,600	6,802	54%
Other Cultivated Crops	229,828	24,736	11%	Not available.	0	Not available.	Not available.	Not available.
Subtotal: Cropland only	421,361	46,171	11%	16,620-32,640	0	16,620-32,640	57,976-73,996	15-19%
Other Agricultural lands	82,418	10,997	13%	0	0	0	9,252	12%
Subtotal: All agricultural land	503,779	57,168	11%	16,620-32,640	0	16,620-32,640	67,227-83,248	14-18%
Total	**769,799**	**167,338**	**22%**	**25,320-41,340**	**50,113-65,692**	**75,433-107,032**	**223,104-254,703**	**29-33%**

[1]Tidal mudflats are not delineated within the BDCP land cover type GIS data base, but are subsumed in acreages shown for tidal communities.

[2]Restored tidal habitat acreage ranges are a component of the 65,000 acre target for restored tidal habitat. Acreage ranges are based on the results of hydrodynamic modeling of realistic hypothetical restoration designs. While these ranges are not the acreage targets for restored tidal habitats, but rather the results of modeling, the hypothetical designs provided verification of the practicability of achieving restoration targets.

Tidal Perennial Aquatic Goals and Objectives

Goal TANC1: The expected outcome is tidal perennial aquatic natural community that supports habitats for covered and other native species and that supports aquatic food web processes.

> **Objective TANC1.1**: Restore or create 10,000 to 20,000 acres of tidal perennial aquatic in the BDCP Restoration Opportunity Areas (Conservation Zones 1, 2, 4, 5, 7, and 11) that supports aquatic food production and habitat for covered and other native species.

Goal TANC2: The expected outcome is biologically diverse tidal perennial aquatic natural community that is enhanced for native species and sustained by natural ecological processes.

> **Objective TANC2.1:** Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal perennial aquatic community for covered and other native species over the term of the BDCP.

Rationale for Goals and Objectives

Tidal Perennial Aquatic Natural Community Extent and Connectivity

The tidal perennial aquatic natural community influences the establishment and persistence of other natural communities. As sediment accumulates in this community, the elevation of the surface of the bottom eventually increases to the point that it is shallow enough to be colonized by emergent vegetation, and the colonized areas may become tidal emergent wetland or valley/foothill riparian natural communities.

Native Biodiversity and Tidal Perennial Aquatic Function

Biologically Diverse Tidal Perennial Aquatic. The tidal perennial aquatic natural community is largely unvegetated; however, where vegetation exists, it is either rooted and frequently submerged or unrooted and floating. Submerged aquatic plant species include native water primrose and eel grass. Dense eel grass beds provide habitat for young fish and other aquatic organisms and are an important food source for waterfowl, although their occurrence in the Plan Area is very limited. Invasive submerged nonnative plant species include Brazilian waterweed and Eurasian watermilfoil. Brazilian waterweed grows in dense stands along the margins of channels and across shallow bays and significantly restricts the access of juvenile fish to shallow water habitat. It also provides excellent habitat for nonnative ambush predators, such as bass and sunfish, by reducing water velocity, resulting in lower levels of suspended matter in the water column which increases water clarity and produces better hunting conditions for nonnative ambush predators (Brown and Michniuk 2007).

Native floating aquatic plant species include duckweed and floating water fern, and generally occur as free-floating beds of plants at the surface or suspended in the water column. Because floating aquatic plants are not rooted, wind and water movement determine distribution and density. In contrast to the smaller native species, water hyacinth, an invasive species, grows in dense mats that can greatly reduce primary productivity within the water column (NMFS 2004) and provide habitat for nonnative ambush predators, such as bass and sunfish.

The flow of primary productivity through food webs has been greatly affected by the introduction of nonnative species. The native copepod, *Eurytemora*, is an important food source for delta smelt and larval longfin smelt. For example, after the introduction of the highly efficient filter-feeding overbite clam into the Delta (Kimmerer and Orsi 1996), this native copepod declined in abundance. This has allowed for increased colonization of the Delta by nonnative copepods, *Pseudodiaptomus* and *Limnoithona* which have lower fish foraging efficiency. Introduced clams in the tidal perennial aquatic natural community, the Asian clam and overbite clam, are highly efficient filter feeders that significantly reduce phytoplankton and zooplankton concentrations in the water column, resulting in reduced food availability for native fishes, such as delta smelt and young Chinook salmon (Kimmerer and Orsi 1996, NMFS 2004, Center for Biological Diversity 2007).

The tidal perennial aquatic natural community supports over 50 species of fish, approximately one-half of which are native. It is used as habitat by fish for foraging, spawning, egg incubation and larval development, juvenile nursery areas, and migratory corridors. Most species spend their entire lives in the tidal perennial aquatic natural community while others may spend certain seasons or parts of their lives in habitats outside of the tidal perennial aquatic natural community, depending on the state of physical factors such as salinity, turbidity, dissolved oxygen, flow rates, and water temperature. The tidal perennial aquatic community also supports many wildlife species including some covered species. For example, where this community borders tidal freshwater emergent wetland community and contains structural elements such as woody debris as basking sites, giant garter snake and western pond turtle may occur.

Nonnative fish species that have been introduced into the tidal perennial aquatic natural community include striped bass, largemouth bass, smallmouth bass, bluegill sunfish, threadfin shad, golden shiner, fathead minnow, common carp, brown bullhead, white catfish, yellowfin goby, shimofuri goby, and shokihaze goby. No introduction of a nonnative fish species has clearly caused the extinction of a native fish species in the Bay-Delta (Cohen and Carlton 1995); however, nonnative introductions may have significantly contributed to the decline of some native species due to predation and competition for shared resources. For example, smallmouth bass has been associated with the decline of hardhead, a native minnow found in the Delta; and introductions of several centrarchid species (sunfish and black basses) have been associated with the extirpation of the native Sacramento perch from the Delta.

Species Protection. Resident and migratory fish use the tidal perennial aquatic natural community for purposes of spawning, rearing, foraging, and escape cover (CALFED 2000). Young steelhead and Chinook salmon forage in the tidal perennial aquatic natural community as fry and juveniles to put on critical weight before entering the ocean.

In addition to its value as habitat for fish, the tidal perennial aquatic natural community provides reproduction, feeding, and resting habitat for many species of mammals and birds. The tidal perennial aquatic natural community is used by shorebirds, wading birds, and waterfowl for foraging, resting, and escape cover, including BDCP covered California least tern that feeds on fish in the tidal perennial aquatic natural community.

Restoring 2,100 acres of tidal freshwater emergent wetland, with inclusions of the tidal perennial aquatic natural community, in Conservation Zone 4 will provide habitat for giant garter snake and provide the potential for future expansion and colonization from nearby giant garter snake populations (Badger Creek and Coldani Marsh/White Slough subpopulations) into the Delta. It will also provide additional protected tidal perennial aquatic habitat to facilitate the north-south movement of giant garter snakes between the Coldani Marsh/White Slough subpopulation and Stone Lakes National Wildlife Refuge. Restoring 5,000 acres of tidal freshwater emergent wetland in Conservation Zone 7 will provide additional giant garter snake habitat and facilitate the expansion of existing populations into the South Delta.

Tidal Perennial Aquatic and Climate Change

Warmer water temperatures from future climate change would be detrimental to temperature-dependent native fish species in the tidal perennial aquatic natural community due to alterations of the timing of optimal temperature regimes required for fish spawning, rearing, and migration (Bennett 2005, Lindley et al. 2007). High water temperatures can also cause lethal and sublethal effects on some species of fish and other organisms in the community during specific life stages. Warmer water temperatures may also promote the success of nonnative species, such as centrarchids (e.g., black basses, sunfish) and cyprinids (e.g., carp), that spawn during periods with warmer water temperatures (Moyle 2002).

Climate change is predicted to cause more precipitation to fall as rain instead of snow and cause earlier melting of the snowpack. These changes would lead to greater peak flows during the rainy season and lower flows during the dry season. Knowles and Cayan (2004) predict that inflows will increase by 20 percent from October through February and decrease by 20 percent from March through September. Such changes could affect species in the tidal perennial aquatic natural community by altering environmental cues, such as changes in flows and temperature that trigger the timing of biological events such as migration and spawning. Changes in these cues could lead to confusion in the timing of migration and spawning which could ultimately affect the growth, fecundity, and survival of individuals.

A combination of reduced outflow from the Plan Area during the dry season and a rising sea level would increase the extent of saltwater intrusion into the Plan Area (Knowles and Cayan 2002, 2004) and could shift the low salinity zone farther upstream, which would influence the amount of rearing habitat available to native estuarine species (USFWS 2004). Reduced flow into the Plan Area during summer and fall could also lead to increased residence time, which could exacerbate the high water temperature and low dissolved oxygen problems that already occur in some portions of the Plan Area. Concentrations of toxic substances may also increase during the summer and fall as flow-driven flushing and dilution decrease.

Sea level rise could negatively affect fish species that rely on shallow water habitat by deepening preferred shallow water areas of the Plan Area and changing them to deep water zones. Conversely, sea level rise may create more shallow water and floodplain areas that inundate more readily, thus providing a benefit to species that use floodplains as rearing habitat.

Conservation Measures for Tidal Perennial Aquatic

- CM4 Tidal Habitat Restoration
- CM11 Natural Communities Enhancement and Management

3.3.2.2.2 Tidal Mudflat

Tidal mudflat is an ephemeral, mostly unvegetated habitat that usually occurs as patches in areas of disturbance or sediment deposition associated with various intertidal elevations of tidal brackish and tidal freshwater emergent wetlands, and with the upper elevations of the tidal perennial aquatic natural community. It also occupies sediment depositional areas along natural and artificial levees that are ephemeral microhabitats within the valley/foothill riparian natural community, as well as in specific habitats such as seasonal floodplain and channel margin habitats.

The extent of tidal mudflat within the Plan Area has been substantially reduced with the construction of levees and dikes, the channelization of waterways, and the conversion of tidal marshes to agricultural and other land uses. This reduction in the extent of tidal mudflat has reduced the availability of foraging habitat that supports shorebird migrations along the Pacific Flyway and has reduced the extent of silt substrates at the interface of tidal perennial aquatic and tidal emergent wetland that supports habitat for covered species. See Section 2.3.4.2, *Tidal Mudflat* in Chapter 2, *Existing Ecological Conditions*, for more detail on the current state of this natural community.

An increase in extent of tidal mudflat habitat is expected to occur through the restoration of tidal brackish and freshwater emergent wetland community, valley/foothill riparian community, and channel margin enhancement in areas that respond to the dynamic processes that lead to disturbance or deposition events that produce tidal mudflat. This restoration of tidal mudflat habitat will provide foraging habitat for shorebirds and wading birds and will create patches of suitable habitat for several BDCP covered plant species.

Tidal Mudflat Goals and Objectives

Goal MFNC1: The expected outcome is areas of tidal mudflat that provide foraging habitat for shorebirds and wading birds, and substrates suitable for the natural establishment of BDCP covered plant species.

Objective MFNC1.1: Restore or create 20 linear miles of edge areas within other natural communities that serve as tidal mudflat substrate and which will support habitat for tidal mudflat-associated species as a component of BDCP restored tidal brackish emergent wetland and tidal freshwater emergent wetland natural communities and channel margin enhancement.

Objective MFNC1.2: Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal mudflat as a component of BDCP restored brackish and freshwater tidal habitat and channel margin enhancement for covered and other native species over the term of the BDCP.

Rationale for Goals and Objectives

Tidal Mudflat Natural Community Extent and Connectivity

The tidal mudflat natural community generally occupies a narrow transition zone in the intertidal zone of various natural communities in the Plan Area. Tidal mudflat is ephemeral and is sustained through disturbances to other nearby communities or through the deposition of mineral soil within the intertidal zone. Tidal mudflats are typically located in a transition area near brackish and freshwater tidal emergent wetland. These wetlands experience disturbances to their vegetation via the restoration of natural tidal and salinity regimes in brackish areas and through flow and sediment related disturbances in freshwater areas.

Under the tidal mudflat goals and objectives, 20 linear miles of edge areas within brackish and freshwater tidal emergent wetland that could support tidal mudflat will be restored, and tidal mudflat will be allowed to develop under natural processes. Restoration of the tidal mudflat natural community is expected to occur through the BDCP efforts to restore brackish and freshwater tidal emergent wetland communities and other natural communities. The restoration of larger extents of brackish and freshwater tidal emergent wetland, valley/foothill riparian communities and the restoration of seasonal floodplain and channel margin habitats will provide more extensive and frequent disturbances than currently occur and will support a greater extent of tidal mudflat community. Tidal mudflat is expected to develop along the narrow transition zone between the tidal perennial aquatic natural community and the brackish and freshwater tidal emergent wetland natural communities and in sediment depositional areas along artificial and natural levees within the valley/foothill riparian natural community. For the implementation schedule of tidal habitat restoration, see the BDCP implementation schedule presented in Chapter 6, *Plan Implementation.*

Native Biodiversity and Tidal Mudflat Function

Biologically Diverse Tidal Mudflat. When exposed at low tide, lower elevation tidal mudflats serve as foraging habitat for waterfowl and shorebirds which consume crustaceans, bivalves, gastropods, aquatic insects, and polychaetes that live in tidal mudflats. When covered at high tide, these same areas serve as shallow open water habitat for several BDCP covered pelagic fish species, including splittail, salmonids, and sturgeon. These species use the area as a shallow water refuge from predators and also forage on benthic invertebrates.

Tidal mudflat is expected to develop naturally from the effective management of brackish and freshwater tidal emergent wetland and will not be specifically enhanced or managed. Most of the physical processes that will be designed into the restoration of tidal emergent wetland are expected to evolve naturally and will produce ephemeral patches of tidal mudflat. Some biological processes in tidal marsh habitats may require active management, such as the control of invasive species; however, there is little current knowledge about the effects of invasive species on tidal mudflat habitats. This uncertainty is expected to be resolved through baseline surveys, effectiveness monitoring, and targeted research.

Species Protection. Two BDCP covered plant species, Mason's lilaeopsis and Delta mudwort, can be found on higher elevation tidal mudflat. Mason's lilaeopsis is more abundant in brackish areas, while Delta mudwort is more abundant in freshwater (Golden and Fiedler 1991, Fiedler and Zebell 1993, Zebell and Fiedler 1996, Meisler 2002, Fiedler et al. 2007). The rate of plant colonization and succession on tidal mudflat depends on the supply of propagules and the distance to clonal plants. Restoration of tidal mudflat will also create patches of suitable habitat for BDCP covered plant species Delta tule pea and Suisun Marsh aster.

Tidal Mudflat and Climate Change

It is expected that sea level rise will shift tidal mudflats to higher elevations in areas with a gradual topographic incline. Where steep levee sides occur, the areal extent of tidal mudflats could be diminished as a result of sea level rise. Additionally, tidal mudflat extent is affected by rates of sedimentation and erosion. If sediment deposition does not match sediment export, the extent of tidal mudflats could change; and it is not clear how climate change will affect sediment deposition and export rates. However, implementation of BDCP tidal mudflat goals and objectives can improve the extent, and thus potential resilience, of this natural community in the face of climatic changes.

Conservation Measures for Tidal Mudflat

- CM4 Tidal Habitat Restoration
- CM11 Natural Communities Enhancement and Management

3.3.2.2.3 Tidal Brackish Emergent Wetland

The tidal brackish emergent wetland natural community is a transitional community between the tidal perennial aquatic natural community and terrestrial upland natural communities; it can also exist as isolated patches on islands (e.g., islands within Suisun Bay). In the Plan Area, tidal brackish emergent wetland natural community currently persists at the following locations: Suisun Marsh, the south side of Suisun Bay, and along the shore and on islands in the saltwater/freshwater mixing zone that extends from near Collinsville westward to the Carquinez

Strait. However, despite its large potential extent, most tidal brackish emergent wetland is present in undiked areas of Suisun Marsh, such as Rush Ranch and Hill Slough. Smaller patches also occur along undiked shorelines on the south shore of Suisun Bay, and on undiked in-channel islands such as Brown's Island. See Section 2.3.4.3, *Tidal Brackish Emergent Wetland* in Chapter 2, *Existing Ecological Conditions,* for more detail on the current state of this natural community.

Substantial reductions in the extent, distribution, and condition of the historical tidal brackish emergent wetland natural community in Suisun Marsh have reduced the extent and diversity of tidal brackish emergent wetland for associated covered and other native species. Prior to extensive anthropogenic modifications of Suisun Marsh that included dike building and drainage, the tidal brackish emergent wetland natural community comprised an estimated 69,000 acres of what was the largest tidal brackish water marsh complex in the western United States (Boul and Keeler-Wolf 2008). Today, only 8,351 acres (12 percent) remain; 5102 acres (61 percent) of which is currently under protected status.

Conservation of the tidal brackish emergent wetland natural community will be achieved by increasing the extent and connectivity of the community, by establishing connectivity with other natural communities along an environmental gradient from aquatic to upland areas, by reestablishing ecological conditions and processes that sustain the community, and by enhancing native biodiversity. Tidal brackish emergent wetland restoration will be implemented in Suisun Marsh through the breaching of dikes around unsubsided areas of the marsh and through site-specific contouring to speed the establishment of natural tidal channels. Restoring tidal brackish marsh habitats along an environmental gradient extending from the tidal perennial aquatic natural community to upland natural communities is expected to increase the abundance and distribution of associated native species, improve connectivity among habitat areas within Suisun Marsh and Suisun Bay, provide nutrients and food to adjacent subtidal aquatic habitat, and to contribute to the long-term conservation of tidal brackish marsh-associated covered species.

Tidal Brackish Emergent Wetland Goals and Objectives

Goal BMNC1: The expected outcome is restored large expanses and interconnected patches of tidal brackish emergent wetland natural community.

> **Objective BMNC1.1:** Restore or create 3,600 to 4,800 acres of tidal brackish emergent wetland in the Suisun Marsh ROA (Conservation Zone 11).

Goal BMNC2: The expected outcome is biologically diverse tidal brackish emergent wetland that is enhanced for native species and sustained by natural ecological processes.

> **Objective BMNC2.1:** Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal brackish emergent wetland for covered and other native species over the term of the BDCP.

Rationale for Goals and Objectives

Tidal Brackish Emergent Wetland Natural Community Extent and Connectivity

The conservation of tidal brackish emergent wetland focuses on restoration and management rather than on protection because of the very limited extent of this community compared to historical conditions, and because most of the existing natural community has been protected or is unlikely to be developed. Two of the largest patches of tidal brackish emergent wetland in Conservation Zone 11, Rush Ranch and Hill Slough, are owned by the Department of Fish and Game and are actively managed for their natural resource values. Much of the remaining area of tidal brackish emergent wetland natural community in Conservation Zone 11 is protected from future development under the Suisun Marsh Protection Plan. Areas of this natural community in Conservation Zone 5, although not under formal protection, occur on mid-channel islands that are subject to strong tidal forces, wave action, and are isolated from roadways. These factors render tidal emergent wetlands in Conservation Zone 5 largely unsuitable for development and therefore, protection is not a priority.

Under the tidal habitat restoration goals and objectives, 65,000 acres of tidal habitat will be restored; of which at least 7,000 acres will be in brackish areas of Suisun Marsh. A portion of the restored area (3,600 to 4,800 acres) will be restored tidal brackish emergent wetland natural community. The extent of acres targeted for Suisun Marsh is in part a function of the potential for wetland restoration based on historical and current conditions. Restoration sites will be chosen based on appropriate marsh plain elevations, hydrodynamic conditions, and environmental gradients. Priority for restoration will be given to sites that were former tidal brackish emergent wetland, that fall within intertidal tidal elevations, and that are suitable for creating a gradient from subtidal habitats to upland habitats through the breaching of dikes. Consideration will also be given to sites that will increase connectivity among preserve lands or that will accommodate sea-level rise. Restoration of tidal brackish emergent wetland natural community in Suisun Marsh will increase the extent and connectivity of an already established network of habitat and will improve foraging and/or dispersal dynamics for a variety of wildlife species. The implementation schedule of tidal habitat restoration is described in the BDCP implementation schedule presented in Chapter 6, *Plan Implementation.*

Native Biodiversity and Tidal Brackish Emergent Wetland Function

Biologically Diverse Tidal Brackish Emergent Wetland. Implementation of tidal brackish emergent wetland natural community restoration actions will aid in the recovery of natural tidal fluctuation that is essential to improve the function of the natural community. Restoration of tidal influence affects water accessibility, soil oxygen status, and soil salinity, all of which are critical factors for the wetland vegetation. Endemic plant species located within and near the intertidal area in this community, such as BDCP covered species Suisun thistle, Suisun Marsh aster, and soft bird's-beak, will benefit from the restoration of tidal influence.

The target restoration goal for the tidal brackish emergent wetland natural community includes the relatively brackish channel margin habitat with tall bulrushes, tules, and cattails; the more brackish transition zone with species-rich vegetation containing a diversity of structural habitats; and the marsh plain that is dominated by low stature salt-tolerant species such as pickleweed and saltgrass and may include bare patches of very saline soil.

Directing the restoration of tidal brackish emergent wetland natural community to the Suisun Marsh is expected to provide the greatest possible benefit for BDCP covered aquatic and terrestrial species and for the tidal brackish emergent wetland natural community which the species depend upon for habitat and food web support. Vegetated marsh plains are also expected to filter non-point source pollution from surface runoff or subsurface infiltration that otherwise would flow into Suisun Bay. The potential restoration areas in Suisun Marsh are extensive and interconnected and will allow for the foraging and dispersal dynamics of a wide range of BDCP covered and other native species.

Enhancing and managing the natural community to maintain variation in inundation, composition, and structure will be critical for maintaining the value of tidal brackish emergent wetland as habitat. Natural physical processes will be restored through the design of the restoration sites and natural site evolution will be allowed. In contrast, some biological processes will require active management. For example, both the transition zone and marsh plain are frequently invaded by nonnative species such as perennial pepperweed and fennel in the intertidal zone and annual grasses immediately above the MHHW line. Tall nonnative plant species form dense patches, excluding native species; and some small nonnative annuals, such as barbgrass (*Hainardia cylindrical*) and rabbitsfoot grass (*Polypogon monspeliensis*), impact BDCP covered soft bird's-beak (a hemiparasite) by functioning as ineffective host plants (Grewell 2005). These invasive species significantly degrade the habitat value of this community and will require active management methods to reduce and prevent increases of their cover at levels that will minimize their negative effects on the community. While methods have been developed to reduce the cover of these species in the short term, there are no long term control solutions; and effective management of invasive species will require focused studies to develop those methods.

The tidal brackish emergent wetland community is frequently invaded by nonnative animals such as feral pigs. Pigs can have significant adverse effects on marsh vegetation, especially BDCP covered Suisun thistle (Fiedler et al. 2007, USFWS 2009a). Other nonnative animals that have been shown to significantly reduce populations of BDCP covered salt marsh harvest mouse, California black rail, and California clapper rail (Suisun Ecological Workgroup 2001) include red fox, feral cats, and rats (Brown 2004, Takekawa et al. 2006). Management methods to reduce or eliminate populations of invasive animals will be developed and implemented.

The range of potential restoration sites vary by past disturbance regime and location in Suisun Marsh. Therefore, this community will be enhanced using techniques that are tailored to each specific restoration site. The combination of unknown past effects and variable current condition means that there will be a broad range of uncertainty in implementing the enhancement techniques, frequencies, and intensities of application that will be informed by baseline surveys, effectiveness monitoring, and targeted research studies.

Species Protection. When fully restored, this community will provide habitat for covered terrestrial species, and will provide structure as well as nutrient and energy flows to the aquatic food web that supports covered fish species that rear and spawn in the channels of the marsh. BDCP covered species expected to benefit from tidal brackish emergent wetland restoration include delta smelt, longfin smelt, all runs of Chinook salmon, Central Valley steelhead, salt marsh harvest mouse, Suisun shrew, Suisun song sparrow, California black rail, California clapper rail, white-tailed kite (foraging), western pond turtle, Suisun thistle, soft bird's-beak, Delta tule pea, Suisun Marsh aster, Delta mudwort, and Mason's lilaeopsis. Restoration of tidal brackish emergent wetland will also provide breeding and wintering habitat for a variety of waterfowl, shorebirds, and other waterbirds in an ecologically functioning landscape within the Suisun Marsh complex.

Tidal Brackish Emergent Wetland and Climate Change

The tidal brackish emergent wetland natural community is directly linked to salinity gradients and sea level. Delta wetlands are particularly sensitive to long-term sea level rise associated with global climate change and changes in Delta sediment discharge. In order to be maintained, the tidal brackish emergent wetland natural community must have the ability to accrete sediments at rates high enough to keep its surfaces intertidal (Watson and Byrne 2009). That accretion rate will in turn depend on how changing salinity and inundation duration affect the species composition of the wetland (Culberson et al. 2004, Watson and Byrne 2009).

The potential restoration sites in Suisun Marsh are generally located on unsubsided mineral soils and are adjacent to upland communities so that restoration actions will be efficient and relatively resilient to the effects of global sea level rise. Additionally, a 900-acre area of similar unsubsided mineral soils will be restored just beyond the eastern limit of the brackish water area in Conservation Zone 5, which could function as refugia for species adapted to brackish conditions from the effects of global climate change.

Conservation Measures for Tidal Brackish Emergent Wetland

- CM4 Tidal Habitat Restoration
- CM11 Natural Communities Enhancement and Management

3.3.2.2.4 Tidal Freshwater Emergent Wetland

The tidal freshwater emergent wetland natural community is typically a transitional community between the tidal perennial aquatic natural community and valley/foothill riparian or terrestrial upland communities, such as grasslands and agricultural lands. In the Plan Area, the tidal freshwater emergent wetland natural community occurs across a range of hydrologic and soil conditions, often occurring at the shallow, slow-moving or stagnant edges of freshwater waterways in the intertidal zone. It frequently experiences long duration flooding.

Prior to the 1860s, the tidal freshwater emergent wetland natural community covered an estimated 87 percent of the Delta, with extensive marshes forming dense stands of vegetation bisected by meandering channels (The Bay Institute 1998). Today, the distribution of the tidal freshwater emergent wetland natural community in the Plan Area is limited to narrow fragmented bands or small patches along island levees, in-channel islands, shorelines, sloughs, and shoals. A total of 8,947 acres of this natural community remain within the Plan Area, 4,990 acres (56 percent) of which is currently under protected status.

Channelization, levee-building, agricultural conversion, urban development, removal of vegetation to stabilize levees, and upstream flood control have reduced the extent of the tidal freshwater emergent wetland natural community and altered its ecological function through changes to flooding frequency, inundation, depth, and duration, and the quantity of sediment deposition. These substantial reductions in the extent, distribution, and condition of tidal freshwater marshes that historically covered most of the Delta have reduced the extent and diversity of tidal freshwater habitats for associated covered and other native plant and wildlife species. See Section 2.3.4.4, *Tidal Freshwater Emergent Wetland* in Chapter 2, *Existing Ecological Conditions*, for more detail on the current state of this natural community.

When fully restored, tidal freshwater emergent wetland will support a complex habitat structure composed of bulrushes, tules, cattails, and other emergent marsh species that will provide habitat for covered terrestrial species and provide nutrient and energy flows to the aquatic food web that supports covered fish species that rear in the channels of the marsh.

Tidal Freshwater Emergent Wetland Goals and Objectives

Goal FMNC1: The expected outcome is restored large, interconnected patches of tidal freshwater emergent wetland natural community.

> **Objective FMNC1.1:** Restore or create 13,900 to 21,600 acres of tidal freshwater emergent wetland in the Cache Slough, West Delta, Cosumnes-Mokelumne, and South Delta ROAs (Conservation Zones 1, 2, 4, 5, 6, and 7).

Goal FMNC2: The expected outcome is biologically diverse tidal freshwater emergent wetland that is enhanced for native species and sustained by natural ecological processes.

> **Objective FMNC2.1:** Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal freshwater emergent wetlands for covered and other native species over the term of the BDCP.

Rationale for Goals and Objectives

Tidal Freshwater Emergent Wetland Natural Community Extent and Connectivity

A total of 65,000 acres of tidal habitats will be restored by the BDCP, of which 13,900 to 21,600 acres will be tidal freshwater emergent wetland. Remnant patches of tidal freshwater emergent wetlands can currently be found near the confluence of the Sacramento and San Joaquin rivers, along Cache and Lindsey sloughs and the Yolo Bypass, along the mainstem and several channels of the San Joaquin, Old, and Middle rivers, Dutch Slough, Lost Slough, and near the confluence of the Cosumnes and Mokelumne rivers.

Tidal freshwater emergent wetland restoration will be implemented across a wide geography in the Delta with most of the restored acreage occurring in the Cache Slough area and in the south Delta. Sites will be selected for restoration based on their spatial distribution, extent, location, and configuration of restored tidal habitat, the ability to minimize impacts to existing habitats or infrastructure, the ability to restore appropriate tidal range to a site, the potential for a site to produce and export productivity to sustain aquatic food webs in the river channels, and the potential to accommodate sea-level rise. Priority will be given to sites that will increase connectivity among preserve lands.

The modification of natural Delta hydrology through levees, drainage, and water exports has reduced the extent and diversity of tidal freshwater habitats for associated covered and other native plant and wildlife species. Tidal brackish emergent wetland restoration will be implemented through the breaching of levees around unsubsided areas of the marsh, combined with site specific contouring to speed the establishment of natural tidal channel morphology and sinuosity. Restoring tidal freshwater marsh habitats along an environmental gradient extending from the subtidal perennial aquatic natural community to upland natural communities is expected to increase the abundance and distribution of associated native wildlife and plant species, improve connectivity among habitat areas within the Plan Area, provide nutrients and food to adjacent subtidal perennial aquatic habitat, and contribute to the long-term conservation of tidal freshwater marsh-associated covered species.

Because the tidal freshwater emergent wetland restoration areas are distributed throughout the Delta, there will be extensive site to site variation in physical and biological characteristics. Given this variability, enhancement actions will use techniques that are tailored to each specific restoration site. The inherent variability among potential restoration sites also means that there will likely be a broad range of uncertainty in implementing the restoration and enhancement techniques. Therefore, restoration and enhancement techniques and effective application frequencies and intensities will be informed by baseline surveys, effectiveness monitoring, and targeted research. For the implementation schedule of tidal habitat restoration, see the BDCP implementation schedule presented in Chapter 6, *Plan Implementation.*

Native Biodiversity and Tidal Freshwater Emergent Wetland Function

Biologically Diverse Tidal Freshwater Emergent Wetland. There are 17 plant community alliances (i.e., unique species assemblages) mapped in the Plan Area that fall within the tidal freshwater emergent wetland natural community (Table 2-8) (Sawyer and Keeler-Wolf 1995, Hickson and Keeler-Wolf 2007). In tidal freshwater emergent wetlands, tules, cattails, and willows (*Salix* spp.) dominate the vegetation along the Sacramento River; while throughout the San Joaquin River area of the Delta, bulrushes, tules, common reed (*Phragmites australis*), and willows are more often the dominant species (Atwater 1980, Watson 2006, EDAW 2007, Hickson and Keeler-Wolf 2007, Watson and Byrne 2009). In some areas of the Delta, generally freshwater areas may become brackish during periods of low flows. These potential salinity changes are driven by the incursion of higher salinity oceanic water from Suisun Bay up the Sacramento and San Joaquin rivers and from salinity transported by the San Joaquin River into the Delta. There may also be local sources of salinity in the vicinity of Lindsey and Cache sloughs that might become less diluted by Sacramento River water under periods of low flows, causing a shift to more salt-adapted species.

The vegetation and associated waterways of the tidal freshwater emergent wetland natural community in the Plan Area provide food and cover for numerous species of birds (e.g., waterfowl, shorebirds, wading birds), mammals, reptiles, emergent aquatic insects, and amphibians. Many tidal freshwater emergent wetlands remaining in the Plan Area are highly altered. This has substantially reduced its value as habitat for many plant and wildlife species. However, the remaining tidal freshwater emergent wetlands are essential wintering grounds for migratory birds.

Some species, such as waterfowl and egrets, have adapted to foraging on certain types of Delta cropland that were converted from historical wetland areas (DFG 2005). These and other species are expected to benefit from restoration of ecologically functioning tidal freshwater emergent wetlands. Many fish in the tidal perennial aquatic natural community will also use tidal freshwater emergent wetland habitat when it is inundated. Younger stages (e.g., larvae, fry) of some fish species rear in shallower waters that support the emergent vegetation of the tidal freshwater emergent wetland natural community; and some fish species use the emergent vegetation as refuge from predation and high flows (The Bay Institute 1998).

In tidal freshwater emergent wetlands, emergent vegetation releases organic debris (“drift”) into the waterways, providing nutrients and cover, and forms the base of the aquatic food chain supporting primary consumers such as microorganisms, macroinvertebrates, and insects.. The tidal freshwater emergent wetland natural community also processes influxes of nutrients that find their way into the aquatic system (“nutrient transformation”), thereby contributing further to the aquatic food web.

Enhancing and managing tidal freshwater marsh to maintain variation in tidal inundation, species composition, and vegetation structure will be critical for supporting the value of tidal freshwater marsh as habitat. Natural physical processes will be restored through the careful design and implementation of habitat restoration. As part of the restoration, natural geomorphology will be allowed to develop.

However, some biological process will require active management. For example, the area immediately above MHHW is often invaded by species such as perennial pepperweed and giant reed (*Arundo donax*), and both species grow as dense monocultures which eliminate native plant species in both riparian and tidal wetland habitats. Invasive species significantly degrade the habitat value of this community and only management actions to reduce and limit their cover to low levels will minimize their adverse effects on the community. For example, the giant reed eliminates native plants, resulting in the reduction of food and habitat for a number of native birds, insects, and other wildlife. While methods have been developed to reduce the cover of invasive species in the short-term, there are no long-term control solutions and effective management of invasive species will require an uninterrupted long-term commitment.

The tidal freshwater emergent wetland community has also been invaded by nonnative animals such as cowbirds and feral cats that can have significant negative effects native wildlife. Management methods to reduce or eliminate populations of nonnative animals will be developed and implemented.

Species Protection. When fully restored, this community will provide habitat for covered terrestrial species, as well as structure and nutrient and energy flows to the aquatic food web that supports covered fish species that rear and spawn in the channels of the marsh. The augmented productivity and structural diversity of the restored tidal freshwater emergent wetland will create a diversity of nesting and foraging habitat for California black rail, greater sandhill crane, tricolored blackbird, giant garter snake, western pond turtle, and several species of waterfowl and shorebirds. It will also provide patches of suitable habitat for covered plant species, such as Delta tule pea, Suisun Marsh aster, Delta mudwort, and Mason's lilaeopsis.

Restoring 2,100 acres of tidal freshwater emergent wetland in Conservation Zone 4 will provide habitat for giant garter snake and provide the potential for future expansion and colonization from nearby giant garter snake populations (Badger Creek and Coldani Marsh/White Slough subpopulations). It will also provide additional protected tidal freshwater emergent wetlands to facilitate the north-south movement of giant garter snakes between the Condani Marsh/White Slough subpopulation and Stone Lakes National Wildlife Refuge. Restoring 5,000 acres of tidal freshwater marsh complex in Conservation Zone 7 will provide additional giant garter snake habitat and facilitate expansion of existing populations into the south Delta.

Greater sandhill crane is also expected to benefit from the restoration of 2,100 acres of tidal freshwater marsh complex in Conservation Zone 4 by providing additional roosting, resting, and foraging habitat within the species' primary use area where the tidal range is sufficiently narrow. Restoration of 5,000 acres of tidal freshwater emergent wetland in Conservation Zone 7 will provide suitable roosting and foraging habitat south of the current primary use area and facilitate expansion of the wintering range.

Tidal Freshwater Emergent Wetland and Climate Change

Since it is intertidal, the tidal freshwater emergent wetland natural community is directly affected by sea level and will be particularly sensitive to the predicted long-term sea level rise associated with global climate change (Nicholls et al. 1999). To persist in the face of rising sea levels the tidal freshwater emergent wetland natural community will have to maintain a maximum MLLW inundation depth of -35 cm by shifting its distribution upslope where it can or by accumulating mineral and organic sediment at a rate that will match that of sea level rise. The upslope shift will also shift tidal freshwater emergent wetland vegetation farther upstream as the tidal area migrates upstream.

Much of the area occupied by tidal freshwater emergent wetland is along armored levees; therefore, the relocation of the intertidal zone would be primarily vertical to the extent that the levees remain above sea level. In areas where sedimentation rates do not match sea level rise or where levees in subsided areas are breached or overtopped, there will be a reduction in the extent of tidal freshwater emergent wetland as it is replaced by the tidal perennial aquatic community. The implementation of BDCP tidal freshwater emergent wetland goals and objectives will increase the extent of this natural community and help ensure its persistence through climatic changes.

Conservation Measures for Tidal Freshwater Emergent Wetland

- CM4 Tidal Habitat Restoration
- CM11 Natural Communities Enhancement and Management
- CM13 Nonnative Aquatic Vegetation Control

3.3.2.2.5 Nontidal Freshwater Perennial Emergent Wetland

The nontidal freshwater perennial emergent wetland natural community is composed of permanently saturated wetlands, including meadows, dominated by emergent plant species that cannot tolerate permanent saline or brackish conditions. It generally occurs with and forms the boundary around the nontidal perennial aquatic natural community, and both are embedded in other natural communities (e.g., agricultural, grassland). Conservation of nontidal freshwater perennial emergent wetland will occur primarily in conjunction with the creation and protection of nontidal perennial aquatic natural community (see below under *Nontidal Perennial Aquatic*).

Historically, nontidal emergent wetland occurred primarily in the Yolo, American, and Cosumnes basins and in depressions along the margins of the Plan Area that ponded water long enough to support emergent aquatic vegetation such as tules, bulrushes, cattails, and other native vegetation. This community was among the most ecologically productive in the Delta, providing important nesting, feeding, and cover habitat for many native species, including BDCP covered species.

The extent of nontidal freshwater perennial emergent wetlands in California, including the Delta, has declined dramatically over the past century due to reclamation and conversion of the natural community to other uses, primarily agriculture (Gilmer et al. 1982, The Bay Institute 1998). Substantial reductions in the extent, distribution, and condition of historical nontidal freshwater perennial emergent wetland that resulted from agricultural conversion and the deterioration of natural hydrology has reduced the extent and diversity of freshwater marsh communities for associated covered and other native plant and wildlife species.

Today, nontidal freshwater perennial emergent wetland in the Plan Area is largely an artifact of agricultural practices or sites managed to maintain waterfowl habitat. Additionally, because of habitat loss and substitution, many native species that historically used tidal marsh habitats in the Delta are now dependent on remnant or created patches of nontidal emergent wetlands. See Section 2.3.4.7, *Nontidal Freshwater Perennial Emergent Wetland* in Chapter 2, *Existing Ecological Conditions,* for more detail on the current state of this natural community.

There are currently only 1,134 acres of nontidal freshwater perennial emergent wetland in the Plan Area, and most of it occurs as small fragmented patches along the edges of channels in the nontidal perennial aquatic and valley/foothill riparian natural communities. Approximately 36 percent of this area (408 acres) is already under a protected status. Creating additional freshwater marsh in association with nontidal perennial aquatic habitat in strategic areas; protecting aquatic habitat migration corridors such as canals and drains; and protecting associated upland habitat are expected to maintain or increase the abundance of native associated wildlife and plant species, improve connectivity among habitat areas within and adjacent to the Plan Area, and contribute to the long-term conservation of freshwater marsh-associated covered species.

Nontidal Freshwater Perennial Emergent Wetland Goals and Objectives

Goal NWNC1: The expected outcome is nontidal freshwater perennial emergent wetland natural community that supports habitat for covered and other native species.

> **Objective NWNC1.1**: Create 400 acres of nontidal freshwater marsh (including components of nontidal perennial aquatic and perennial emergent wetland communities) that functions as habitat for the giant garter snake, tricolored blackbird, and western pond turtle within or adjacent to habitat occupied by the Caldoni Marsh/White Slough giant garter snake subpopulation in Conservation Zone 4 and the Yolo/Willow Slough giant garter snake subpopulation in Conservation Zone 2.

Goal NWNC2: The expected outcome is biologically diverse nontidal freshwater perennial emergent wetland communities that are enhanced for native species and sustained by ecological processes.

> **Objective NWNC2.1**: Maintain and enhance the habitat functions of protected and created nontidal freshwater perennial emergent wetlands for covered and other native species over the term of the BDCP.

Rationale for Goals and Objectives

Nontidal Freshwater Perennial Emergent Wetland Natural Community Extent and Connectivity

Conservation of nontidal freshwater perennial emergent wetland will occur through the protection and management of agricultural and grassland landscapes throughout the Plan Area that include remnant patches of nontidal emergent wetland, associated canals and streams, and associated upland habitat. Focused conservation will include the creation of 400 additional acres of nontidal freshwater perennial emergent wetland and associated nontidal perennial aquatic habitat within a larger protected landscape. This approach will focus on the protection and expansion of two existing giant garter snake subpopulation centers.

While nontidal freshwater emergent wetland natural community will be protected throughout much of the Plan Area in coordination with the protection of other natural communities (e.g., agricultural lands, grasslands), the conservation strategy for nontidal freshwater perennial emergent wetland and nontidal perennial aquatic natural communities is focused on restoring these communities in areas where the greatest benefit to covered species can be achieved. The strategy involves protecting, enhancing, and restoring these communities primarily for the benefit of two giant garter snake subpopulation centers: the Caldoni Marsh/White Slough subpopulation in Conservation Zone 4 and the Yolo/Willow Slough subpopulation in Conservation Zone 2.

Emergent marsh and associated open water habitat will be created in association with existing occupied habitats to protect and allow for expansion of these subpopulations. Surrounding agricultural lands will be targeted for acquisition in order to build larger contiguous preserves in these areas that support a network of irrigation canals and other aquatic features in addition to the restored wetland habitats within the agricultural matrix of these two areas. In this way, the protected landscape and restored wetland habitats will provide additional aquatic habitat and protect associated movement corridors and upland habitats for these subpopulations.

As these conservation areas are designed, agricultural parcels will be selected based on their proximity and connectivity to occupied sites and opportunities for restoration and enhancement. Restored habitats will be created with appropriate patch sizes and within the existing agricultural matrix to maximize connectivity and the potential for expansion and dispersal. This approach is designed to protect the existing subpopulation centers and create opportunities for the expansion of these subpopulations.

With targeted conservation of 400 acres of nontidal freshwater perennial emergent wetland and perennial aquatic natural communities under the BDCP, approximately 1,948 acres of the combined communities would be protected, an 18 percent increase in the extent of protected habitat of these types. Additional protection will occur in conjunction with the conservation of other natural communities and through enhancement and management of those natural communities. For the implementation schedule of nontidal marsh restoration, see the BDCP implementation schedule presented in Chapter 6, *Plan Implementation.*

Native Biodiversity and Nontidal Freshwater Perennial Emergent Wetland Function

Biologically Diverse Nontidal Freshwater Perennial Emergent Wetland. All patches of nontidal freshwater perennial emergent wetland natural community mapped in the Plan Area are dominated by broad-leaf cattail (Hickson and Keeler-Wolf 2007). Other plant species frequently found in Plan Area nontidal freshwater perennial emergent wetlands include tules, bulrushes, sedges, rushes, and other emergent plant species.

The nontidal freshwater perennial emergent wetland natural community is among the most productive wildlife habitat in California (DFG 2005) providing primary productivity through its aquatic food web; aquatic habitat for native fish, amphibians, and reptiles; food, cover, and water for mammals, reptiles, amphibians, and birds; and vegetation structure for predator avoidance and nesting of wildlife. Some species, such as BDCP covered giant garter snake, rely on freshwater emergent wetlands for their entire life cycle. The BDCP covered California red-legged frog uses this natural community as breeding habitat; and migrating waterfowl use it as foraging and loafing habitat.

These ecological functions provided by nontidal freshwater perennial emergent wetlands in the Plan Area are limited by habitat fragmentation and small patch sizes. Protection and creation of this natural community will focus on reestablishing these functions within the two giant garter snake preserves and elsewhere on preserved BDCP lands.

Created and protected nontidal freshwater perennial emergent wetland areas will be actively managed to promote high value wetland habitat. These areas will require regular monitoring and periodic manipulation of herbaceous emergent vegetation and possibly floating aquatic vegetation to maintain the appropriate balance of open water and vegetation components that will benefit BDCP covered species. Because the sites occur within agricultural areas, they will require careful management and monitoring of some agricultural practices, such as aerial application of pesticides and fertilizers, water control, and maintenance of buffers. Nonnative centrarchid fish (bass and sunfish) and bullfrog are known predators of giant garter snake and western pond turtle, and their populations may need to be periodically controlled. Additionally, the nontidal freshwater perennial emergent wetland community may be invaded by nonnative animals such as cowbirds and feral cats, as well as nonnative plants, such as ludwigia, that can have adverse effects on native wildlife. Management methods to reduce or eliminate populations of nonnative animals and plants will be developed and implemented.

Species Protection. Agricultural lands surrounding two existing giant garter snake subpopulation centers will be targeted for acquisition in an effort to establish two 1,000-acre preserves to provide for the conservation of giant garter snake and other nontidal freshwater perennial emergent wetland and agriculture-associated covered species. Freshwater marsh creation will occur within the preserves in selected areas, and the marsh will be designed to build off of existing occupied giant garter snake sites to improve connectivity among habitat areas within and adjacent to the Plan Area. Creation and protection of the preserves is also expected to increase the abundance of other covered species, such as western pond turtle and tricolored blackbird and contribute to the long-term conservation of nontidal freshwater perennial emergent wetland-associated covered species.

Nontidal Freshwater Perennial Emergent Wetland and Climate Change

Sea level rise will affect the location, extent, and composition of the nontidal freshwater perennial emergent wetland natural community, in places where the natural community exists at or below current sea level, as a result of increased water elevation, increased saltwater intrusion, and a tidal hydrological regime. Nontidal freshwater perennial emergent wetland locations existing at water's edge will become more deeply immersed or, in the case of overtopped levees, deeply flooded. Flooded depressions in upland areas presumably already support this natural community, and it is not likely that natural processes in these upland areas would replace the area that will be lost closer to sea level. Implementation of BDCP nontidal freshwater perennial emergent wetland goals and objectives will increase the extent of this natural community and associated habitat services, despite potential losses of this natural community resulting from climate change.

Conservation Measures for Nontidal Freshwater Perennial Emergent Wetland

- CM3 Natural Communities Protection
- CM10 Nontidal Marsh Restoration
- CM11 Natural Communities Enhancement and Management

3.3.2.2.6 Nontidal Perennial Aquatic

The nontidal perennial aquatic natural community can be found in association with any terrestrial community and can occur as isolated ponds or as the open water component of nontidal freshwater perennial emergent wetland and valley/foothill riparian communities. Conservation of nontidal perennial aquatic natural community will occur primarily in conjunction with the creation and protection of nontidal freshwater perennial emergent wetland (See above under *Nontidal Freshwater Perennial Emergent Wetland*).

Historically, the nontidal perennial aquatic natural community occurred primarily in the Yolo, American, and Cosumnes basins and in depressions along the margins of the Plan Area that ponded water for sufficient duration and depth to support areas of open water among emergent aquatic vegetation such as tules, bulrushes, cattails, and other native vegetation. This community provided important open water habitat for waterfowl, other water birds, and many other native species.

The distribution and historical functions of the Delta nontidal perennial aquatic community have been substantially reduced from historical conditions through the effects of agricultural conversion and land management practices resulting in the loss of natural hydrology. Today, the nontidal perennial aquatic community in the Plan Area is largely an artifact of agricultural practices or sites managed to maintain waterfowl habitat. Additionally, because of habitat loss and conversion, many native species that historically used tidal marsh habitats in the Delta are now dependent on remnant or created patches of nontidal perennial aquatic habitat. See Section 2.3.4.6, *Nontidal Perennial Aquatic* in Chapter 2, *Existing Ecological Conditions*, for more detail on the current state of this natural community.

There are currently 5,341 acres of the nontidal perennial aquatic natural community in the Plan Area, most of which occurs as small fragmented patches along the edges of channels. Approximately 23 percent of this area (1,239 acres) is already under a protected status. Creating additional nontidal perennial aquatic habitat in association with nontidal freshwater perennial emergent wetland in strategic areas, protecting aquatic habitat migration corridors such as canals and drains, and protecting associated upland habitat are expected to maintain or increase the abundance of native associated wildlife and plant species, improve connectivity among habitat areas within and adjacent to the Plan Area, and contribute to the long-term conservation of nontidal perennial aquatic-associated covered species.

Conservation of nontidal perennial aquatic will occur through the protection and management of agricultural and grassland landscapes throughout the Plan Area that include remnant patches of nontidal emergent wetland, associated canals and streams, and associated upland habitat. Focused conservation will include the creation of 400 additional acres of nontidal freshwater perennial emergent wetland (See Objective NWCN1.1) that includes the emergent wetland and associated nontidal perennial aquatic habitat components within a larger protected landscape. This approach will focus on the protection and expansion of two existing giant garter snake subpopulation centers. Agricultural lands surrounding these subpopulation centers will be targeted for acquisition in an effort to establish two 1,000-acre preserves to provide for the conservation of giant garter snake and other freshwater emergent wetland and agriculture-associated covered species. Nontidal freshwater perennial emergent wetland creation will occur within the preserves in selected areas designed to build off of existing occupied giant garter snake sites and improve connectivity among habitat areas within and adjacent to the Plan Area. Creation and protection of the preserves is also expected to increase the abundance of other covered species, such as western pond turtle and tricolored blackbird and contribute to the long-term conservation of nontidal perennial aquatic-associated covered species.

Nontidal Perennial Aquatic Goals and Objectives

Goal NANC1: The expected outcome is nontidal perennial aquatic communities that support habitat for covered and other native species.

Objective NANC1.1. Restore 400 acres of nontidal marsh as per Objective NWNC1.1

Goal NANC2: The expected outcome is biologically diverse nontidal perennial aquatic communities that are enhanced for native species and sustained by ecological processes.

> **Objective NANC2.1**: Maintain and enhance the habitat functions of protected and created nontidal open water habitats for covered and other native species over the term of the BDCP.

Rationale for Goals and Objectives

Nontidal Perennial Aquatic Natural Community Extent and Connectivity

While the nontidal perennial aquatic natural community will be protected throughout much of the Plan Area in coordination with the protection of other natural communities (e.g., agricultural habitats, grasslands), the conservation strategy for nontidal perennial aquatic and nontidal freshwater perennial emergent wetland natural communities is focused on restoring these communities in areas where the greatest benefit to covered species can be achieved. The strategy involves protecting, enhancing, and restoring these communities primarily for the benefit of two giant garter snake subpopulation centers: the Caldoni Marsh/White Slough subpopulation in Conservation Zone 4 and the Yolo/Willow Slough subpopulation in Conservation Zone 2.

Nontidal freshwater perennial emergent wetland and associated open water habitat will be created in association with existing occupied habitats to protect and allow for expansion of these subpopulations. Surrounding agricultural lands will be targeted for acquisition in order to build larger contiguous preserves in these areas that support a network of irrigation canals and other aquatic features in addition to the restored wetland habitats within the agricultural matrix of these two areas. In this way, the protected landscape and restored wetland habitats will provide additional aquatic habitat and protect associated movement corridors and upland habitats for these subpopulations.

As these conservation areas are designed, agricultural parcels will be selected based on their proximity and connectivity to occupied sites and opportunities for restoration and enhancement. Restored habitats will be created with appropriate patch sizes and within the existing agricultural matrix to maximize connectivity and the potential for expansion and dispersal. This approach is designed to protect existing subpopulation centers and create opportunities for the expansion of these subpopulations.

With the additional conservation of 400 acres of nontidal freshwater perennial emergent wetland and perennial aquatic natural communities under the BDCP, approximately 1,948 acres of the combined communities would be protected, an 18 percent increase in the extent of protected habitat of these types. Protection of giant garter snake upland refuge habitat will be expanded in appropriate areas adjacent to the habitat creation sites. For the implementation schedule of nontidal marsh restoration, see the BDCP implementation schedule presented in Chapter 6, *Plan Implementation.*

Native Biodiversity and Nontidal Perennial Aquatic Function

Biologically Diverse Nontidal Perennial Aquatic. A significant ecosystem function of the nontidal perennial aquatic natural community is primary productivity through its aquatic food web. The nontidal perennial aquatic natural community provides habitat for a variety of species, from single-celled organisms to semi-aquatic mammals. There are non-plant primary producers such as diatoms, desmids, and filamentous green algae that often form the base of the nontidal perennial aquatic food web. Zooplankton (e.g., rotifers, copepods, and cladocerans) also live suspended in the water column, grazing on phytoplankton.

Plant species vary with inundation depth and distance from shore. There are submerged aquatics (e.g., native pondweed and invasive nonnative Brazilian waterweed) and floating aquatics (e.g., native duckweed and invasive nonnative water hyacinth). The submerged portions of these plants provide a substrate for smaller algae and cover for smaller aquatic animals, including fish; however, the invasive Brazilian waterweed, Eurasian watermilfoil, and water hyacinth form thick mats that exclude native vegetation and associated wildlife (SFEI 2003).

A variety of aquatic insects use the nontidal perennial aquatic natural community for their larval stage. Wildlife species that use the nontidal perennial aquatic natural community for resting and foraging include waterfowl, shorebirds, semi-aquatic mammals (e.g., beaver, muskrat, and river otter), piscivorous birds (e.g., bald eagles and osprey), and insectivorous birds and bats that prey on insects that gather over open water. Small ponds of the nontidal perennial aquatic natural community can also serve as brooding habitat for ducks nesting in nearby upland habitats. Some water-dependent species, such as BDCP covered western pond turtle, require adjacent upland, riparian woodlands, or emergent wetlands for cover or nesting habitat.

Species Protection. Created and protected nontidal perennial aquatic habitat will be actively managed to promote high habitat function for giant garter snake and western pond turtle. These areas will require regular monitoring and periodic manipulation of herbaceous emergent vegetation and possibly floating aquatic vegetation to maintain the appropriate balance of open water and vegetative components. Because the sites occur within agricultural areas they will require the careful management and monitoring of some agricultural practices, such as aerial application of pesticides and fertilizers, water control, and maintenance of buffers. Nonnative centracharid fish (bass and sunfish) and bullfrog are known predators of giant garter snake and western pond turtle and their populations may need to be periodically controlled. Additionally, the nontidal perennial aquatic habitat may be invaded by nonnative plants, such as ludwigia, that can have adverse negative effects on native wildlife. Management methods to reduce or eliminate populations of the nonnative animals and plants will be developed and implemented.

While designed specifically to meet the ecological requirements of giant garter snake, restored freshwater marshes will also provide habitat for other aquatic and marsh-associated covered species, such as the western pond turtle and tricolored blackbird.

Nontidal Perennial Aquatic and Climate Change

Sea level rise will affect the location, extent, and composition of the nontidal perennial aquatic natural community, in places where the natural community exists at or below current sea level, as a result of increased water elevation, increased saltwater intrusion, and a tidal hydrological regime. Flooded depressions in upland areas presumably already support this natural community, and it is not likely that natural processes in these upland areas would replace the area that will be lost closer to sea level. Implementation of BDCP nontidal perennial aquatic goals and objectives will increase the extent of the natural community and associated habitat services, despite potential losses of this natural community resulting from climate change.

Conservation Measures

- CM3 Natural Communities Protection
- CM10 Nontidal Marsh Restoration
- CM11 Natural Communities Enhancement and Management

3.3.2.2.7 Valley/Foothill Riparian

Valley/foothill riparian natural community historically occurred above the tidal zone along the margins of the Delta, except in the Cache Slough area and eastern Contra Costa County, on the eastern margin of the Yolo Basin, and along channels and sloughs of the Sacramento and San Joaquin rivers. Since reclamation and levee construction began under the Swamp and Overflow Land Act of 1850, substantial reductions in the extent, distribution, and condition of valley/foothill riparian communities from agricultural conversion, stream channelization, and urbanization have reduced the extent and diversity of valley/foothill riparian natural community for associated covered and other native plant and wildlife species.

Currently, the valley/foothill riparian natural community represents less than 4 percent of the total acreage in the Plan Area. In general, riparian communities do not occur in large patches as do other vegetation types. Instead, they tend to be distributed across the landscape as narrow corridors along watercourses or as isolated remnant patches near watercourses. The majority of the valley/foothill riparian natural community occurs as blackberry scrub, or willow/blackberry scrub with occasional patches of cottonwood, willow and oak trees. The largest patches are associated with levee blowouts on Delta Islands that lead to the establishment of isolated patches of willow scrub.

The main riparian corridors in the Plan Area are found along the San Joaquin, Sacramento, Old, Middle, and Mokelumne rivers, with the Sacramento River currently supporting the smallest extent of valley/foothill riparian natural community due to extensive engineered levees. Some smaller drainages, such as Putah Creek and Elk Slough, retain relatively continuous but narrow corridors of riparian woodland. These remnant riparian communities, while highly degraded relative to their historical occurrence, continue to provide habitat for several BDCP covered species, including riparian brush rabbit, Swainson's hawk, white-tailed kite, yellow-breasted chat, yellow-billed cuckoo, and valley elderberry longhorn beetle.

Valley/foothill riparian natural community currently covers a total of 17,338 acres in the Plan Area. Most of this acreage is distributed among Conservation Zones 2 through 7, with smaller amounts in the other 5 conservation zones. In Conservation Zones 2 and 4, most of the acreage of existing valley/foothill riparian natural community is already protected. In Conservation Zone 3, however, less than 1 percent of the total 2,080 acres of valley/foothill riparian natural community is currently protected. Of the total 17,338 acres of valley/foothill riparian natural community existing in the Plan Area, 5,339 acres (30.8 percent) are under protected status. See Section 2.3.4.5, *Valley/Foothill Riparian* in Chapter 2, *Existing Ecological Conditions*, for more detail on the current state of this natural community.

Conservation of valley/foothill riparian natural community will be achieved through the restoration of 5,000 acres of riparian forest and scrub in Conservation Zones 1, 2, 4, 5, 7, and/or 11. Riparian habitat will be restored in conjunction with tidal habitat, floodplain habitat, and channel margin restoration activities and through directed planting to restore habitat specifically for riparian brush rabbit.

Riparian Natural Community Goals and Objectives

Goal VRNC1: The expected outcome is restored large expanses and interconnected corridors of valley/foothill riparian natural community.

> **Objective VRNC1.1**: Restore or create 5,000 acres of valley/foothill riparian in Conservation Zones 1, 2, 4, 5, 6, 7, and/or 11.

Goal VRNC2: The expected outcome is biologically diverse valley/foothill riparian natural community that supports native species and is sustained by natural ecological processes.

> **Objective VRNC2.1**: Maintain and enhance the habitat and ecosystem functions of BDCP restored valley/foothill riparian and patches of riparian forest and scrub present on BDCP preserved lands over the term of the BDCP.

> **Objective VRNC2.2**: Establish seasonal buffers around riparian habitats occupied by covered species to minimize disturbance during the breeding season.

> **Objective VRNC2.3**: Restore connectivity of valley/foothill riparian corridors along linear watercourses to enhance habitat for covered species and facilitate wildlife movement.

Rationale for Goals and Objectives

Riparian Natural Community Extent and Connectivity

Restoration of valley/foothill riparian natural community will occur in restored floodplains and along main channels. This is expected to establish a more natural ecological gradient extending from shallow subtidal aquatic to upland transitional habitats. Along with BDCP conservation of other natural communities, valley/foothill riparian restoration will increase the abundance and distribution of associated native wildlife and plant species; improve connectivity among habitat areas within and adjacent to the Plan Area; improve genetic interchange among native riparian-associated species' populations; provide nutrients and food to adjacent aquatic habitats; and contribute to the long-term conservation of riparian-associated BDCP covered species.

Priority for restoration will be given to sites that provide a range of environmental gradients; increase connectivity between preserve lands; and provide additional habitat for species with currently very limited distributions. Under the goals and objectives for valley/foothill riparian natural communities, 5,000 acres will be restored with the aim of providing a full range of seral stages. Riparian restoration will be conducted in association with the restoration of tidal and nontidal wetlands, seasonally inundated floodplains, and channel margin enhancement, reestablishing a greater degree of hydrological connectivity with riparian areas, naturally promoting the regeneration and establishment of native plants, including willow-dominated scrub.

Most of the riparian restoration in the Plan Area will be in restored seasonally inundated floodplain habitat and associated with tidal restoration in Conservation Zone 7, where currently only 4.5 percent is under protected status. Restoration will also be implemented in Conservation Zones 1-6 associated with tidal habitat restoration and channel margin enhancement. On restored floodplains, restoration will be in large patches (typically over 100 acres) while restoration associated with tidal habitat and channel margins will be mostly long and narrow patches. Following restoration and other BDCP actions, the amount of valley/foothill riparian natural community in the Plan Area under protected status will be increased by 80 percent. For the implementation schedule of valley/foothill restoration, see the BDCP implementation schedule presented in Chapter 6, *Plan Implementation.*

Native Biodiversity and Valley/Foothill Riparian Function

Biologically Diverse Riparian Communities. Under a regime of natural disturbances, primarily flooding, riparian natural communities tend to vary widely in terms of both vegetation composition and structure. For example, willow thickets and mature riparian gallery forests represent riparian communities at different seral stages. Obligate and facultative riparian species may use all or only a subset of riparian communities. For example, least Bell's vireo is more likely to occur in willow-dominated riparian; yellow-breasted chat is more likely to occur in dense riparian scrub with a relatively sparse overstory; and yellow-billed cuckoo is more likely to occur in a relatively dense cottonwood/willow forest. To meet the ecological requirements of riparian-associated covered species, habitat management activities will focus on maintaining the full range of riparian communities and processes that support those communities. Existing riparian natural communities protected in BDCP conservation lands are expected to be somewhat degraded due to past or current land use practices and the spread of nonnative plants. Riparian communities will be enhanced using techniques tailored to vegetation type and site. Enhancement techniques and frequencies and intensities of application will be informed by baseline surveys, effectiveness monitoring, and targeted studies. Techniques that could be used to enhance riparian communities include but are not limited to cattle exclusion, selective application of herbicides, mowing, mechanical removal, and supplemental seeding of natives. Enhancing riparian communities within the BDCP conservation lands will likely require applying a number of these management techniques simultaneously at different sites.

Riparian passerine birds including least Bell's vireo have been adversely affected by habitat loss and cowbird parasitism. Management of riparian natural communities will address the impact of cowbird parasitism, based on site-specific conservation objectives, the documented extent of parasitism, and its impacts on the locally-occurring native species. Management of cowbird parasitism may involve cowbird trapping as appropriate.

Species Protection. Riparian restoration will create additional habitat and potential for local range expansion of several species including riparian woodrat, riparian brush rabbit, Townsend's big-eared bat (roosting and foraging), yellow-breasted chat, least Bell's vireo, western yellow-billed cuckoo, Swainson's hawk (nesting), white-tailed kite (nesting), western pond turtle, valley elderberry longhorn beetle, slough thistle, Delta button-celery, Suisun Marsh aster, and side-flowering skullcap, delta smelt, all runs of Chinook salmon, and Central Valley steelhead.

Several of the covered terrestrial wildlife species are riparian obligate birds and mammals. This is true of the riparian woodrat and the riparian brush rabbit among mammals, and the yellow-breasted chat, yellow-billed cuckoo, and least Bell's vireo among birds. Other terrestrial wildlife species use riparian natural communities extensively. Swainson's hawk and white-tailed kite forage in open country, but nest in tall trees, often in patches of riparian forest.

For all of the BDCP covered species listed above, as well as numerous other native riparian species, population declines and/or range contractions have been linked mainly or exclusively to loss of riparian habitat. The restoration of 5,000 acres of riparian natural communities in the Plan Area represents an important, positive development toward the conservation of all those species. Crucial to the conservation of the riparian woodrat and the riparian brush rabbit in particular is habitat restoration and management in Conservation Zone 7, where most of the riparian restoration will be implemented with most of it in large patches.

Restoration and protection of riparian natural communities with connectivity between them will provide an opportunity for some species to recolonize some of their historical distribution. These riparian corridors will also provide important connectivity for wildlife movement among various other natural communities within and adjacent to the Plan Area.

Riparian and Climate Change

Future climate change can affect the valley/foothill riparian natural community in a number of ways. Increased variability in precipitation will change the timing, duration, and magnitude of Delta inflows, resulting in more intense winter flooding and greater erosion of riparian habitats (Field et al. 1999, Hayhoe et al. 2004). Increased variability in precipitation can also produce prolonged droughts, making riparian vegetation more prone to fires.

A rise in sea level can affect the valley/foothill riparian natural community through increased water elevation and increased salt water intrusion. As water levels rise, riparian vegetation at the water's edge will become more frequently flooded, causing species intolerant of longer inundation periods to migrate upslope if suitable habitat is present. Changes in channel water salinity may also cause species shifts. Implementation of BDCP valley/foothill riparian goals and objectives can improve the extent, and thus potential resilience, of this natural community in the face of climate change.

Conservation Measures for Valley-Foothill Riparian

- CM3 Natural Communities Protection
- CM4 Tidal Habitat Restoration
- CM5 Seasonally Inundated Floodplain Restoration
- CM6 Channel Margin Habitat Enhancement
- CM7 Riparian Habitat Restoration
- CM11 Natural Communities Enhancement and Management

3.3.2.2.8 Grassland

Although California native grassland originally covered one-quarter of the land mass of the state (Barbour et al. 2007, Stromberg 2010), it has recently been identified as one of the twenty most endangered ecosystems in the United States (Noss et al. 1995). Once occurring in the Central Valley as widespread, species-rich prairies (Keeler-Wolf et al. 2007) with a high density of perennial grasses, valley grasslands today are highly-fragmented and dominated by nonnative annual grasses and other species. In the Plan Area, valley grassland comprises one of the two most common natural or seminatural vegetation communities, occupying approximately one-fourth of non-cultivated lands.

Direct and indirect anthropogenic influences on this landscape have resulted in the reduction, conversion, and fragmentation of valley grassland. These changes in turn have led to diminished ecological conditions necessary to sustain a well-functioning grassland natural community. Degradation of grassland quality and quantity has contributed to almost complete conversion of the vegetation community from perennial to annual grasses in less than two centuries.

Many native grassland species have been reduced in abundance or distribution through these processes. However, native plant species remain rich in number, persisting and coexisting with nonnative plants in traditional locations within remaining grasslands. Some animal species have also adjusted well to the new type of grassland. Thus, the current grassland community still offers highly valuable habitats to many grassland dependent species. See Section 2.3.4.12, *Grassland* in Chapter 2, *Existing Ecological Conditions*, for more detail on the current state of this natural community.

Conservation of grassland has three general intentions: increase grassland extent and connectivity to improve habitat quantity; recover native biodiversity at every level; and restore ecological functions necessary to sustain this natural community.

Grassland Goals and Objectives

Goal GRNC1: The expected outcome is grassland comprised of large interconnected patches or contiguous expanses.

> **Objective GRNC1.1**: Protect a minimum of 8,000 acres of grassland in Conservation Zones 1, 8, and 11. At least 1,000 acres will be protected in Conservation Zone 8, with the remainder distributed throughout these three Conservation Zones.

> **Objective GRNC1.2**: Restore 2,000 acres of grassland to connect fragmented patches of protected grassland.

Goal GRNC2: The expected outcome is biologically diverse grassland managed to enhance native species and sustained by natural ecological processes.

> **Objective GRNC2.1**: Restore and sustain a mosaic of grassland vegetation alliances, reflecting local water availability, soil chemistry, soil texture, topography, and disturbance regimes, with consideration of historical states.

> **Objective GRNC2.2**: Increase the relative cover of native grasses and forbs in native grassland vegetation alliances.

> **Objective GRNC2.3**: Increase opportunities for wildlife movement through grassland habitat.

> **Objective GRNC2.4**: Increase burrow availability for burrow-dependent species.

> **Objective GRNC2.5**: Increase prey, especially small mammals and insects, for grassland-foraging species.

Rationale for Goals and Objectives

Grassland Natural Community Extent and Connectivity

In determining the aerial extent and spatial configuration of grasslands to be conserved, the following criteria were considered: habitat value of the grasslands that currently exist within the Plan Area; ecological and evolutionary processes that sustain grasslands; spatial and functional needs of covered grassland species, including genetic exchange; and projected impacts on grasslands resulting from implementation of the BDCP.

Large contiguous grasslands within the Plan Area are present in Conservation Zones 1, 2, 4, 6, 8, and 11. Zones 3, 5 and 7 contain few large patches of grassland and Zones 9 and 10 have many small fragments of grassland distributed throughout a matrix of urban and agricultural land cover. Of those zones with areas of large existing grasslands, grassland in Zones 2 and 4 have largely been protected. 76 percent of the grassland in Zone 2 (Yolo Bypass Wildlife Area) and 67 percent of the grassland in Zone 4 (Stone Lakes NWR and Cosumnes River Preserve) are currently protected.

Zone 6 contains large areas of unprotected grasslands, but the zone is in the deeply subsided portion of the Delta and is intersected by large channels that make connection to adjacent islands impossible. The fact that the grasslands occur on deeply subsided areas also makes them susceptible to future levee failures and does not allow for the establishment of natural environmental gradients of uplands to marsh and aquatic habitats. Grasslands in this zone do not support many covered species.

Most critical for grassland conservation are Zones 1, 8, and 11. These zones are situated at the periphery of the Delta where elevations are suitable for upland habitats adjacent to restored tidal habitats. Protection and enhancement of grasslands adjacent to restored tidal marsh habitats would reestablish one of the most important historical environmental gradients (along the water-land interface) that has been largely lost due to construction of levees and reclamation of wetlands. These areas will also be more able to adapt to changes in sea level because they are at higher elevations. Grasslands in these zones also often co-occur with vernal pool complex or alkali seasonal wetland natural communities. Some protected grasslands in Zones 1 and 11 can be conserved to build upon existing and planned preserves between these two zones in Solano County. Protection of additional grasslands in this area will protect an important connection between Suisun Marsh and the Cache Slough area. Zone 8 has little protected grassland but is located near important areas for conservation that were identified in the East Contra Costa County HCP/NCCP. Habitats in these three zones support a variety of BDCP covered species and are especially important areas in the Plan Area for vernal pool plant and animal species, California tiger salamander, western burrowing owl, and rare grassland plant species. In addition to providing habitat for these species, Zone 8 supports and is adjacent to the best habitats in the Plan Area for California red-legged frog and San Joaquin kit fox.

Currently approximately 17 percent of grassland in Zones 1, 8, and 11 is protected. With the additional conservation of 8,000 acres of grassland that is proposed under the BDCP, approximately 74 percent would be protected. This would put habitat conservation in these areas on par with Zones 2 and 4 (76 percent and 67 percent, respectively).

Priority for restoration will be given to sites that provide a range of environmental gradients and increase connectivity between preserve lands. Under the BDCP, 65,000 acres of tidal habitats will be restored which include subtidal, intertidal, and transitional upland habitats. Lands acquired for restoration of these tidal habitats will include regions of higher elevation lands that would accommodate sea level rise and would also contribute to the goals and objectives for the grassland natural community. These lands would be considered high priority for grassland restoration. For the implementation schedule of grassland restoration and protection, see the BDCP implementation schedule presented in Chapter 6, *Plan Implementation.*

Native Biodiversity and Grassland Function

Biologically Diverse Grasslands. Valley grassland is species-rich, with 50 plant species commonly found in 30 x 30 m plots (Heady et al. 1991). Grassland plant species exist in patches of plant communities called (vegetation) alliances, which are unevenly spread throughout the grassland and sometimes extend into other nearby natural communities as well. Valley grassland is an extremely productive natural community, but is still not well understood.

Before the introduction of livestock grazing and modern agriculture practices, alliances characterized by perennial grasses were common in the Central Valley. Barry (1972) estimated that 99 percent of the pre-contact purple needlegrass (*Nassella pulchra*) alliance has disappeared in the valley grassland community. While its historical extent and abundance are still under debate (and classification of sub-communities (associations) under this alliance remains incomplete), it is assumed that various patches of perennial grasses, many in bunch form, and associated forbs, were widely distributed in the Central Valley (D'Antonio et al. 2007) before changes in land use affected this natural community. Native grassland vegetation alliances are likely to be found within the BDCP conservation lands, but these grasslands are expected to be degraded (i.e., low relative cover of native species) due to past and current land uses practices (e.g., deep soil disturbance and heavy grazing) and the competitive spread of nonnative plants.

Many grasslands to be conserved in the Plan Area will require intensive management that mimics natural pressures on the system; however, where possible, natural ecological processes will be allowed to influence grassland structure, succession, and heterogeneity. Historically, herbivory and fire determined native grass vigor and distribution. Wind exacerbates arid conditions characteristic of valley grasslands, and wind spreads fire, which likely maintained historical grassland extent and distribution, and contributed to the mosaic of vegetation alliances and structure, in turn determining patch dynamics of animal habitats. Natural ecological processes should be allowed to drive structure and dynamics in BDCP grasslands as much as possible.

Species Protection. In the Plan Area, there is now a limited distribution of purple needlegrass, along with several other alliances of perennial grass. Another bunchgrass, alkali sacaton (*Sporobolus airoides*), is often found on alkali or sodic stratum. In contrast, stolonous (non-bunching) creeping rye-grass (*Leymus triticoides*) covers wetter areas at the margins of riparian and emergent wetland communities. Valley grasslands, in this sense, exist as transitional zones which reflect underlying environmental gradients and create ecotones in the Bay Delta region.

Recent studies show that purple needlegrass influences soil chemistry and soil structure and contributes to underground soil heterogeneity (Parker and Schimel 2010), which is already enriched by critical microorganisms (fungi, bacteria, nematodes) and bioturbation by burrowing rodents. In native grasslands, these subterranean processes in turn contribute to diversity of flora composition above ground. On the other hand, local homogenization of soil properties caused by annual nonnative grasses are thought to create a feedback loop that encourages their invasion.

Grassland communities in the Plan Area exhibit complexity and diversity at all spatial scales, and perennial grasses and related ecological processes play a pivotal role in dynamically sustaining that complexity. Successful restoration of grassland alliances, especially those comprised of native perennial grasses will likely benefit not only the characteristic species, but valley grasslands as integrated communities (as well as nearby natural communities) by promoting essential ecological functions.

The grassland flora of the Central Valley and Bay Delta evolved under the influence of prehistoric herbivores, for example large herds of deer, elk, pronghorn, and other grazing animals. Although dense concentrations of most of these large mammals and their predators are no longer present, deer and medium-sized carnivores (e.g., gray fox, coyote) still inhabit the Plan Area. Herbivores and carnivores with a propensity to move widely will especially benefit from increases in the extent and connectedness of grasslands. This goal is underscored by the California Essential Wildlife Connectivity Project (Spencer et al. 2010), an interagency, multi-stakeholder effort steered by DFG and Caltrans to identify, map, and implement wildlife movement corridors and habitat linkages throughout the State. Twenty-four of the 192 “Essential Connectivity Areas” identified by this project occur in the Central Coast Ecoregion of the state with six of these in or adjacent to the Plan Area. In the Central Coast Ecoregion, the landcover in the identified Essential Connectivity Areas is 25 percent grassland or herbaceous, second only to the Great Central Valley in the representation of this landcover type within important wildlife movement corridors.

A large proportion of animal species that inhabit grasslands are either fossorial or burrow-dependent, attributes which provide access to constant underground habitats, presumably for temperature regulation and for protection from fire and predators. Some fossorial grassland mammals can be considered keystone species because the burrows they dig are critical to the survival of many other species and essential for a well-functioning grassland community. For example, California ground squirrels excavate burrows that provide substantial benefits to native covered species, including San Joaquin kit fox (den sites), western burrowing owl (nesting and roosting habitat), and California red-legged frog, California tiger salamander, and western spadefoot toad (upland aestivation sites). Unfortunately, ground squirrels have been the target of widespread poisoning campaigns in California where they threaten levees or are perceived as pests. Loss and fragmentation of grasslands have also reduced ground squirrel distribution and abundance. By increasing the extent of grassland, and the abundance and distribution of host burrowers, many native species will benefit.

Grasslands in the Plan Area provide foraging habitat for predators by supporting populations of small animals (mice, voles, rabbits, insects, amphibians, reptiles) on which they prey. Sufficient prey populations are critical to the health and persistence of predator populations. Enhancing the extent and abundance of rodent, lagomorph, and insect (e.g., grasshopper) populations will increase the prey base for San Joaquin kit fox and other carnivores, and raptor species, including Swainson's hawk, western burrowing owl, and white-tailed kite. Grassland conservation and restoration will also help to offset impacts to agricultural lands that produce prey for covered species.

Other ecological factors, in addition to the size and density of rodent populations, may limit populations of covered species in the Plan Area. For example, the population of San Joaquin kit fox may be limited by mortality from road kill, poisoning, coyote predation, or competition from nonnative red foxes (U.S. Fish and Wildlife Service 1998). However, there is evidence in other parts of the kit fox range that abundance of prey affects reproductive success (Egoscue 1975; White and Ralls 1993). Although research to date suggests that prey abundance is important, a lack of studies in the northern portion of the kit fox range contributes to uncertainty about the efficacy of this conservation measure in BDCP grasslands.

Because of this uncertainty, adaptive management and targeted studies are required to understand factors controlling kit fox and other predator populations and to improve management techniques. Pilot studies of management methods that enhance the rodent prey base will be conducted through the Adaptive Management Program, and effective management measures will be incorporated into grassland management actions.

Grasslands and Climate Change

The most decisive factor determining grassland presence or absence is soil water accessibility (Bartoleme et al. 2007). In the Plan Area, precipitation greatly influences soil water level and accessibility at any given location. Seasonal and annual variations in rainfall amount and pattern are vast in this region, and valley grasslands respond significantly to such stochastic fluctuations. For example, an area dominated by lush grasses in a rainy year may exhibit a vivid display of wildflowers the following spring. Therefore, it is expected that valley grasslands will be influenced, perhaps in unexpected ways, by near-future and long-term climate change. Implementation of all BDCP goals and objectives for grassland, especially promotion of underground processes, is expected to substantially improve the flexibility and resilience of this natural community and contribute to its persistence.

Conservation Measures for Grasslands

- CM3 Natural Communities Protection;
- CM8 Grassland Communities Restoration; and
- CM11 Natural Communities Enhancement and Management.

3.3.2.2.9 Alkali Seasonal Wetland Complex

The alkali seasonal wetland complex natural community is distributed within or adjacent to grasslands and adjacent to tidal marshes and oak savanna. It is associated with seasonally saturated alkali soils along the northwestern and southwestern margins of the Delta and around the perimeter of Suisun Marsh. Alkali seasonal wetland complex was once very common in the Central Valley and portions of the Plan Area; however, conversion of land to agriculture, waterfowl habitat, and commercial and urban land use has eliminated or degraded the habitat functions of the alkali seasonal wetland complex natural community through direct removal of vegetation, removal of watershed topography by leveling of the land, and the establishment of nonnative plants. For example, in east Contra Costa County the historical extent of this community has been reduced from 8,800 acres to 2,720 acres, 30 percent of its historical extent (SFEI 2010). These reductions in the extent, distribution, and condition of alkali seasonal wetland complex have reduced the diversity of native plant species uniquely associated with alkali soils and habitat for associated covered and other native wildlife species.

There are approximately 3,723 acres of alkali seasonal wetland complex natural community in the Plan Area that generally exist as two contrasting DFG vegetation types. One type, which is by far the most extensive, is dominated by perennial saltgrass (*Distichlis spicata*); while the other type is rare, covers approximately 260 acres, and is dominated by woody iodine bush shrubs. Saltgrass grasslands are typically characterized by having low productivity and are grazed by both native wildlife and domestic livestock. Because saltgrass is a prostrate grass it creates a visually open habitat that provides foraging habitat for raptors. Iodine bush habitat provides a structurally diverse habitat with open areas of salt scalds and very low herbaceous vegetation for foraging by wildlife as well as closed canopy shrub-dominated areas for cover. See Section 2.3.4.8, *Alkali Seasonal Wetland Complex* in Chapter 2, *Existing Ecological Conditions*, for more detail on the current state of this natural community.

Currently 2,769 acres (74 percent) of alkali seasonal wetland complex natural community in the Plan Area are in a protected status. Protecting and enhancing additional alkali seasonal wetland complex natural community in conjunction with adjoining natural communities is expected to maintain or increase the abundance of native wildlife and plant species, improve connectivity among habitat areas within and adjacent to the Plan Area, and contribute to the long-term conservation of alkali seasonal wetland complex and grassland natural communities associated covered species.

Alkali Seasonal Wetland Goals and Objectives

Goal AWNC1: The expected outcome is protected alkali seasonal wetland complex natural community that represents a range of environmental conditions and is adjacent to other conserved lands.

> **Objective AWNC1.1**: Protect 400 acres of alkali seasonal wetland complex natural community in Conservation Zones 1, 8, and/or 11.

Goal AWNC2: The expected outcome is biologically diverse alkali seasonal wetland complex natural community with improved native biodiversity, habitat heterogeneity, and the ability to support populations of covered and other native species.

> **Objective AWNC2.1**: Maintain and, where habitat functions for covered species can be increased, increase the diversity and relative cover of native grasses and forbs.

Rationale for Goals and Objectives

Alkali Seasonal Wetland Natural Community Extent and Connectivity

In determining the extent and spatial configuration of alkali seasonal wetland complex natural community to be conserved, the following criteria were considered: the habitat value of alkali seasonal wetland complex that currently exists within the Plan Area; the spatial and functional needs of covered species that use alkali seasonal wetland complex; and the projected impacts on alkali seasonal wetland complex resulting from the implementation of the BDCP. Under the alkali seasonal wetland complex natural community goals and objectives, 400 acres of the community will be protected in Conservation Zones 1, 8, and/or 11, which correspond to the same areas where impacts will occur.

Additionally, alkali seasonal wetland complex natural community in Conservation Zones 1, 8, and 11 is situated at elevations that are suitable for serving as upland habitats adjacent to restored tidal habitats; and in Conservation Zones 1 and 11 can be protected to enhance the spatial extent and connectivity of existing and planned preserves in Solano County that span tidal and upland habitats. Further, the protection of additional alkali seasonal wetland complex natural community in this area will protect the habitat connectivity between Suisun Marsh and Cache Slough and maintain its function as a movement corridor for wildlife.

Protection of 400 acres of alkali seasonal wetland complex natural community under the BDCP will prevent the removal or degradation of these alkali seasonal wetlands from future changes in land use. Even though 74 percent of the current extent of this natural community is protected, it is a rare community that warrants further protection. Its current extent is only a small fraction of its historical extent before it was converted to other land uses; therefore, preserving as much remaining area as possible is important for preserving the biota and preserving the hydrological function of the alkali seasonal wetland complex natural community which requires a more extensive watershed than the vernal pool complex natural community. Following full implementation of the BDCP, the extent of protected alkali seasonal wetland complex natural community in the Plan Area will be increased from 2,769 acres to 3,112 acres, a 12 percent net increase accounting for the loss of 57 acres of protected alkali seasonal wetland complex. For the implementation schedule of alkali seasonal wetland complex protection, see the BDCP implementation schedule presented in Chapter 6, *Plan Implementation.*

Native Biodiversity and Alkali Seasonal Wetland Complex Natural Community Function

Biologically Diverse Alkali Seasonal Wetland Complex. While alkali seasonal wetland complex natural community may be perennial grassland that is dominated by saltgrass or woody scrub dominated by iodine bush, it typically has a diverse forb component that consists of spring vernal pool-like vegetation in areas of heavy clay or salt scalds followed by summer flowering tarweeds, tarplants (*Hemizonia* and *Holocarpha* spp.), *Atriplex* (*Atriplex* spp.) and perennial gumplant (*Grindelia* spp.). They also support diverse assemblages of native ground-nesting bees and other important pollinators for both native and agricultural plant species. Saltgrass is found in most areas of alkali seasonal wetland complex natural community, while the iodine bush shrub is found within the Plan Area only near the Clifton Court Forebay. The saltgrass-dominated areas generally provide a lower, non-woody physical structure with relatively fast nutrient and carbon cycling. The iodine bush-dominated areas tend to have a patchy distribution of shrubs, providing greater structural variation and relatively slower carbon cycling

Enhancement and management of protected alkali seasonal wetland complex natural community is expected to improve native biodiversity and enhance the function of this natural community for covered and other species. Careful planning will be required to resolve uncertainties regarding appropriate management regimes for this community type in the context of a larger diverse and managed landscape. Alkali seasonal wetland complex natural community in the Plan Area is generally interspersed with or adjacent to grassland and vernal pool complex, and all three communities are generally managed together within large pastures. There is very little information available regarding the appropriate management of alkali seasonal wetland complex per se, but there is one long-term grazing study available for mixed exotic annual and saltgrass perennial grassland for the Jepson Prairie area (Swiecki and Bernhardt 2008). To resolve this general lack of information, enhancement techniques and effective application frequencies and intensities will be informed by baseline surveys, effectiveness monitoring, and targeted research. Techniques that could be used to enhance alkali seasonal wetland complex within the context of the other communities include but are not limited to: appropriate grazing regimes including grazing exclusion, prescribed burning, and the appropriate use of herbicides to control invasive nonnative plant species. Enhancing the alkali seasonal wetland complex natural community will likely require applying multiple management techniques simultaneously and the spatial separation of some of the techniques.

Species Protection. Brittlescale and heartscale habitat consists of ephemeral drainages within the alkali seasonal wetland complex natural community, while Delta button-celery occupies clay flats that periodically flood. Specific habitat acreage requirements for brittlescale, heartscale, and Delta button-celery are necessary to ensure that the specific habitat conditions required by these species are included within the alkali seasonal wetland complex natural community that will be protected (see Species Goals and Objectives). Other BDCP covered species expected to benefit from alkali seasonal wetland complex natural community protection and enhancement include San Joaquin kit fox, Townsend's big-eared bat, tricolored blackbird, Suisun song sparrow, western burrowing owl, Swainson's hawk, white-tailed kite, giant garter snake, western pond turtle, California red-legged frog, California tiger salamander, western spadefoot toad, and Carquinez goldenbush. For the implementation schedule of alkali seasonal wetland complex natural community protection and enhancement, see the BDCP implementation schedule presented in Chapter 6, *Plan Implementation.*

Alkali Seasonal Wetland Complex and Climate Change

Alkali seasonal wetland complex natural community is generally located at elevations that will not be directly inundated by rising sea level, but could be subjected to vegetation changes through altered hydrology in adjacent tidal areas. Another potential impact of climate change would be driven by increased variability in precipitation. The species present in this community are adapted to variable precipitation; and increased variability could lead to changes of the vegetation within the community. Implementation of BDCP alkali seasonal wetland complex natural community goals and objectives can improve the extent, and thus potential resilience, of this community in the face of climatic changes.

Conservation Measures for Alkali Seasonal Wetland Complex

- CM3 Natural Communities Protection
- CM11 Natural Communities Enhancement and Management

3.3.2.2.10 Vernal Pool Complex

The vernal pool complex natural community is characterized by both isolated and interconnected groups of vernal pool wetlands and seasonal swales within the matrix of grassland or alkali seasonal wetland natural communities. Vernal pools in California provide habitat for a number of endemic and rare species (Jain 1979, Jones and Stokes Associates 1990, Skinner and Pavlik 1994, Solomeshch et al. 2007). A single vernal pool may support over 100 species of native plants and animals (USFWS 2005).

Within the Plan Area, there are 6,954 acres of vernal pool complex, of which 68 percent is found in the grassland natural community, 31 percent is found in the alkali seasonal wetland complex, and 1 percent is found in other natural community types. The vernal pool complex is uncommon in the Plan Area, found only in a few locations along the very margin of the Plan Area. Vernal pools are found west of the Sacramento River from Putah Creek south to the gently sloped terraces immediately to the north and east of the Montezuma Hills; on the north and eastern margins of Suisun Marsh; east of the Sacramento River in the Stone Lakes area; and west of the San Joaquin River from Byron to Discovery Bay (Witham 2003, ESA 2005, Leigh Fisher

Associates 2005, Williamson et al. 2005, Witham 2006, Baraona et al. 2007, Kleinschmidt Associates 2008, Rains et al. 2008). See Section 2.3.4.9, *Vernal Pool Complex* in Chapter 2, *Existing Ecological Conditions*, for more detail on the current state of this natural community.

Conversion of land for agricultural and urban uses has eliminated or degraded the habitat functions and value of vernal pool complex natural community through direct the removal of vegetation, the elimination of vernal pool watershed topography with land leveling, and disruption of natural seasonally hydrology by flood irrigation. The reduction in the extent, distribution, and condition of vernal pools has reduced the diversity of native vernal pool plant species such as BDCP covered alkali milk-vetch, Heckard's peppergrass, and legenere. It has also eliminated habitat for associated covered and other native wildlife species such as BDCP covered vernal pool shrimp species.

Of the 6,958 acres of vernal pool complex in the Plan Area, 4,379 acres (63 percent) is currently under protected status. Preserving, restoring, and enhancing additional remaining vernal pool complex in conjunction with surrounding grassland habitats is expected to further maintain or increase the abundance of native wildlife and plant species, improve connectivity among habitat areas within and adjacent to the Plan Area, and contribute to the long-term conservation of vernal pool- and grassland-associated covered species, including western spadefoot toad, California tiger salamander, vernal pool shrimp species, and various vernal pool plant species.

Vernal Pool Complex Goals and Objectives

Goal VPNC1: The expected outcome is protected vernal pool complex natural community that represents a range of environmental conditions and is adjacent to other conserved lands.

> **Objective VPNC1.1**: Protect 300 acres of vernal pool complex in Conservation Zones 1, 8, and 11.

Goal VPNC2: The expected outcome is restored biologically diverse vernal pool complex natural community with improved native biodiversity, habitat heterogeneity, and the ability to support populations of covered and other native species.

> **Objective VPNC2.1**: Restore 200 acres of vernal pool complex natural community in Conservation Zones 1, 8, and/or 11 within patches of protected grassland that supports habitat for the western spadefoot toad, California tiger salamander, and the covered vernal pool shrimp and plant species.

> **Objective VPNC2.2**: Maintain and, where habitat functions for covered species can be enhanced, increase the diversity and relative cover of native grasses and forbs.

Rationale for Goals and Objectives

Vernal Pool Complex Natural Community Extent and Connectivity

In determining the extent and spatial configuration of vernal pool complex natural community to be conserved, the following criteria were considered: the habitat value of the community that currently exists within the Plan Area; the extent and distribution of the community that is currently under protected status; the spatial and functional needs of covered species that use the community as habitat; and the projected impacts on the community resulting from implementation of the BDCP. Under the vernal pool complex natural community goals and objectives, 300 acres of vernal pool complex will be protected and 200 acres of vernal pool complex will be restored in Conservation Zones 1, 8, or 11.

Vernal pool complex natural community is distributed within or adjacent to a variety of natural communities on relatively impermeable soils in shallow basins and drainages on level terrain along the margins of the Plan Area. In the Plan Area, the vernal pool complex natural community consists of four fairly uniform types: annual grassland vernal pools in the Stone Lakes area; clay alluvium vernal pools and playa pools running from Putah Creek south to Cache Slough; Montezuma Block vernal pools and playa pools in the Jepson Prairie/Montezuma Hills area; and alkaline sink/meadow vernal pools in the Byron/Clifton Court Forebay area.

These areas are generally at the margins of the species distributions where the vernal pool complex natural community transitions into other natural communities such as tidal brackish or tidal freshwater emergent wetland. The community can also grade into the agricultural habitat natural community where its unique characteristics are blurred to varying degrees by human driven impacts such as land leveling and ripping, altering the supply of water through flood irrigation.

BDCP actions will increase the amount of extant vernal pool complex natural community in protected status in the Plan Area by 300 acres from a current 4,379 acres, or 63 percent, to 4,679 acres, or 67 percent of the total 6,959 acres of vernal pool complex. The BDCP will also restore and additional 200 acres of vernal pool complex natural community in the Plan Area. The net increase in area of both restored and protected vernal pool complex, accounting for a small loss of lower quality vernal pool complex, will result in a total of 4,849 acres vernal pool complex in protected status.

All of the vernal pool complex natural community in the Plan Area is found within Conservation Zones 1, 4, 8, 9, and 11. Most of the community present in Conservation Zone 4 is already protected; while in Conservation Zone 9, it consists of small patches that are isolated among developed areas and agricultural land. Vernal pool complex natural community in Conservation Zones 1, 8, and 11 is situated at elevations that are suitable for serving as upland habitats adjacent to restored tidal habitats and additionally, in Conservation Zones 1 and 11, can be protected to build upon existing and planned preserves in Solano County between these conservation zones. Protection of additional vernal pool complex natural community in this area will protect an important connection between Suisun Marsh and the Cache Slough area. Vernal pool complex natural community in Conservation Zone 8 consists of relatively rare alkaline sink/meadow vernal pools that warrant protection. For the implementation schedule of vernal pool complex natural community protection and restoration, see the BDCP implementation schedule presented in Chapter 6, *Plan Implementation.*

Native Biodiversity and Vernal Pool Complex Function

Biologically Diverse Vernal Pool Complex. The restoration of 200 acres of vernal pool complex natural community will enhance native biodiversity and habitat heterogeneity within the Plan Area. Priority for restoration will be given to sites that display clear vernal pool signatures on aerial imagery, possesses relatively natural hydrology, provide a range of environmental gradients, and that will increase connectivity between protected lands. Under the vernal pool complex natural community goals and objectives, 200 acres of vernal pool complex will be restored in Conservation Zones 1, 8, or 11; and 300 acres will be protected in those conservation zones.

Vernal pool complex natural community in the Plan Area is generally interspersed with the grassland and alkali seasonal wetland complex natural communities; and all three communities are generally managed together, although there is very little experience in managing and alkaline sink/meadow vernal pools.

There is very little information available regarding the appropriate management of the types of vernal pool complex found in the Plan Area but there is one long-term grazing study available for mixed exotic annual and saltgrass perennial grassland for the Jepson Prairie area. To resolve this general lack of information, restoration and enhancement techniques and effective application frequencies and intensities will be informed by baseline surveys, effectiveness monitoring, and targeted research. Techniques that could be used to enhance vernal pool complex within the context of the other communities include but are not limited to: appropriate grazing regimes including grazing exclusion; prescribed burning; and the appropriate use of herbicides to control invasive nonnative plant species. Enhancing vernal pool complex will likely require applying multiple management techniques simultaneously and the spatial separation of some of the techniques.

The vernal pool complex is essentially an amphibious ecosystem with differing functions dependent upon whether it is in a flooded or dry stage. When flooded, it contains ephemeral aquatic invertebrates, the immature stages of amphibians, and hosts waterfowl. As the water recedes, the ecosystem services first change from those of a fully aquatic system to a wetland, and then to a terrestrial ecosystem (Williams 2006). Through this process the food web linkages break down as the community becomes more integrated with the terrestrial landscape around it. When dry, it is integrated with the surrounding terrestrial ecosystems and provides foraging habitat for native wildlife, and is typically managed as rangeland and grazed by sheep or cattle.

Vernal pools are defined in large part by their hydrology, which has three components: 1) the source of water; 2) the duration of inundation and waterlogged soil phases; and 3) the seasonal timing of these phases. Rainfall is the primary source of water to vernal pools as it falls directly into the vernal pool or is transported a short distance across the watershed of the vernal pool; however, there can be groundwater transport to a vernal pool through a shallow perched aquifer or a combination of rainfall and creek flooding (ESA 2005, Williamson et al. 2005, Rains et al. 2008). The duration and timing of the inundation and waterlogged soil phases also vary; with hard-pan vernal pools having shorter phases centered during the middle of the wet season, while clay-pan and clay vernal pools have longer phases extending earlier and later into the wet season (ESA 2005, Williamson et al. 2005, Rains et al. 2008).

Vernal pool plant species are generally adapted to survive standing water throughout winter and spring and dry soils in summer (CALFED 2000, Solomeshch et al. 2007). Duration of inundation correlates with two clear functional plant groups (Zedler 1987, 1990, Barbour et al. 2003, Barbour et al. 2005, Barbour et al. 2007). Plants found at the edge of pools are adapted to the fluctuating hydrology of shallow vernal pools or to the edges of deep vernal pools. These species are prone to elimination by competition with upland exotic grass species or through thatch accumulation (Barry 1995, Griggs 2000, Marty 2005). The second functional plant group is adapted to the longer inundation periods of the pool basins.

Vernal pool plant species also vary among the four types of vernal pool complex in the Plan Area. The annual grassland type found in the Stone Lakes area is dominated by Eurasian annual grasses with a varying mixture of native grasses and herbs depending on the farming history of the site. The clay alluvium vernal pools and playa pools type from Putah Creek south to Cache Slough is dominated in the spring by either Eurasian annual grasses or a variable mixture of saltgrass and native herbs and dominated in the summer by native tarweeds, or the exotic yellow starthistle. The Montezuma Block vernal pools and playa pools type in the Jepson Prairie/Montezuma Hills area is similar to the clay alluvium vernal pools and playa pools type, but extensive areas are also in agriculture production as dry-farmed wheat. The alkaline sink/meadow vernal pools type in the Byron/Clifton Court Forebay area has surrounding vegetation that is typically dominated by native grasses such as saltgrass and alkali ryegrass or by woody shrubs like iodine bush and subshrubs such as bush seepweed and alkali heath.

In the Plan Area, nonnative species invade and degrade the vernal pool complex at various points along the moisture gradient. The margins of vernal pools are often dominated by the nonnative Italian ryegrass, while the deeper portions of hardpan pools are invaded by low mannagrass (Gerlach et al. 2009). Other parts of vernal pool complexes are often invaded by perennial pepperweed (Swiecki and Bernhardt 2002, Witham 2003, ESA 2005, Witham 2006, ESA 2007, Gerlach et al. 2009).

Species Protection. The vernal pool complex natural community is utilized as habitat by a number of wildlife species. Some use the community only for a specific part of their life history. For example, amphibians such as California tiger salamander and western spadefoot toad use vernal pools and playa pools for breeding, but are otherwise essentially terrestrial animals. Some waterfowl forage in vernal pools and playa pools during the wet season, consuming invertebrates (ducks and shorebirds) and vegetation (geese) (Medeiros 1976, Reiner and Swenson 2000). Some species spend their entire lives in vernal pools and playa pools, for example the five crustacean species covered under the BDCP (mid-valley fairy shrimp, Conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, vernal pool tadpole shrimp, and California linderiella).

Vernal pool complex natural community protection and restoration will provide habitat for BDCP covered western spadefoot toad, California tiger salamander, mid-valley fairy shrimp, Conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, vernal pool tadpole shrimp, California linderiella, alkali milk-vetch, heartscale, brittlescale, San Joaquin spearscale, dwarf downingia, Delta button-celery, Boggs Lake hedge-hyssop, legenere, and Heckard's peppergrass. Most of the BDCP covered vernal pool plant species are generally confined to small scattered populations growing in vernal pools and swales on alkaline clay soils. When they occur on unprotected land they are especially vulnerable to agriculture intensification or development. BDCP tidal restoration activities could also potentially affect some occurrences. In such cases, surveying for and protecting individual occurrences of these species is an effective conservation strategy that can yield population level benefits.

Vernal Pool Complex and Climate Change

Climate change is expected to alter the vernal pool complex natural community. Because this natural community is generally located at elevations that will not be directly impacted by rising sea level, the primary impact of climate change is predicted to be driven by changes in the hydrological regime due to increased variability in precipitation. The species present in this community are adapted to existing hydrological conditions, such that increased variability of precipitation would likely lead to a shorter and more variable wet season or similar changes in the inundation period. It is not known how increased variability in pool hydrology would affect the plants and animals inhabiting them, but because these species are adapted to current conditions, the impacts will likely be negative. In addition, rising average temperatures could result in increased evapotranspiration rates and therefore shorter wetted periods for vernal pools, the impacts of which are expected to be adverse to native plants and wildlife. The implementation of BDCP vernal pool complex natural community goals and objectives will increase the extent of this natural community and help ensure its persistence through climatic changes.

Conservation Measures for Vernal Pool Complex

- CM3 Natural Communities Protection
- CM9 Vernal Pool Complex Restoration
- CM11 Natural Communities Enhancement and Management

3.3.2.2.11 Inland Dune Scrub

Inland Dune Scrub occurs in only one location in the Plan Area. It is found along the south shore of the San Joaquin River immediately east of the city of Antioch within the Antioch Dunes National Wildlife Refuge (ADNWR) and on two adjacent (PG&E) properties. These areas of inland dune scrub are fully protected by ownership or conservation Memoranda of Understanding (MOUs). These protected lands are completely isolated from other terrestrial habitats by development to the west, south, and east, and by the San Joaquin River to the north.

Historically, the 190-acre dune paralleled the San Joaquin River shore for 2 miles and was 0.15 mile wide and 120 feet tall (Howard and Arnold 1980, SFEI (San Francisco Estuary Institute) 2010). Mining of the sand in the late 19^{th} and early 20^{th} century for the manufacture of pottery, bricks, asphalt and concrete reduced the extent of the dunes. After WWII, commercial development occurred in the area where the dune had been mined, and the sand mining moved eastward. The USFWS negotiated a purchase to establish the 55-acre Antioch Dunes National Wildlife Refuge (ADNWR) with the sand dunes that remained in 1980. See Section 2.3.4.13, *Inland Dune Scrub* in Chapter 2, *Existing Ecological Conditions*, for more detail on the current state of this natural community.

To increase the level of conservation benefits provided to inland dune scrub species, the BDCP inland dune scrub conservation will be implemented through the funding of appropriate management actions and studies.

<u>Inland Dune Scrub Goals and Objectives</u>

Goal IDSC1: The expected outcome is support for funding of the USFWS management and enhancement of the inland dune scrub natural community on the Antioch Dunes National Wildlife Refuge.

> **Objective IDSC1.1:** The BDCP will support the funding of the USFWS program for management, enhancement, and monitoring of inland dune scrub natural community on the Antioch Dunes National Wildlife Refuge at an annual amount of $XX.XX for X years.

<u>Rationale for Goals and Objectives</u>

Inland Dune Scrub Natural Community Extent and Connectivity

Currently, the degraded remnants of the inland dune scrub natural community are being managed exclusively for the three endangered species which the ADNWR was established to protect. The inland dune scrub natural community transitions into tidal brackish emergent wetland along its border with the San Joaquin River (USFWS (United States Fish & Wildlife Service 1984, 2001); and its other three sides are bordered by commercial developments. Management actions to increase the dune-like characteristics of ADNWR have included creating small dunes with dredged sand material (USFWS 1984a, 2001). Additionally there are captive breeding and propagation reintroduction program for Lange's metalmark, Contra Costa wallflower, and Antioch Dunes evening primrose (Johnson et al. 2007, USFWS 2008).

Native Biodiversity and Inland Dune Scrub Function

Biologically Diverse Inland Dune Scrub. Inland dune scrub is more similar to the vegetation of sandy soils in the San Joaquin Valley and Mojave Desert than to coastal scrub communities (Howard and Arnold 1980). The pre-disturbance species composition of the vegetation was not well described; however, based on early charts and a postcard dating from the early 1900s, the vegetation contained widely scattered large valley oaks, live oaks, various shrub species, and numerous herbaceous species (Howard and Arnold 1980, SFEI (San Francisco Estuary Institute) 2010).

The BDCP inland dune scrub natural community is defined by the presence of two vegetation types. One vegetation type consists of a broadleaf shrubland that was classified as the *Lupinus albifrons* (silver bush lupine) Antioch Dunes alliance (5 acres), and the other is a dwarf shrub vegetation type classified as the *Lotus scoparius* (deerweed) Antioch Dunes alliance (15 acres).

The primary problematic nonnative plant species in this community are annual grasses such as ripgut brome, vetches, and yellow starthistle (*Centaurea solstitialis*) (USFWS 2001a) which form dense patches that crowd out native plant species and reduce habitat quality for wildlife and invertebrates. The current management plan for the Antioch Dunes NWR invasive nonnative plant species control efforts includes hand pulling of individual invasive plants through the efforts of volunteers, targeted herbicide application, controlled burns, the restoration of some dune-like topography, and planting of nursery-grown nakedstem buckwheat (USFWS 2001a, 2008).

The Antioch Dune has also been known as an entomological hotspot since the 1930s when research entomologists began collecting in what is now the Sardis Unit of the ADNWR (Howard and Arnold 1980, Arnold 1983). A total of 27 taxa were described from Antioch Dunes during that decade. Eight of those taxa are endemic to the Antioch Dune. Four are now extinct, three are of uncertain status, and the eighth is the federally and state endangered Lange's metalmark butterfly (*Apodemia mormo langei*).

Species Protection. The BDCP conservation actions for the inland dune scrub natural community are consistent with and help to achieve the recovery objectives for Lange's metalmark butterfly identified in the 5-year Review (USFWS 2008). The Lange's metalmark butterfly captive breeding and release program will include the nursery propagation and out-planting of the white-flowered, sand-associated, ecotype of nakedstem buckwheat and the management of the nakedstem buckwheat to create dense patches of older plants with an extensive layer of leaf litter. The required sizes of self-sustainable Lange's metalmark butterfly populations have not yet been determined, but may be revealed as the controlled propagation studies proceed.

Lange's metalmark butterfly is endemic to areas of Oakley sand soil in east Contra Costa County that support nakedstem buckwheat which is its larval host plant and its adult nectar plant (Arnold 1983). Contra Costa wallflower and Antioch Dunes evening primrose are microendemics that only occur on the Antioch Dune itself. Lange's metalmark butterfly is entirely dependent on a particular white-flowered, sand-associated, ecotype of nakedstem buckwheat (*Eriogonum nudum* ssp. *auriculatum*) that has a later and longer blooming season than ecotypes growing on rocky areas nearby on Mt. Diablo. Additionally, its dependence on the plant extends to the leaf litter that accumulates near the base of large plants growing in large clumps (Arnold 1983).

Historically, nakedstem buckwheat occurred on the 190-acre Antioch Dune; in an area 1.5 miles southeast of the Antioch Dune as a 3-mile long by 1.5-mile wide 3,000-acre oblong patch on the Oakley sand soil southwest of Oakley; and in an unknown location near Brannan Island (Howard and Arnold 1980, Arnold 1983, 2005, SFEI (San Francisco Estuary Institute) 2010). The dune habitat has been reduced to 20 acres by sand mining, and the rest of the habitat was lost through development and agriculture. The remaining 20 acres of habitat has been further degraded by nonnative invasive plants such as vetches and annual grasses, and older dense stands of nakedstem buckwheat have been lost to wildfires (United States Fish & Wildlife Service 2001, 2008).

Inland Dune Scrub and Climate Change

The primary impact of climate change on the inland dune scrub natural community is predicted to be driven by changes in the hydrological regime due to increased variability in precipitation. The species present in this community are adapted to variable precipitation, and it is uncertain how they will be affected by increased variability. The inland dune scrub natural community is generally located at elevations that will not be directly impacted by rising sea level. Implementation of BDCP inland dune scrub goals and objectives will help ensure propagation of sensitive inland dune scrub species.

Conservation Measures for Inland Dune Scrub

- CM11 Natural Communities Enhancement and Management

3.3.2.2.12 Agricultural Habitats

The majority of lands in the Delta are currently used for agriculture. Agricultural habitats in the Plan Area formerly consisted of extensive brackish and freshwater wetlands, open grasslands, broad riparian systems, and oak woodlands. By the mid-1800s, reclamation of wetlands began to transform the Delta into an agricultural region with a complex system of channelized waterways and Delta "islands." The conversion of natural vegetation to agriculture eliminated large areas of native habitats. Nevertheless, some agricultural systems continue to support abundant wildlife and provide essential breeding, foraging, and roosting habitat for many resident and migrant wildlife species; although they generally support a less diverse community of wildlife compared with most native habitats (Fleskes et al. 2005, EDAW 2007, USFWS 2007a, Kleinschmidt 2008).

The agricultural landscape within the Plan Area is a dynamic matrix of a variety of land cover types, including perennial, semi-perennial, and seasonally or annually rotational crops. The large extent of the rotational crops results in a cover type matrix that is subject to change annually based primarily on agricultural economic conditions. This dynamic land management regularly changes habitat values at the field level for agriculture-associated BDCP covered species, while the overall landscape habitat values may change more slowly. See Section 2.3.4.14*, Agricultural Habitats* in Chapter 2, *Existing Ecological Conditions,* for more detail on the current state of this natural community.

Some BDCP covered species utilize agricultural habitats and in some cases have come to rely on the habitat value of certain agricultural landscapes, practices, and crop types. A reduction in agricultural acreage in the Plan Area will occur largely as a result of restoring tidal and nontidal wetland habitats. These restored habitats will incorporate a range of ecological gradients and will thus include associated grassland, open water, riparian, and other habitats. The removal of agricultural habitats through restoration of wetlands and associated communities will reduce the extent of upland agricultural habitats. However, the reduction in cropland acreage will be largely offset by 1) the value of restored wetlands and associated communities that will provide higher value habitat to some agriculture-associated species such as giant garter snake, greater sandhill crane, white-tailed kite, and tricolored blackbird; and 2) the stabilization of higher value agricultural cover types on BDCP protected lands.

Agricultural Habitat Goals and Objectives

Goal ALNC1: The expected outcome is increased habitat functions for covered and other native species that are supported by agricultural land cover types and management practices.

> **Objective ALNC1.1**: Maintain and protect the functions of 4,600 acres of rice lands as habitat for giant garter snake, western pond turtle, tricolored blackbird, white-tailed kite, waterfowl, and migrant shorebirds in Conservation Zone 2. This objective may be partially or fully achieved by maintaining an equivalent extent of natural or managed lands that support habitat functions similar to rice lands for associated covered and other native wildlife species.

> **Objective ALNC1.2**: Maintain and protect the functions of 12,020 to 28,040 acres of non-rice agricultural lands as foraging habitat for Swainson's hawk, white-tailed kite, and tricolored blackbird that are located within 8 miles of occupied Swainson's hawk nesting habitat.

> **Objective ALNC1.3**: Of the maintained 12,020 to 28,040 acres of non-rice agricultural lands, maintain at least 3,000 acres of pasture that supports western burrowing owl foraging habitat. This objective may be partially or fully achieved through preservation of other land cover types that provide moderate-value or greater habitat function for the western burrowing owl.

Objective ALNC1.4: Of the maintained 12,020 to 28,040 acres of non-rice agricultural lands, maintain at least 4,800 acres that supports greater sandhill crane foraging habitat within its Winter Use Area and within 2 miles of known roosting sites in Conservation Zones 3, 4, 5 and/or 6.

Objective ALNC1.5: Of the maintained 12,020 to 28,040 acres of non-rice agricultural lands and 4,600 acres of rice lands, maintain and protect 1,000 acres within or adjacent to habitat occupied by the Yolo/Willow Slough giant garter snake subpopulation in Conservation Zone 2.

Objective ALNC1.6: Of the maintained 12,020 to 28,040 acres of non-rice agricultural lands, maintain and protect 1,000 acres within or adjacent to habitat occupied by the Caldoni Marsh/White Slough giant garter snake subpopulation in Conservation Zone 4.

Objective ALNC1.7: Target agricultural land conservation to provide connectivity between other protected lands.

Objective ALNC1.8: Maintain and protect the small patches of important wildlife habitats associated with agricultural lands that occur within BDCP conserved agricultural lands, including isolated valley oak trees, trees and shrubs along field borders and roadsides, remnant groves, riparian corridors, water conveyance channels, grasslands, and wetlands.

Rationale for Goals and Objectives

Agricultural Habitats Extent and Connectivity

Delta crop types include small grains such as wheat and barley, field crops such as corn, sorghum, and safflower, truck crops such as tomatoes and sugar beets, forage crops such as hay and alfalfa, pastures, orchards, and vineyards (CALFED 2000, DWR 2007). The distribution of crop types in production in the Plan Area varies, depending on crop-rotation patterns and market forces. For example, over the past few decades there has been a two-fold increase in acreage used to produce corn, making it the number one crop in acreage grown; and an 18-fold increase in vineyards (DWR 2007).

Changes in crop production can have substantial effects on the habitat value of agricultural habitats for wildlife, particularly birds. Hay, grain, row crops, and irrigated pastures support abundant rodent populations, providing foraging habitat for bird species such as Swainson's hawk, white-tailed kite, and burrowing owl. Conversion of pastures, row crops, and similar agricultural habitats to orchards and vineyards has been noted as a factor affecting raptors such as Swainson's hawk (Estep 2008).

Irrigated pastures, alfalfa, and annually cultivated irrigated cropland provide foraging habitat for BDCP covered Swainson's hawk, white-tailed kite, western burrowing owl, greater sandhill crane, and tricolored blackbird. Grain, corn, and rice fields provide foraging habitats for sandhill cranes, waterfowl, wading birds, and shorebirds. Upland and seasonally flooded agricultural habitats and wetlands of the Delta support an estimated 10 percent of the waterfowl population that annually winter in California (CALFED 1998). Rice fields provide foraging habitat for many bird species as well as important aquatic habitat for giant garter snakes and western pond turtle. Orchards and vineyards, conversely, provide limited wildlife value, particularly to BDCP covered species. Orchards and vineyards develop a dense overstory canopy that generally precludes access by foraging Swainson's hawks, white-tailed kites, western burrowing owls, and other agricultural land-associated covered species.

While the agricultural landscape of the Delta is important to BDCP covered and other native species, only a portion of the landscape is utilized in any give year due to conversions and crop rotations that result in long-term (i.e., orchards, vineyards) or short-term reductions in habitat value. The use of conservation easements and fee title to protect the wildlife habitat functions for BDCP covered species will maximize habitat functions and eliminate the dynamic fluctuations in habitat functions of 4,600 acres of rice land and 12,020 to 28,040 acres of non-rice agricultural lands under BDCP conservation protection. Agricultural land placed under conservation protection under the BDCP will increase from the current 11 percent to a range of between 14 to 18 percent.

While some agriculture-associated covered species, such as Swainson's hawk are highly mobile and do not necessarily require connectivity of large preserved habitat patches, other species, such as giant garter snake and western pond turtle, will benefit from acquiring contiguous agricultural parcels that facilitate expansion of existing populations and dispersal and other movements between occupied areas and connectivity to suitable unoccupied areas. For example, connectivity of protected agricultural habitats (and restored tidal marsh and nontidal marsh) in Conservation Zone 4 will provide additional connectivity to Stone Lakes National Wildlife Refuge and facilitate northward expansion of the Coldani Marsh/White Slough giant garter snake subpopulation.

The reduction in agricultural acreage in the Plan Area will occur largely as a result of restoring tidal habitats. These restored habitats will incorporate the range of ecological gradients and will thus include associated grassland, open water, riparian, and other habitats. Most of the covered species associated with agricultural habitats including giant garter snake, Townsend's big-eared bat, white-tailed kite, tricolored blackbird, and greater sandhill crane, will use the restored habitats and benefit from the restoration activities. The distribution and abundance of these species is unlikely to be affected, and may benefit, as a result of the conversion of agricultural acreage to restored tidal marsh communities. For the implementation schedule of agricultural habitat preservation, see the BDCP implementation schedule presented in Chapter 6, *Plan Implementation.*

Native Biodiversity and Agricultural Habitats Function

Biologically Diverse Agricultural Habitats. Although cropland vegetation is grown as a monoculture using tillage or herbicides to eliminate unwanted vegetation, interspersed within the agricultural landscape are small patches or linear corridors of natural vegetation and other natural features, such as riparian woodland and scrub, wetlands, ponds, hedgerows, tree rows, and small patches of isolated native or nonnative trees that provide habitat for songbirds, raptors, reptiles, amphibians, and small mammals. Maintenance of these small but important wildlife habitats can benefit BDCP covered wildlife species. Agricultural habitats in the Plan Area are not known to support any BDCP covered plant species.

Covered wildlife species that use agricultural habitats use other habitats to meet life requirements. For example, agricultural lands are used primarily for foraging by several species that nest in riparian areas, roadside trees, or isolated trees and groves. Wetlands, streams, ponds, hedge rows, groves, and other remnant natural or created habitats are key to providing the full range of habitat elements necessary to support BDCP covered species in agricultural habitats. These native and sometimes nonnative (e.g., eucalyptus groves) are important elements within the agricultural matrix that provide essential habitat for these agricultural-associated covered species. Management of protected lands will therefore focus on the protection and enhancement of these key elements.

*Species Protection***.** Several covered species and many other native species (e.g., shorebirds, waterfowl) are associated with agricultural lands, which are used as surrogate landscapes for native communities that they replaced. Some of these species, such as Swainson's hawk and white-tailed kite, use agricultural lands as foraging habitat while they find nesting habitat in remnant patches or riparian habitat or other native and nonnative trees occurring within the agricultural matrix. Agricultural lands meet other life requirements for other covered species, such as giant garter snake and western pond turtle.

There are two primary components of giant garter snake conservation under BDCP: 1) the establishment of agricultural land preserves that will include nontidal freshwater perennial emergent wetland restoration associated with two existing subpopulations; and 2) protection of existing rice land values in the Yolo Bypass to minimize the effects of increased inundation duration and extent. Protection of other agricultural lands and restoration of tidal wetlands in Conservation Zones 4 and 7 will also benefit giant garter snake.

Although dependent on the aquatic environment, the giant garter snake occurs within the agricultural landscape where it uses interconnected watercourses (primarily irrigation canals) and associated freshwater emergent wetland habitat and rice lands during the active season and adjacent uplands during the inactive season. Maintaining an agricultural matrix that includes suitable interconnected canals with reliable water and associated emergent vegetation and adjacent upland habitats is essential for conservation of this species. Protection and management of agricultural lands within and adjacent to existing subpopulations will provide security for these occupied habitats and allow for additional expansion into adjacent protected areas. A 1,000 acre preserve is considered sufficient to protect and allow for expansion of these subpopulations. Agricultural lands within the preserves are also expected to be compatible with other BDCP covered species, including Swainson's hawk, white-tailed kite, greater sandhill crane, tricolored blackbird, and Townsend's big-eared bat.

In addition, the protection of 4,600 acres (the existing extent of rice land acres potentially affected by BDCP actions in the Yolo Bypass) of rice land or lands with equivalent value will help to sustain or increase giant garter snake use of the Yolo Bypass.

Swainson's hawk and white-tailed kite find the highest value foraging habitat on agricultural lands within the Plan Area. However, as noted above, only a portion of the landscape is suitable in any given year due to crop rotations and conversions to unsuitable cover types. The protection and management of between 12,020 and 28,040 acres of non-rice agricultural land distributed throughout the agricultural landscape within the Plan Area will ensure long-term stability of high value foraging habitat for these wider-ranging species.

Greater sandhill crane is also closely associated with agricultural lands in the Delta and will benefit from the protection of at least 4,000 acres of agricultural land within its primary use area (refer to species model in Appendix A, *Covered Species Accounts*). Agricultural lands managed as crane foraging habitat will include high value crops such as corn, wheat, alfalfa, and irrigated pasture. Close proximity to known roosts increases the opportunity for foraging use.

While not providing optimal habitat conditions, the burrowing owl also uses some agricultural habitats including hay crops and irrigated pastures. These are considered moderate value cover types for burrowing owl (refer to species model in Appendix A, *Covered Species Accounts*). Agricultural land conservation will also include the protection of at least 3,000 acres of pastureland suitable for western burrowing owl. This cover type is compatible with Swainson's hawk, white-tailed kite, and greater sandhill crane use.

Also, as noted above, many of the BDCP covered species associated with agricultural habitats, including giant garter snake, Townsend's big-eared bat, white-tailed kite, tricolored blackbird, and greater sandhill crane, will use the BDCP restored habitats and benefit from the restoration activities. The distribution and abundance of these species is unlikely to be affected, and may benefit, as a result of the conversion of agricultural acreage to restored tidal marsh communities.

Agricultural Habitats and Climate Change

Agricultural habitats may be particularly sensitive to precipitation changes and long-term sea level rise associated with global climate change. Increased variability in precipitation is likely to reduce the reliability of water supply available for irrigating crops at critical times of the year; and crop types cultivated may change with elevated ambient temperatures. With sea level rise exacerbating current conditions, a powerful earthquake in the region could collapse levees, leading to major saltwater intrusion and flooding throughout the Delta if flows were sufficiently low, altering the tidal prism and causing substantial changes to the agricultural areas (Mount and Twiss 2005). Areas within levees that are currently farmed could be impaired. Climate change impacts on agricultural habitats and its potential effect on covered species is addressed primarily by restricting the extent of conservation that occurs within areas that are currently below sea level in the Central Delta.

Conservation Measures for Agricultural Habitats

- CM3 Natural Communities Protection
- CM11 Natural Communities Enhancement and Management

3.3.2.2.13 Managed Wetland

The managed wetland natural community consists of areas that are intentionally flooded and managed (including associated ditches and drains) during specific seasonal periods to enhance habitat values for specific wildlife species. Typically, managed wetlands are flooded during the winter in anticipation of the arrival of migratory birds. This is followed by a slow draw down of the water to manage plant seed production and control mosquito populations. Some summer irrigation may also be conducted. Salinity of managed wetlands is determined by their proximity to the more brackish waters of the western Delta.

Currently, distribution of the managed wetland natural community in the Plan Area is largely in the northern, central, and western portions of the Delta, as well as in Suisun Marsh. Substantial acreage of this natural community can be found in the Yolo Bypass, the Stone Lakes National Wildlife Refuge, the Cosumnes River Preserve, and in Suisun Marsh. Delta islands that support areas of managed wetland include Mandeville, Medford, Bradford, Van Sickle and Chipps islands, and Holland Tract.

As a surrogate for natural marshes, managed wetlands provide productive seasonal wetlands interspersed with permanent wetlands in an effort to support large populations of waterfowl and shorebirds with the production of seeds and invertebrates. Managed wetlands are also maintained to provide nesting and resting or loafing areas. Some of the nutrients and primary productivity of managed wetlands can be transferred to adjacent natural wetlands through water management activities and movements of waterfowl and shorebirds. See Section 2.3.4.10, *Managed Wetland* in Chapter 2, *Existing Ecological Conditions,* for more detail on the current state of managed wetlands.

BDCP restoration of tidal wetlands will replace some existing managed wetlands that currently provide habitat for wintering and breeding waterfowl and migrant shorebirds. While tidal restoration is expected to replace most of the habitat functions removed through this conversion, it could potentially affect the distribution and abundance of some species.

Managed Wetland Goals and Objectives

Goal MWNC1: The expected outcome is maintenance of the current level of habitat functions provided by existing managed wetlands in the Plan Area through enhancement and restoration of natural communities on BDCP conservation lands, such that those wildlife functions do not preclude achievement of the Central Valley Joint Venture (CVJV) Implementation Plan's waterfowl and shorebird conservation targets for the Delta and Yolo Basin.

Objective MWNC1.1: Maintain the level of wintering and breeding waterfowl habitat functions currently supported by habitats in the Plan Area through protection, restoration, and management of habitat of equivalent function on BDCP conservation lands.

Objective MWNC1.2: Maintain the current level of migrant shorebird habitat functions currently supported by habitats in the Plan Area through protection, restoration, and management of habitat of equivalent function on BDCP conservation lands.

Goal MWNC2: The expected outcome is biologically diverse managed wetlands that are enhanced for native species.

Objective MWNC2.1: Maintain and enhance the habitat functions of BDCP managed wetlands present on BDCP preserved lands over the term of the BDCP.

Rationale for Goals and Objectives

Managed Wetland Extent

The Central Valley Joint Venture (CVJV) has developed wetland acreage goals for nine basins within the Central Valley. The acreage goals for the Suisun basin have been surpassed while the restoration goal for wetlands in the Delta basin is 19,000 acres. The intent of BDCP is to maintain or increase the habitat functions for wintering and breeding waterfowl and migrant and breeding shorebirds supported by the Plan Area habitats to ensure that BDCP actions will not impede attainment of the goals established by the CVJV Implementation Plan for the Delta and Yolo Basin.

Biodiversity and Managed Wetland Function

Biologically Diverse Managed Wetlands. Managed wetlands are managed primarily to promote use by birds. A wide variety of waterfowl and other birds migrating along the Pacific Flyway use the managed wetland natural community when inundated. In the Plan Area, BDCP covered greater sandhill cranes forage and roost in managed wetlands; many ducks, geese, wading birds, and shorebirds forage and loaf in managed wetlands. Abundant and diverse plant and invertebrate populations in managed wetlands provide important food resources for migrating waterfowl, bats, and many other wildlife species that forage in and over these wetlands.

Managed wetland vegetation typically consists of robust, perennial emergent vegetation and annual-dominated moist-soil grasses and forbs in freshwater areas and pickleweed and brass buttons in brackish water areas. The managed wetland natural community is subjected to the same invasive nonnative plant species as the tidal brackish emergent wetland and tidal freshwater emergent wetland natural communities. However, because management operations include discing and the manipulation of flooding duration, there are more opportunities to control invasive species. One managed wetland invasive, perennial pepperweed (*Lepidium latifolium*), is a serious threat that may be spread through discing; adding complexity to land management. Other problematic invasive plant species include pampas grass (*Cortaderia selloana*), giant reed (*Arundo donax*), and the nonnative genotype of common reed (*Phragmites australis*).

Because they are often confined behind levees, environmental gradients in managed wetlands are generally controlled through active management actions such as discing and soil contouring to provide a variety of ponding depths and widths. Variations in flooding timing, duration, and water quality are used to control species composition, primary productivity, water temperature, salinity, and the timing of exports of primary productivity.

Species Protection. Managed to appropriate depths and interspersed with berms and other upland edges, managed wetlands can provide high value roosting habitat for greater sandhill cranes. Creation of additional crane roosting habitat within the crane's traditional use area will provide additional roosting opportunities, allow for greater dispersal within the use area, and facilitate use of foraging habitats that may currently be underused due to the lack of roosting habitat. Crane roosting habitat may also provide additional managed wetland habitat for waterfowl and shorebirds.

Managed Wetland and Climate Change

Seasonal changes in precipitation and sea level rise are the aspects of climate change that will most affect managed wetlands. Potential reductions of and changes in timing of flows through the Central Valley will likely reduce the amount of water available for managed wetlands management actions, such as flooding at precise times of the season to provide habitat and food for waterfowl. Additionally, the managed wetland natural community may be impacted by sea level rise as much of it is near or below sea level and protected from flooding by levees. Higher sea level, increased winter river flooding, and more intense winter storms will significantly increase the hydraulic forces acting on the levees, threatening managed wetlands.

Conservation Measures for Managed Wetland

- CM3 Natural Communities Protection
- CM11 Natural Communities Enhancement and Management

3.3.2.2.14 Other Natural Seasonal Wetland

The other natural seasonal wetlands natural community encompasses all remaining natural (i.e., not managed) seasonal wetland communities other than the vernal pool complex and alkali seasonal wetland complex natural communities. The other natural seasonal wetlands natural community includes seasonally ponded, flooded, or saturated soils dominated by grasses, sedges (*Carex* spp.), or rushes (*Juncus* spp.) including degraded vernal pools that were not included in the vernal pool complex natural community.

In the Plan Area, this natural community generally occurs on degraded sites consisting primarily of seasonally ponding areas in agricultural fields. It also occurs as a temporarily flooded perennial forb vegetation type that is exclusively found in a field near the Cosumnes River. While small, isolated, and degraded, these sites may still provide some habitat value to covered species (e.g., vernal pool fairy shrimp) and other native species. In some cases, other natural seasonal wetlands provide opportunities for restoration and in other cases retention of these sites within the agricultural matrix can provide important refugia for a variety of BDCP covered and other native species. See Section 2.3.4.11, *Other Natural Seasonal Wetlands* in Chapter 2, *Existing Ecological Conditions*, for more detail on the current state of this natural community.

Other Natural Seasonal Wetlands Goals and Objectives

Goal ONSW1: The expected outcome is increased habitat functions that support BDCP covered species in other natural seasonal wetland natural community within maintained and protected agricultural habitat areas.

> **Objective ONSW1.1**: Integrate management of other natural seasonal wetland natural community with management of BDCP maintained and protected agricultural lands to increase habitat functions for covered species.

Rationale for Goals and Objectives

Other Natural Seasonal Wetlands Biodiversity and Function

The ecological gradient observable between seasonal wetlands and surrounding terrestrial natural communities is marked by transitions in plant and wildlife species; this is most pronounced during the wetted phase. When flooded, the other natural seasonal wetlands natural community supports an aquatic food web that may be functionally similar to that found in undisturbed vernal pools and natural seasonal wetlands (Alexander 1976, Barclay and Knight 1981, Scheffer 2004, Williams 2006). As the water recedes, its ecosystem characteristics change from those of a fully aquatic system to those of a terrestrial ecosystem (Williams 2006), and its food web linkages break down as the community becomes more integrated with the terrestrial landscape in which it is embedded.

Plant species found in the other natural seasonal wetlands natural community consist of a mixture of exotic and native perennial forbs, grasses, sedges, and rushes that are tolerant of temporary flooding, ponding, or soil saturation during winter and spring months. Problematic invasive plant species in this natural community include low mannagrass, Italian ryegrass, and perennial pepperweed. Invertebrates of the other natural seasonal wetlands natural community are the main source of food for waterfowl and shorebirds (Silveira 1998) which also use the wetlands in their dry state for resting and seed foraging areas (USFWS 2007a, Kleinschmidt Associates 2008).

In some cases other natural seasonal wetlands may provide, or have the potential for providing value to some covered and other native species. Agricultural lands managed under BDCP for agriculture-associated species may contain small patches of other natural seasonal wetland. These sites may provide current habitat value as refugia for species that otherwise occur within the agricultural matrix, or they may provide opportunities for restoration (e.g., vernal pools).

Other Natural Seasonal Wetlands and Climate Change

Climate change is expected to impact the other natural seasonal wetlands natural community primarily through changes in the hydrological regime brought about by increased variability in precipitation. The species present in this natural community are adapted to existing hydrological conditions. Increased variability in precipitation could lead to a shorter more variable wet season, bringing changes to the inundation period. It is unknown how increased variability in seasonal wetland hydrology would affect the plants and animals inhabiting them, but because these species are adapted to current conditions, the impacts will likely be negative. In addition, rising average temperatures could result in increased evapotranspiration rates, and therefore shorter wetted periods for seasonal wetlands; the impacts of which are expected to be adverse to native plants and wildlife.

Conservation Measures for Other Natural Seasonal Wetland

- CM11 Natural Communities Enhancement and Management

3.3.2.3 Covered Fish Species Goals and Objectives

[Note to Reviewers: *The BDCP consultants most recently provided preliminary covered fish species goals and objectives in July 2009. Those objectives are being developed, refined, and revised using the logic chain process, which has been informed by independent science review. The logic chain process is intended to inform plan development and implementation. It is not intended to identify regulatory requirements, nor will every objective developed using the logic chain be incorporated into the BDCP conservation strategy. The objectives below reflect the current work in progress from the consultants. The level of detail for longfin smelt, for example, represents the level of detail the logic chain process will ultimately develop for other species. The objectives below do not represent a consensus position of the Steering Committee regarding the objectives of the BDCP.*

Ecosystem- and natural community-level goals and objectives, which were not addressed by the Logic Chain Group, are provided in Sections 3.3.2.1 and 3.3.2.2 and were derived from the July 2009 draft Conservation Strategy and the November 2010 Terrestrial Conservation Strategy.

Next Steps for Completing Goals and Objectives

The following outlines recommended steps for continuing and completing the development of objectives and metrics in accordance with the Logic Chain process as revised per input from the August 2010 Logic Chain independent review panel. These next steps are intended to build on *the discussions and subsequent work products from the logic chain workshop held on October 26-27, 2010.*

1. ***Complete Logic Chain Objective Worksheets** – convene additional technical workshops to complete specific species worksheets.*

   a. *Convene subteam for focused meetings to discuss and finalize the worksheets.*

   b. *Where existing information is insufficient to establish numeric targets, the subteams will identify specific study needs to develop such information, including a timeframe for conducting such.*

   c. *Where there is disagreement regarding an objective, or metric, the details of the disagreement will be documented for resolution at a policy level.*

   ***Timeframe:** The goal is to be done by end of January 2011.*

2. ***Revise Community Goals –**review and revise ecosystem and natural community goals as necessary to be consistent with the species objectives.*

   ***Timeframe:** The goal is to be done by end of January 2011.*

3. ***Review Proposed Conservation Measures in Light of Consensus Objectives** – once objectives have been agreed to, review existing conservation measures to identify gaps and make changes as needed.*

   ***Timeframe:** The goal is to be done by end of February 2011.*

4. ***Refine Proposed Metrics** – based on #1,#2, #3 above, refine or revise the draft metrics proposed in Section 3.6.*

   ***Timeframe:** To the extent possible, refinements should be complete by the end of February in order to allow inclusion in the complete draft plan. It has not been determined at this time the level of detail necessary prior to BDCP authorization/permitting and the additional refinements that could be developed after the plan has been authorized/permitted.*

5. ***Develop Recommendations for the Monitoring and Adaptive Management Program** – based on all of the above.*

   ***Timeframe**: Some changes may be recommended after February for inclusion in the draft plan in 2011, but it is also likely that additional refinements in both programs would be made after BDCP authorization/permitting.]*

3.3.2.3.1 Delta Smelt

[***Note to Reviewers:*** *Draft goals and objectives for delta smelt have not been discussed by the logic chain team and therefore are not included herein. Goals and objectives for delta smelt will be developed in accordance with the next steps noted above]*

3.3.2.3.2 Longfin Smelt

Stressor: Physical Spawning Habitat Loss and Modification.

BDCP Objective: Increase extent and availability of quality longfin smelt physical spawning habitat.

Relation to Global Objectives: Increasing the extent/availability and quality of spawning habitat for longfin smelt may have positive effects on productivity and abundance.

Indicator: Spatial extent of quality habitats available for longfin smelt spawning. Attributes of "quality spawning habitat (i.e. what makes a habitat "quality spawning habitat") remain to be defined as they are largely unknown at this time. The position and extent of spawning habitat is believed to track the position of the low salinity zone.

Locations: Suisun Bay, Suisun Marsh, West Delta, lower Sacramento River, lower San Joaquin (historical spawning area)

Timing (e.g. seasonality) of stressor reduction: Spawning season roughly ~December - April

Attribute: Spatial Extent: Acreage of accessible habitat

Quality: Undefined as micro-habitat requirements are unknown. Further research in this ecosystem needed.

Quantity or State: Maintain/improve existing, and increase the areal extent of longfin smelt spawning habitat that meets certain quality specifications (may be divided into "high", "medium" and "low" quality or accessibility) by ________% or by ___ acres

Confidence that "Quantity or State" are sufficient to attain objective Unknown as the hypothesis that longfin smelt are limited by physical spawning habitat substrate is undocumented and attributes of spawning micro-habitat are undefined.

Time Frame (defined herein as the time from implementation of CM's or suites of CM's until Objective may reasonably be attained). Use of newly created or improved spawning habitat substrate by spawning adults and larvae could be assessed within a few years. Attainment of Objective would be assessed after implementation of habitat restoration and following several years (~5) years in which conditions would have been expected to limit spawning habitat prior to restoration.

Stressor: Degraded pelagic habitat for larval and early life stage longfin smelt.

BDCP Objective: Increase the extent (overlap of acceptable parameters of key habitat variables) and improve quality of the physical/chemical attributes of longfin smelt pelagic habitat.

Relation to Global Objectives: Increasing the extent and improving the quality of the physical/chemical attributes of longfin smelt pelagic habitat (including transport/retention dynamics) will increase longfin smelt abundance and productivity.

Indicator(s):

1) Volume of longfin smelt's preferred pelagic habitat conditions (e.g. temperature, depth, turbidity, salinity) during critical winter and spring periods;
2) Magnitude and duration of flows that promote transport and retention of longfin smelt (e.g. gravitational circulation) in the LSZ.

These are well-indexed by the variable "X2" (the 2ppt bottom isohaline) – the frequency distribution of X2 values in different months indicates the state of longfin smelt pelagic habitat over time.

Locations: Low Salinity Zone (i.e. location changes depending on hydrology of a given year).

Timing (e.g. seasonality) of stressor reduction: Winter-Spring (December-June)

Attribute: TBD

Quantity or State: TBD

Confidence that "Quantity or State" are sufficient to attain Objective: TBD

Time Frame: TBD

Stressor: Increased food Limitation due to food web suppression.

BDCP Objective: Increased density of longfin smelt preferred prey.

Relation to Global Objectives: Abundance and productivity are expected to increase with an increasing longfin smelt food supply

Indicator: 1) longfin smelt preferred prey items (mysids, Eurytemora, amphipods, *Psuedodiaptomous*, etc)(additional system-wide indicators include: 1) individual growth rates or condition index to understand extent of food limitation and 2) diet studies -- to determine if the longfin smelt diet has been affected by restoration-related impacts to food supplies).

Locations: the low salinity zone (0-6psu)

Timing (e.g. seasonality) of stressor reduction: TBD

Attribute: Density of prey and at least one of the following

1) individual growth rates or proportion of maximum ration attatined (Pmax)
2) condition index and
3) diet studies -- to determine if the increase in food translates to decrease in food limitation

Quantity or State: A 10x increase in prey density would be required, at a minimum, on the basis of rough approximations of trophic transfer relationships found in many food webs. [Importantly, the committee did not determine what level of increase in the longfin smelt population would be required].

Alternative basis for quantity/state of this objective might be to identify prey density during historical period of desired longfin smelt abundance (e.g. 1967-1984) and establish this as the objective.

Time Frame: Expectation of time required to attain objective varies with type of conservation measure employed.

Confidence that "Quantity or State" are sufficient to attain Objective:

Differs depending on the conservation measures employed

Potential covariate in unmanaged stressors: unimpaired hydrology (food abundance sensitive to outflow). In other words, effectiveness of non-flow related measures is evaluated against expectation of food web productivity given the relationship between prey density and hydrology in a given year (modifications to actual hydrology as well as other physical habitats are both expected to play a role in food web productivity).

Stressor #: Increased toxin concentrations (pyrethroids, Organophosphates, surfactants).

BDCP Objective: Reduce toxic compound concentrations to below identified thresholds that impede productivity of the longfin smelt food supply (ie, that produce detectable effects on those things that longfin smelt eat).

Indicator: Concentrations of identified toxins and zooplankton bioassays

Locations: Will vary by toxin. They should be measured where they would potentially effect longfin smelt. Pyrethroids would be measured in sediment, organophosphates in the water column, etc. Some (but not all) potential toxins might be measured as concentration in fish tissues; in this case it would be necessary to correlate body-burden with fish condition, performance, and fertility.

Timing (e.g. seasonality) of stressor reduction: Step 1: determine when/where food limitation is occurring. Step 2: evaluate water toxicity indicators at those times/places relative to other areas

Attribute: Intentionally left blank [unknown]

Quantity or State: Intentionally left blank [unknown]

Time Frame: Intentionally left blank [unknown]

Confidence that "Quantity or State" are sufficient to attain Objective: The current effect of toxins on the populations of organisms that longfin smelt eat is unknown.

Stressor #: Increased nutrient concentrations (ammonium) and/or altered N:P ratios.

BDCP Objective: Reduce nutrient concentrations to below identified thresholds that impede productivity of the longfin smelt food supply (ie, that produce detectable effects on those things that longfin smelt eat) and/or that support levels of toxic organisms (e.g. microsystis) that inhibit attainment of longfin smelt distribution objectives.

Relation to Global Objectives: Limitation of the food supply potentially constrains longfin smelt abundance and productivity. If the limitation is regionally specific, foodweb limitations may constrain longfin smelt distribution as well.

Nutrient levels that encourage growth of toxic organisms like *microcystis* may be limited longfin smelt distribution.

Indicator: Concentrations of identified nutrients; intensity of Microcystis bloom? Restoration of spring-summer diatom blooms…

Locations: Suisun Bay in the late spring-fall.

Timing (e.g. seasonality) of stressor reduction: May-October

Attribute: Diatom blooms, zooplankton population responses

Quantity or State: Intentionally left blank [unknown]

Time Frame: May-Octoberish [unknown]

Confidence that "Quantity or State" are sufficient to attain Objective: The current effect of nutrients on the populations of organisms that longfin smelt eat is unknown. Some research has indicated levels of ammonium that may inhibit production at the base of the food web (phytoplankton), though if/how improving phytoplankton growth in certain years will transfer to longfin smelt is unknown. The ammonium threshold (~4 umolar?) is fairly certain; concentrations below this are not expected to inhibit primary production.

Stressor #: Entrainment

BDCP Entrainment Objective (A): For winter protection of reproductive adults: combined SWP and CVP December through February salvage of juvenile and adult longfin smelt shall not exceed ___ times the value of the Fall Midwater Trawl longfin smelt index (all ages) from the previous September through December.

For winter spring protection of larvae and early juveniles: Larvae entrainment modeled by surface oriented particles (DSM2 particle tracking model) shall not exceed ___ of surface oriented particles from the sampling stations ___, while longfin smelt larvae are being detected at ___ of ___ sampling locations in the San Joaquin River and south Delta .

Relation to Global Objectives: Reducing entrainment of reproductive, larval, and early juvenile longfin smelt will increase productivity (survival and total egg production)

Indicator: See above

Locations: Salvage measured at Project Diversions and impingement (or relevant measure) at Mirant Power Plant. Stock of spawning aged fish measured by FMWT and/or other survey at existing survey stations.

Timing (e.g. seasonality) of stressor reduction: Dec-June. longfin smelt entrainment is a greater concern during low outflow periods when X2 is nearer the south Delta export facilities.

Attribute: X2 OMR and other flow variables

Quantity or State: See above.

Time Frame: Measure efficacy should be detectable in first few years after implementation in which low outflow conditions would make longfin smelt susceptible to entrainment. Attainment of objective would be evaluated after several years of "susceptible conditions".

Confidence that "Quantity or State" are sufficient to attain Objective: Needs further documentation – see K. Newman Life Cycle model? In particular, pre-screen mortality estimates for longfin smelt should be studied.

BDCP Entrainment Objective (B): Spawning and larval migration spatial extent will not be limited by entrainment mortality or diversion-related impacts to habitat

Relation to Global Objectives: Reducing entrainment of spawning, larval, and early juvenile longfin smelt in the lower San Joaquin River will allow for increased spatial distribution of spawning

Indicator: X2 and OMR flows

Locations: Old and Middle River flow gauges on either side of Bacon Island and QWEST – the flow estimate for the San Joaquin River at Jersey Point in the DAYFLOW database (where flow is currently measured)

Timing (e.g. seasonality) of stressor reduction: Dec-June. longfin smelt entrainment is a greater concern in years when outflow conditions place X2 close to the south Delta export facilities.

Attribute: Net average flow in Old and Middle River and at Jersey Point

Quantity or State: OMR Flows not to be more negative than ___ cfs December – June (spawning-larval period)

Time Frame: Measure efficacy could be modeled prior to plan implementation. Ground-truthing this estimate in the field requires some substantial new sampling/monitoring. Effect would be expected to materialize in concert with restoration efforts in the south Delta including improved flows and reduction in *Egeria*.

Confidence that "Quantity or State" are sufficient to attain Objective: Conceptual model for longfin smelt indicates that continued entrainment-related mortality in the South Delta could be a factor in declining detection for spawning activity in that region. Research needs re: longfin smelt reproductive site fidelity.

3.3.2.3.3 Chinook Salmon

Stressors Addressed: Habitat loss; flow alterations; predation;; impingement and entrainment; passage impediments; and illegal harvest

Stressors Not Addressed: Contaminants; ocean conditions; and access to historical spawning habitat.

Goal CHSA1: Contribute to conditions that will support increased abundance, increased spatial extent of key lifestages, restore genetic diversity and increase productivity of all runs of Chinook salmon.

Objective CHSA1.1: Increase habitat extent, availability, and quality for juvenile Chinook salmon of all runs, including presence of suitable food resources.

Stressor: Habitat loss, food limitation, and passage impediments.

Objective CHSA1.2: Increase growth rates of juvenile Chinook salmon of all runs while rearing in the Plan Area.

Stressor: See CHSA1.1

Objective CHSA1.3: Help to maintain adequate dissolved oxygen levels in the Stockton Deep Water Ship Channel to avoid blocking migration of adult fall-run Chinook salmon and spring-run Chinook salmon once a viable run is established in the San Joaquin River.

Stressor: Low dissolved oxygen concentrations on the San Joaquin River near Stockton

Objective CHSA1.5: Increase immigration success by __% and reduce migratory delays by __%

Stressor: Altered flow conditions, poor water quality, exposure to unscreened water diversions, entrainment

Objective CHSA1.6: The total percentage of juvenile Chinook salmon entrained at the CVP and SWP pumps shall not exceed __% of the Juvenile Production Estimate (JPE) (methods for determining JPE and target entrainment percentages to be determined for each run including an analysis of data by water year type to scale the targets accordingly)

Stressor: Entrainment of juvenile salmon at unscreened water diversions and CVP and SWP pumping plants.

Objective CHSA1.7: Reduce illegal harvest of adult Chinook salmon (all runs).

Stressor: Illegal take of covered species.

Objective CHSA1.8: Reduce susceptibility to, and impact of predation by nonnative predatory fish on juvenile outmigrants by _%.

Stressor: High densities of nonnative fish that prey on outmigrating salmon (NMFS 2009).

Objective CHSA1.9: Manage salmonid hatchery operations to minimize genetic affects on all naturally producing Chinook salmon run.

Stressor: Threats of hatchery programs in the Central Valley to spring-run Chinook salmon stock genetic integrity.

3.3.2.3.4 Central Valley Steelhead

Stressors Addressed: Habitat loss; flow alterations; predation;; impingement and entrainment; passage impediments; and illegal harvest.

Stressors Not Addressed: Contaminants; access to historical spawning habitat.

Goal STEE1: Contribute to conditions that will support increased abundance, increased spatial extent of key lifestages, restore genetic diversity and increase productivity of Central Valley steelhead.

Objective STEE1.1: Increase extent, availability, and quality of migration habitat for juvenile steelhead.

Stressor: Flow alterations, predation, poor water quality, habitat loss

Objective STEE1.2: Increase growth rates of juvenile steelhead while rearing in the Plan Area.

Stressor: See STEE1.1

Objective STEE1.3: Improve upstream and downstream passage for steelhead. Increase immigration success by __%.

Stressor: Passage impediments, flow alterations, low dissolved oxygen concentrations on the San Joaquin River near Stockton

Objective STEE1.4: Increase survival of outmigrating smolts by **__**%

Stressor: Flow alterations

Objective STEE1.5: The total percentage of juvenile steelhead entrained at the CVP and SWP pumps shall not exceed **__**% (methods for determining the percentage of entrainment and target entrainment levels to be determined with targets scaled according to water year type)

Stressor: Entrainment at unscreened water diversions and CVP and SWP pumping plants

Objective STEE1.6: Reduce illegal harvest of adult steelhead

Stressor: Illegal take of covered species.

Objective STEE1.7: Reduce susceptibility to, and impact of predation by nonnative predatory fish on juvenile outmigrants

Stressor: Predation caused by high densities of nonnative predatory fish

Objective STEE1.8: Manage salmonid hatchery operations to minimize genetic effects on all naturally producing steelhead run.

Stressor: Threats to natural steelhead posed by hatchery programs, including: (1) mortality of natural steelhead in fisheries targeting hatchery-origin steelhead; (2) competition for prey and habitat; (3) predation by hatchery-origin fish on younger natural fish; (4) genetic introgression by hatchery-origin fish that spawn naturally and interbreed with local natural populations; and (5) disease transmission (NMFS 2009).

3.3.2.3.5 Sacramento Splittail

Stressors Addressed: Habitat loss and food limitations, entrainment, predation by nonnative predators;

Stressors Not Addressed: Toxins and Contaminants

Goal SASP1: Contribute to conditions that will support the increased abundance and productivity of of Sacramento splittail in the Plan Area.

Objective SASP1.1: Increase access to, and availability of suitable spawning, rearing and foraging habitat for splittail. Increase the total surface area of inundated floodplain habitat by ___% when Delta inflow is __ cfs. [**Note to Reviewers**: *Look at the acreage to flow curve relationship. Look for opportunities to maximize the flooding for 30 days.]*

Stressor: Habitat loss, particularly loss of floodplain and channel margin habitat

Objective SASP1.2: Increase food availability for all life stages of Sacramento splittail by ___%.

Stressor: Food limitation

Objective SASP1.3: Help to maintain multiple spawning cohorts of Sacramento splittail as part of the breeding population.

Objective SASP1.4: The total percentage of splittail entrained at the CVP and SWP pumps shall not exceed __% (methods for determining the percentage of entrainment and target entrainment levels to be determined with targets scaled according to water year type)

Stressor: Entrainment

Objective SASP1.5: Reduce predation of splittail by centrachids and other predators.

Stressor: Predation by nonnative fish

3.3.2.3.6 Green Sturgeon

Stressors Addressed: Habitat loss; flow alterations; passage impediments; entrainment; dredging and illegal harvest.

Stressors Not Addressed: Contaminants, invasive species.

Goal GRST1: Contribute to conditions that will support the increased abundance, productivity, distribution and life-history and genetic diversity of green sturgeon in the Plan Area.

Objective GRST1.1: Improve rearing habitat for green sturgeon. [***Note to Reviewers:*** *Logic Chain Objective* #5)

Stressor: Habitat loss.

Objective GRST1.3: Improve upstream passage success for adult green sturgeon through the Fremont Weir and other operational gates/barriers. [***Note to Reviewers:*** *Logic Chain Objective #2]*

Stressor: Passage impediments.

Objective GRST1.4: The total percentage of green sturgeon entrained at the CVP and SWP pumps shall not exceed __% (methods for determining the percentage of entrainment and target entrainment levels to be determined with targets scaled according to water year type)

Stressor: Entrainment.

Objective GRST1.5: Determine through targeted studies the significance of poaching to the population and based upon study results, reduce poaching of adult green sturgeon in the Plan Area.

Stressor: Poaching green sturgeon

Objective GRST1.6: Avoid and minimize adverse effects of construction or maintenance dredging related to BDCP activities on green sturgeon.

Stressor: Construction or maintenance dredging related to BDCP activities.

3.3.2.3.7 White Sturgeon

Stressors Addressed: Habitat loss; flow alterations; passage impediments; entrainment; dredging and illegal harvest.

Stressors Not Addressed: Contaminants, , invasive species

Goal WHST1: Contribute to conditions that will increase the abundance, productivity and distribution of white sturgeon in the Plan Area.

Objective WHST1.1: Improve rearing habitat conditions for white sturgeon.

Stressor: Habitat loss, invasive plant species *[**Note to Reviewers:** Tidal marsh allocanthous support of clams and other macro-crustaceans contribute to the prey base of sturgeon]*

Objective WHST1.3: Improve upstream passage success for adult white sturgeon through the Fremont and Lisbon weirs and other operational gates.

Stressor: The Fremont Weir is a documented barrier to white sturgeon (Z. Matica, Department of Water Resources, pers. comm.).

Objective WHST1.4: The total percentage of white sturgeon entrained at the CVP and SWP pumps shall not exceed __% (methods for determining the percentage of entrainment and target entrainment levels to be determined with targets scaled according to water year type) [***Note to Reviewers:** Entrainment is a low magnitude stressor for sturgeon, currently. This should be addressed during real-time operations*]

Stressor: White sturgeon entrainment from agricultural operations, power plants, and the state and federal water project facilities

Objective WHST1.5: Reduce poaching of adult white sturgeon in the Plan Area

Stressor: Poaching of adult white sturgeon.

Objective WHST1.6: Avoid and minimize adverse effects of construction or maintenance dredging related to BDCP activities on white sturgeon.

Stressor: Construction or maintenance dredging related to BDCP activities

3.3.2.3.8 River Lamprey

Stressors Addressed: Habitat loss; flow alterations; passage impediments; and illegal harvest.

Stressors Not Addressed: Contaminants, predation by nonnative species, and dredging

Goal RILA1: Contribute to conditions that will support the maintenance and restoration of river lamprey distribution and abundance to higher levels than present.

Objective RILA1.1: Restore and/or enhance river lamprey rearing habitat.

Stressor: Habitat loss.

Objective RILA1.3: Identify impediments/barriers to upstream passage of adult river lamprey and implement lamprey-specific passage and protection measures.

Stressor: Passage impediments. **Objective RILA1.4**: Help maintain flow conditions that facilitate outmigration of juvenile river lampreys.

Stressor: Flow alterations.

3.3.2.3.9 Pacific Lamprey

Stressors Addressed: Habitat loss; flow alterations; passage impediments and illegal harvest.

Stressors Not Addressed: Contaminants, predation by nonnative species and dredging

Goal PALA1: Contribute to conditions that will support the maintenance and restoration of Pacific lamprey distribution and abundance to higher levels than present.

Objective PALA1.1: Restore and/or enhance Pacific lamprey rearing habitat.

Stressor: Habitat loss.

Objective PAILA1.2: Reduce stranding of Pacific lamprey ammocoetes

Stressor: Passage impediment caused by dewatering of channels

Objective PALA1.4: Help maintain flow conditions that facilitate outmigration of juvenile Pacific lampreys.

Stressor: Flow alterations.

3.3.2.4 Covered Wildlife and Plant Species Goals and Objectives

This section presents goals and objectives that provide for the conservation of covered wildlife and plant species. Conservation for covered species is addressed primarily through ecosystem and natural community goals and objectives. For some species, additional species-specific goals and objectives were deemed necessary for conservation and are included below. This section lists the applicable natural community and species-specific goals and objectives for each covered species and presents the rationale and conservation approach that will be used to achieve them. Table 3-11 presents the expected extent of each covered wildlife and plant species' habitat that will be protected and restored in the Plan Area with full BDCP implementation.

Table 3-11. Expected Extent of Conserved Species Habitat Types in Conservation Zones 1-11 with BDCP Implementation

Covered Species	*Total Extent (acres)*	*Total Existing Preserved (acres)*	*Percent Existing Preserved (acres)*	*BDCP Preserved (acres)* **A**	*BDCP Restored (acres)* **B**	*BDCP Conserved (acres)* **A+B**	*Total Conserved with BDCP Implementation* **(Existing +BDCP)**	*Percent Conserved with BDCP Implementation*
San Joaquin kit fox								
Breeding habitat	5,217	638	12%	1,000	0	1,000	1,557	31%
Riparian woodrat	1,539	97	6%	0	300	300	394	22%
Salt marsh harvest mouse								
Wetland habitat	11,124	9,600	86%	0	3,600-4,800	3,600-4,800	10,831-12,031	89-90%
Upland habitat	2,815	2,334	83%	350-700	350-700	700-1,400	2,416-3,116	85-100%
Riparian brush rabbit	2,894	138	5%	0	300	300	435	14%
Townsend's western big-eared bat								
Roosting and primary foraging habitat	6,892	1,876	27%	0	5,000	5,000	6,720	58%
Suisun shrew	28,741	22,590	79%	0	3,600-4,800	3,600-4,800	20,518-21,718	79-80%
Tricolored blackbird								
Nesting habitat	24,036	14,372	60%	0	17,900-26,800	17,900-26,800	28,852-37,752	76-81%
Foraging habitat: non-agriculture	99,587	40,818	41%	8,700	0	8,700	45,653	49%
Foraging habitat: agriculture	275,937	33,097	12%	16,620-32,640	0	16,620-32,640	47,253-63,273	50-68%
Suisun song sparrow	26,959	21,177	79%	0	3,600-4,800	3,600-4,800	19,979-21,179	79-80%
Yellow-breasted chat								
Primary nesting and migratory habitat[20]	8,640	3,125	36%	0	≥2,000	≥2,000	≥4,722	≥47%
Secondary nesting and migratory habitat	5,530	1,896	34%	0	≤3,000	≤3,000	≤4,561	≤57%
Least Bell's vireo	14,139	5,008	35%	0	≥2,000	≥2,000	≥6,272	≥42%
Western burrowing owl								
High-value habitat	78,447	26,261	34%	8,000	2,000	10,000	34,281	46%
Moderate- value habitat	52,800	16,214	31%	>3,900	0	>3,900	>19,094	>39%
Western Yellow-Billed Cuckoo								
Breeding Habitat	6,826	2,763	41%	0	>1,000	>1,000	>3,356	>46%
California Least Tern								
Foraging habitat	86,240	18,080	21%	0	10,000-20,000	10,000-20,000	28,016-38,016	29-36%
Greater sandhill crane								
Roosting/Foraging habitat[21]	11,829	6,743	57%	0	320	320	7,063	60%
Foraging habitat	184,257	33,259	18%	>4,800	0	>4,800	>34,373	>19%
California black rail	33,563	24,593	73%	0	17,500-26,400	17,500-26,400	36,828-45,728	82-85%
California clapper rail	7,895	5,013	64%	0	3,600-4,800	3,600-4,800	8,294-9,494	74-77%

[20] Suisun Marsh/Upper Yolo Bypass Nest and Migratory Habitat acreage totals have been assumed to be equivalent to Primary Habitat and have been combined with the Primary Habitat acreage totals. For further definition of the Suisun Marsh/Upper Yolo Bypass Nest and Migratory Habitat, refer to Yellow-breasted Chat species account documented within Appendix A, *Covered Species Accounts*.

[21] Restoration is aimed at roosting habitat, which can be a component of foraging habitat depending on agricultural management practices.

Table 3-11. Expected Extent of Conserved Species Habitat Types in Conservation Zones 1-11 with BDCP Implementation (continued)

Covered Species	*Total Extent (acres)*	*Total Existing Protected (acres)*	*Percent Existing Protected (acres)*	*BDCP Protected (acres)* **A**	*BDCP Restored (acres)* **B**	*BDCP Conserved (acres)* **A+B**	*Total Conserved with BDCP Implementation* **(Existing +BDCP)**	*Percent Conserved with BDCP Implementation*
Swainson's hawk								
Foraging habitat	436,417	75,743	17%	20,020-36,040	0	20,020-36,040	88,935-104,955	23-26%
Nesting habitat	10,149	3,258	32%	0	4,000	4,000	6,789	50%
White-tailed kite								
Breeding habitat	13,714	4,518	33%	0	4,000	4,000	7,951	47%
Foraging habitat	478,251	101,068	21%	24,620-46,040	0	24,620-46,040	112,851-134,271	26-31%
Giant garter snake								
Aquatic breeding, foraging and movement[22]	19,824	5,725	29%	≥6,900	13,690-22,040	≥20,590-≥28,940	≥25,994-≥34,344	≥79-83%
Upland aestivation and movement[23]	190,805	31,954	17%	7,100	0	7,100	36,113	20%
Western pond turtle								
Aquatic habitat	78,511	30,591	39%	0	27,900-46,800	27,900-46,800	53,855-72,755	54-61%
Dispersal habitat	579,334	109,348	19%	4,000	0	4,000	98,528	19%
Upland nesting and overwintering	54,880	19,738	36%	≥5,230	5,000	≥10,230	≥27,958	≥50%
California red-legged frog								
Aquatic habitat	117	4	3%	3	0	3	7	6%
Upland cover and dispersal habitat	4,984	640	13%	1,000	0	1,000	1,560	33%
Western spadefoot toad								
Aquatic breeding habitat	6,791	4,256	63%	300	200	500	4,746	69%
Terrestrial cover and aestivation habitat	14,352	5,071	35%	8,400	500	8,900	13,821	99%
California tiger salamander								
Aquatic breeding habitat	6,772	4,255	63%	300	200	500	4,746	68%
Terrestrial cover and aestivation habitat	14,352	5,071	35%	8,400	500	8,900	13,821	99%
Valley elderberry longhorn beetle								
Riparian vegetation	17,130	5,310	31%	0	5,000	5,000	9,583	46%
Lange's metalmark butterfly	1,108	67	6%	0	0	0	67	6%
Vernal pool shrimp species (*Vernal pool tadpole shrimp, conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, mid valley fairy shrimp, and California linderiella*)	6,821	4,319	63%	300	200	500	4,810	69%

[22] Preservation and 400 acres of restoration is targeted for primary zone giant garter snake habitat in CZ's 2 and 4.

[23] Preservation is targeted for primary zone giant garter snake habitat in CZ's 1, 2, 4, and/or 5.

Table 3-11. Expected Extent of Conserved Species Habitat Types in Conservation Zones 1-11 with BDCP Implementation (continued)

Covered Species	*Total Extent (acres)*	*Total Existing Protected (acres)*	*Percent Existing Protected (acres)*	*BDCP Protected (acres)* **A**	*BDCP Restored (acres)* **B**	*BDCP Conserved (acres)* **A+B**	*Total Conserved with BDCP Implementation* **(Existing +BDCP)**	*Percent Conserved with BDCP Implementation*
Vernal pool plant species (*Alkali milk-vetch, San Joaquin spearscale, Boggs Lake hedge-hyssop, Heckard's peppergrass, dwarf downingia, and legenere*)	6,958	4,380	63%	300	200	500	4,850	69%
Heartscale and brittlescale	496	127	26%	150	0	150	274	56%
Slough thistle	1,831	188	10%	0	≥1,000	≥1,000	≥1,188	≥42%
Suisun thistle and soft bird's-beak	1,225	869	71%	0	3,600-4,800	3,600-4,800	3,890-5,090	92-94%
Delta button celery	3,345	270	8%	≥100	≥1,000	≥1,100	≥1,369	≥32%
Contra Costa Wallflower	20	17	85%	0	0	0	17	85%
Carquinez goldenbush	1,032	391	38%	300	0	300	689	70%
Delta tule pea and Suisun Marsh aster	5,948	3,699	62%	0	16,970-26,470	16,970-26,470	19,593-29,093	90-93%
Mason's lilaeopsis and delta mudwort	6,931	1,717	25%	0	16,980-26,560	16,980-26,560	18,617-28,197	78-85%
Antioch Dunes evening primrose	20	17	85%	0	0	0	17	85%
Side-flowering skullcap	2,495	701	28%	0	0	0	689	28%
Caper-fruited tropidocarpum	1,410	21	2%	≥100	0	≥100	≥121	≥9%

3.3.2.4.1 San Joaquin Kit Fox

In Northern California, the San Joaquin kit fox is a year-round resident of grassland habitats (Swick 1973, Hall 1983, Bell 1994), although it may also sometimes forage in fallow fields and irrigated row crops (Bell 1994). Its home range size is highly variable and tends to be related to prey abundance (White and Ralls 1993, White and Garrott 1999); its territories range from less than 2.6 square kilometers (sq km) (1 square mile [sq mi]) up to approximately 31 sq km (12 sq mi) (Morrell 1972, Knapp 1978, Zoellick et al. 1987b, Paveglio and Clifton 1988, Spiegel and Bradbury 1992, White and Ralls 1993). Habitat loss and fragmentation due to urbanization and agricultural expansion are the principal factors that have been implicated in the decline of the San Joaquin kit fox in the San Joaquin Valley (Laughrin 1970, Jensen 1972, Morrell 1975, Knapp 1978). By 1979, only an estimated 6.7 percent of the San Joaquin Valley floor's original native habitat south of Stanislaus County remained untilled and undeveloped (USFWS 1983). In its northern range, continued urbanization, primarily in Contra Costa and Alameda counties, water storage and conveyance projects, road construction, energy development, and other activities continue to reduce and fragment its remaining grassland habitat and contribute to kit fox declines through displacement, isolation of populations, creation of barriers to movement, direct and indirect mortality, and the reduction of prey populations (USFWS 1998a).

Applicable Natural Community Goals and Objectives

Goal GRNC1: The expected outcome is grassland comprised of large interconnected patches or contiguous expanses.

> **Objective GRNC1.1**: Protect a minimum of 8,000 acres of grassland in Conservation Zones 1, 8, and 11. At least 1,000 acres will be protected in Conservation Zone 8, with the remainder distributed throughout these three Conservation Zones.

Goal GRNC2: The expected outcome is biologically diverse grassland managed to enhance native species and sustained by natural ecological processes.

> **Objective GRNC2.1**: Restore and sustain a mosaic of grassland vegetation alliances, reflecting local water availability, soil chemistry, soil texture, topography, and disturbance regimes, with consideration of historical states.

> **Objective GRNC2.2**: Increase the relative cover of native grasses and forbs in native grassland vegetation alliances.

> **Objective GRNC2.3**: Increase opportunities for wildlife movement through grassland habitat.

> **Objective GRNC2.4**: Increase burrow availability for burrow-dependent species.

> **Objective GRNC2.5**: Increase prey, especially small mammals and insects, for grassland-foraging species.

Rationale and Conservation Approach

Since the primary stressor on the kit fox is the loss and fragmentation of its grassland habitat through urban and agricultural expansion, protection of grassland habitat is considered the most effective approach to the kit fox's conservation (Figure 3-14). In the recovery plan for the San Joaquin kit fox and other San Joaquin Valley upland species (USFWS 1998a), the recommended conservation strategy is centered on establishing a network of conservation areas and reserves. During the implementation of BDCP, conservation of the kit fox will similarly be provided through habitat protection, with an emphasis on protecting the largest remaining contiguous patches of habitat, and ensuring habitat connectivity with adjacent occupied areas. Because kit fox habitat within the Plan Area is located along the margin, rather than in the core, of the species' range, the possibility exists that BDCP conservation measures will be implemented outside the boundaries of the Plan Area, but this will occur only if and where conservation measures are expected to maximize the benefit for kit fox conservation. This contingency would be selected should a specific opportunity arise for conservation in a core kit fox habitat area, consistent with conservation plans for those locations as described in Section 3.2.4, *Development of the Terrestrial Resources Component of the Conservation Strategy*.

Conservation of San Joaquin kit fox in the Plan Area will focus on the preservation and enhancement of 1,000 acres of its grassland breeding, foraging, and dispersal habitat (Table 3-5).

Protection of kit fox habitat will focus in particular on acquiring the largest remaining contiguous patches of unprotected grassland breeding habitat, which are located in Conservation Zone 8 south of Highway 4 (see Appendix A, *Covered Species Accounts*). Conservation Zone 8 supports 74 percent of the modeled kit fox grassland breeding habitat in the Plan Area (Table 3-11). Following BDCP implementation, the percent of modeled kit fox breeding, foraging, and dispersal habitat protected in Conservation Zone 8 will increase from 16 percent to 42 percent.

Kit fox home ranges are large; therefore, habitat connectivity is key to the conservation of the species. Breeding habitat present in Conservation Zones 7, 9, and 10 occurs only in small fragmented patches, which by themselves are likely to be of limited value to the kit fox (see Appendix A, *Covered Species Accounts*). Even protected grassland habitat in Conservation Zone 8 is unlikely to encompass an entire home range. For this reason, protected habitat will be acquired in locations that provide connectivity to existing protected breeding habitats in Conservation Zone 8 and to other adjoining kit fox habitat within and adjacent to the Plan Area. Connectivity to occupied habitat adjacent to the Plan Area will help ensure the movement of kit fox to larger habitat patches outside of the Plan Area.

Declines in prey abundance associated with ground squirrel poisoning programs have been identified as a stressor contributing to reduced kit fox abundance (see habitat model in Appendix A, *Covered Species Accounts*). Consequently, protected grassland will be managed and enhanced to increase the abundance and distribution of kit fox mammalian prey species (e.g., discontinued use of pesticides, manipulation of topography, mowing for increasing ground squirrel densities).

In summary, the Plan Area lies along the margin of the kit fox's distribution, where conservation measures might provide only limited benefits. However, should the proposed kit fox habitat conservation actions be implemented in the Plan Area, they are still expected to maintain sufficient habitat area to sustain or increase the existing Plan Area kit fox population. The same proposed habitat conservation actions are also expected to maintain connectivity with occupied core populations that are adjacent to the Plan Area and are covered under adjacent and overlapping HCP/NCCPs. Conservation measures may be implemented outside rather than within the Plan Area. Such a conservation approach would be selected only where conservation benefits are expected to be greater than from conservation measures implemented within the Plan Area.

<u>*Applicable Conservation Measures*</u>

- CM3 Natural Communities Protection
- CM8 Grassland Communities Restoration
- CM9 Vernal Pool Complex Restoration
- CM11 Natural Communities Enhancement and Management

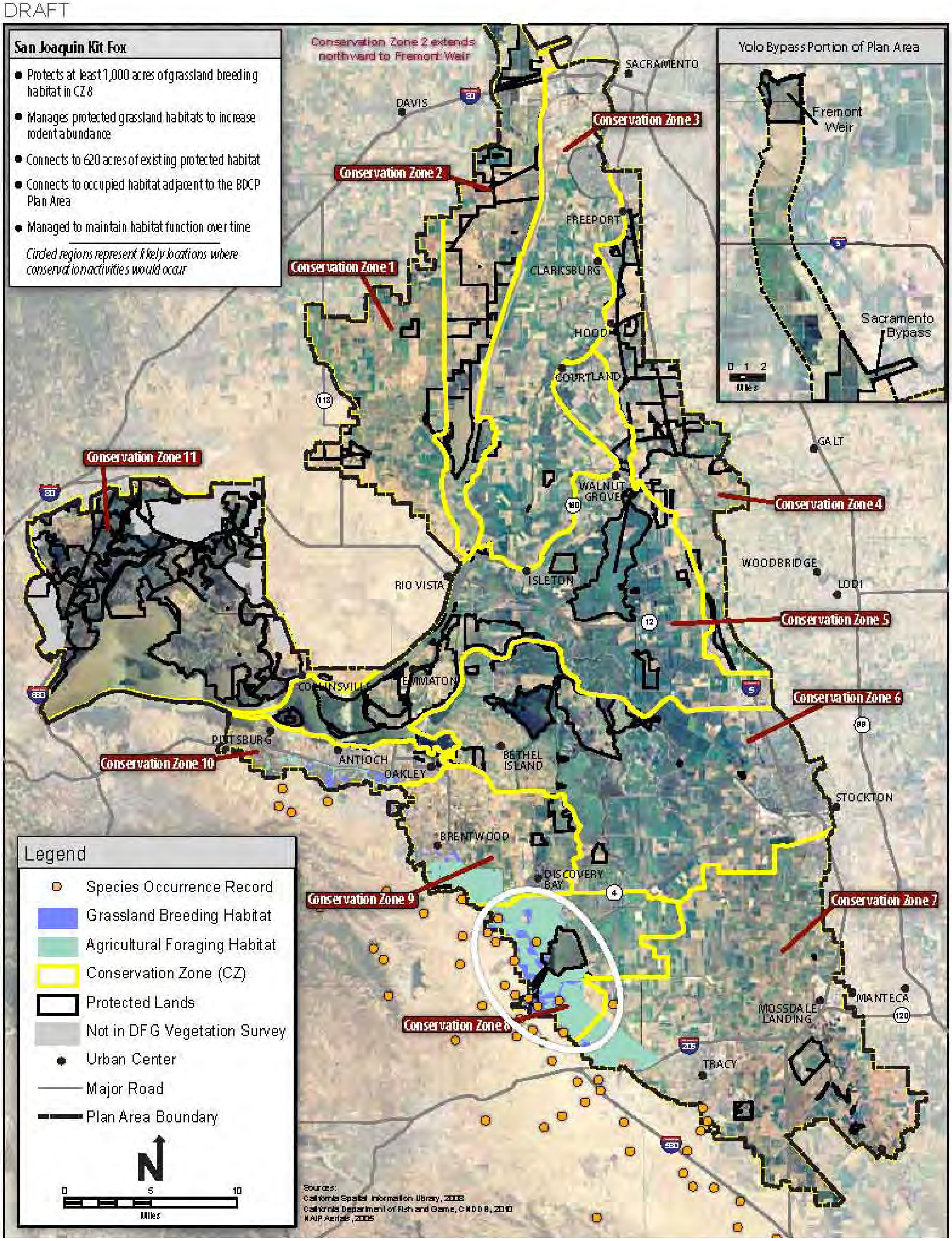

Figure 3-14. San Joaquin Kit Fox Habitat Distribution and Conservation Strategy

3.3.2.4.2 Riparian Woodrat

The riparian woodrat (*Neotoma fuscipes riparia*) is a subspecies of the dusky-footed woodrat that occurs in riparian woodland with an overstory canopy of trees and a moderate to dense shrub understory, reaching its highest densities in willow thickets growing under a canopy of valley oaks (Williams 1986, USFWS 1998a). It is not known to occur in the Plan Area, but the only verified extant population of riparian woodrat is only 2 miles east of the Plan Area in Caswell Memorial State Park along the Stanislaus River (Williams 1986, 1993). Small patches of potentially occupied valley oak riparian forest occur along the San Joaquin River from the southern tip of the Plan Area north to approximately the Interstate 5 overcrossing near Lathrop (Appendix A, *Covered Species Accounts*).

The riparian woodrat is a federally listed species and a state species of special concern (Williams 1986). Once occupying a larger range, it is now confined to the lower portions of the San Joaquin and Stanislaus rivers in northern San Joaquin County (Williams 1986, 1993, USFWS 1998a). Habitat loss and fragmentation are considered the main causes for the riparian woodrat's range contraction. There has been a nearly 90 percent reduction in the extent of riparian communities along major streams flowing onto the floor of the northern San Joaquin Valley (Katibah 1983), much of the loss is due to habitat conversion to agricultural lands and the construction of large dams and canals (Appendix A, *Covered Species Accounts*).

Applicable Natural Community Goals and Objectives

Goal VRNC1: The expected outcome is restored large expanses and interconnected corridors of valley/foothill riparian natural community.

> **Objective VRNC1.1**: Restore or create 5,000 acres of valley/foothill riparian in Conservation Zones 1, 2, 4, 5, 6, 7, and/or 11.

Goal VRNC2: The expected outcome is biologically diverse valley/foothill riparian natural community that supports native species and is sustained by natural ecological processes.

> **Objective VRNC2.1**: Maintain and enhance the habitat and ecosystem functions of BDCP restored valley/foothill riparian and patches of riparian forest and scrub present on BDCP preserved lands over the term of the BDCP.

> **Objective VRNC2.3**: Restore connectivity of valley/foothill riparian corridors along linear watercourses to enhance habitat for covered species and facilitate wildlife movement.

Species-Specific Goals and Objectives

Goal RIWR1: The expected outcome is restored and protected habitat for the riparian woodrat.

> **Objective RIWR1.1:** Of the 5,000 acres of restored valley/foothill riparian, restore and manage 300 acres to meet the ecological requirements of the riparian woodrat in Conservation Zone 7.

Rationale and Conservation Approach

Habitat protection and, where appropriate, habitat restoration, is the central component of the conservation strategy recommended in the Recovery Plan for the riparian woodrat and other upland species of the San Joaquin Valley (USFWS 1998a). The Recovery Plan establishes an overall goal of establishing three riparian woodrat populations based on conservation actions aimed at protecting and restoring riparian habitat, together with species reintroduction (USFWS 1998a). The overall BDCP biological goal for the riparian woodrat is to restore suitable riparian woodrat habitat to provide for the species' conservation; this is congruent with the Recovery Plan (Figure 3-15) (see Appendix A, *Covered Species Accounts*). Conservation will be directed towards restoring valley/foothill riparian within the Plan Area to provide habitat that could allow for future reintroduction or expansion of the existing riparian woodrat population into the Plan Area. The 5,000 acres of valley/foothill riparian to be restored under the Plan is expected to include patches of riparian vegetation that supports riparian woodrat habitat. These patches will increase the likelihood of future colonization of Plan Area habitats by the riparian woodrat.

Additionally, of the 5,000 acres of riparian habitat to be restored under the Plan, BDCP will restore and manage 300 acres of riparian vegetation with specific riparian woodrat habitat attributes, including a willow understory and oak overstory. Riparian woodrat habitat would be restored in patches of at least 25 acres, which is believed to exceed the minimum habitat patch size requirements for the species. The extent of existing known occupied habitat is approximately 250 acres (see Appendix A, *Covered Species Accounts*). Restoration of 300 acres of additional habitat is expected to contribute to conservation of the riparian woodrat by substantially increasing the extent of available and protected habitat.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM7 Riparian Habitat Restoration
- CM11 Natural Communities Enhancement and Management

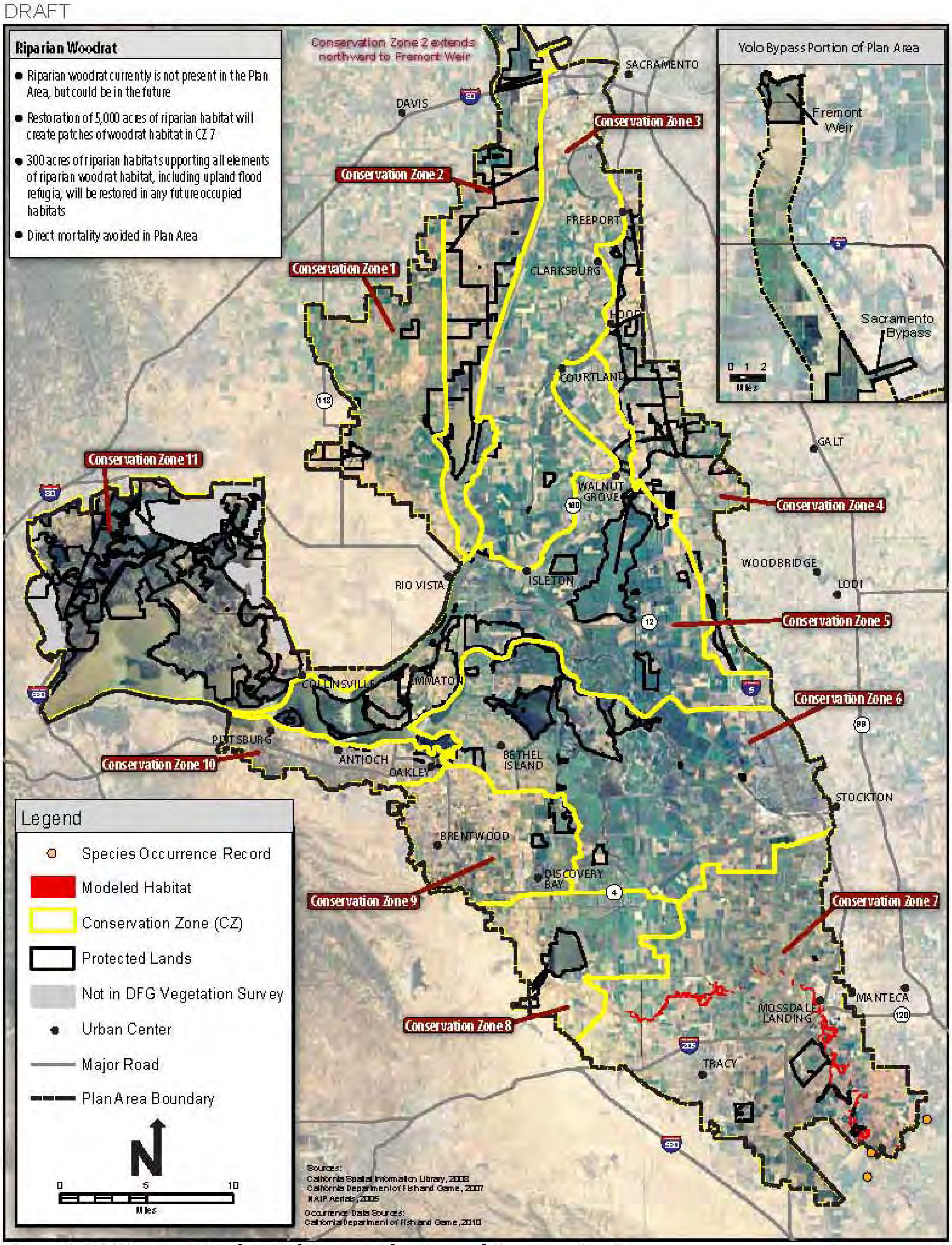

Figure 3-15. Riparian Woodrat Habitat Distribution and Conservation Strategy

3.3.2.4.3 Salt Marsh Harvest Mouse

The salt marsh harvest mouse is a small rodent endemic to the salt and brackish marshes of San Francisco, San Pablo, and Suisun Bays (USFWS 2001b). It depends on salt marshes as its optimal habitat and is primarily found in vegetation dominated by pickleweed. Upland refugia are important during high tide events so that it can escape flooded low-lying marshlands (see Appendix A, *Covered Species Accounts*). Much of the occupied habitat in Suisun Marsh consists of suitable patches of tidal brackish emergent wetland within a nontidal managed and diked wetland complex (including upland grasslands used as refugia during high tide events) that the mouse has adapted to following the reclamation of historical Suisun Bay tidal marshes. The size of salt marsh harvest mouse populations in Suisun Marsh are likely limited by habitat fragmentation.

The recovery plan for this state and federally endangered species was completed in 1984 and is currently under revision (Appendix A, *Covered Species Accounts*). The historical range of the species likely included most of the marshland in the San Francisco Bay Area. Today, the species might occupy an area representing only approximately 15 percent of the historical salt marsh habitat formerly found in the San Francisco Bay Area (Dedrick 1989). Much of this remaining habitat is isolated by dikes and landfill, is subject to backfilling, subsidence, and vegetation changes, and as a result is unlikely to support salt marsh harvest mouse (Shellhammer 1989). Thus, the remaining populations are small and separated by large areas of unsuitable habitat, and the loss and degradation of tidal marsh habitats continue to be the most significant threat to the salt marsh harvest mouse and other tidal marsh species.

Applicable Natural Community Goals and Objectives

Goal BMNC1: The expected outcome is restored large expanses and interconnected patches of tidal brackish emergent wetland natural community.

> **Objective BMNC1.1:** Restore or create 3,600 to 4,800 acres of tidal brackish emergent wetland in the Suisun Marsh ROA (Conservation Zone 11).

Goal BMNC2: The expected outcome is biologically diverse tidal brackish emergent wetland that is enhanced for native species and sustained by natural ecological processes.

> **Objective BMNC2.1:** Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal brackish emergent wetland for covered and other native species over the term of the BDCP.

Rationale and Conservation Approach

Because the primary stressor on the salt marsh harvest mouse is loss of its tidal marsh habitat due to urban and agricultural expansion, the recovery plan for the salt marsh harvest mouse emphasizes habitat protection, enhancement, and restoration as essential to the conservation and recovery of the species (USFWS 1984b). BDCP-proposed restoration, enhancement, and management of tidal habitat and associated refugia in Suisun Marsh is consistent with the 1984 Recovery Plan for the salt marsh harvest mouse (Figure 3-16). It also helps to achieve the salt marsh harvest mouse objectives of the draft tidal marsh ecosystems recovery plan (USFWS 2010) and the objectives of the Suisun Marsh Restoration Plan (under development).

Restoration of tidal habitat will remove and degrade patches of tidal brackish emergent wetland that are currently occupied by salt marsh harvest mouse; therefore, restoration will be sequenced and located in a manner that minimizes any initial, temporary loss of habitat. Approaches for restoring tidal habitat to support salt marsh harvest mouse habitat are described in Conservation Measure CM4 Tidal Habitat Restoration. Restored tidal habitats will be designed to the extent practicable within site constraints to provide the full range of environmental gradients from tidal areas to uplands that existed under historical conditions in Suisun Marsh. This approach is expected to result in restoration of patches of salt marsh harvest mouse habitat within a mosaic of larger marsh plain habitat. A total of between 3,600 and 4,800 acres[24] of tidal wetland and 350 to 700 acres of associated upland habitat is expected to be restored in the Suisun Marsh (Conservation Zone 11) and provide high value habitat for the salt marsh harvest mouse. It is anticipated that following completion of all tidal habitat restoration in Suisun Marsh, tidal marsh plain habitats will be restored in patches larger than currently found (characterized by habitat fragmentation by dikes, roads, and other infrastructure, as well as unsuitable habitat). These larger unfragmented patches are expected to be of higher ecological value to the salt marsh harvest mouse and facilitate population expansion and growth in Suisun Marsh. The transitional upland component of restored tidal habitats will be designed to provide flood refugia (grassland) habitat during high tide events.

BDCP actions are expected to initially impact salt marsh harvest mouse wetland habitat in Suisun Marsh, but most marshes to be impacted will be managed wetlands. Over the full course of BDCP implementation, BDCP actions will preserve and restore a greater amount of tidal marsh than will be impacted, and thus significantly advance the conservation of the salt marsh harvest mouse.

Nonnative predators (e.g., feral cats) are believed to be an important stressor on the salt marsh harvest mouse. Therefore, the design and management of restored habitat will include control of nonnative predators (e.g., through direct removal of predators or through design of restored habitats that minimize access of predators into occupied habitats).

<u>*Applicable Conservation Measures*</u>

- CM3 Natural Communities Protection
- CM4 Tidal Habitat Restoration
- CM11 Natural Communities Enhancement and Management

[24] Restored tidal habitat acreage ranges are a component of the 65,000 acre target for restored tidal habitat. Acreage ranges are based on the results of hydrodynamic modeling of realistic hypothetical restoration designs. While these ranges are not the acreage targets for restored tidal habitats, but rather the results of modeling, the hypothetical designs provided verification of the practicability of achieving restoration targets.

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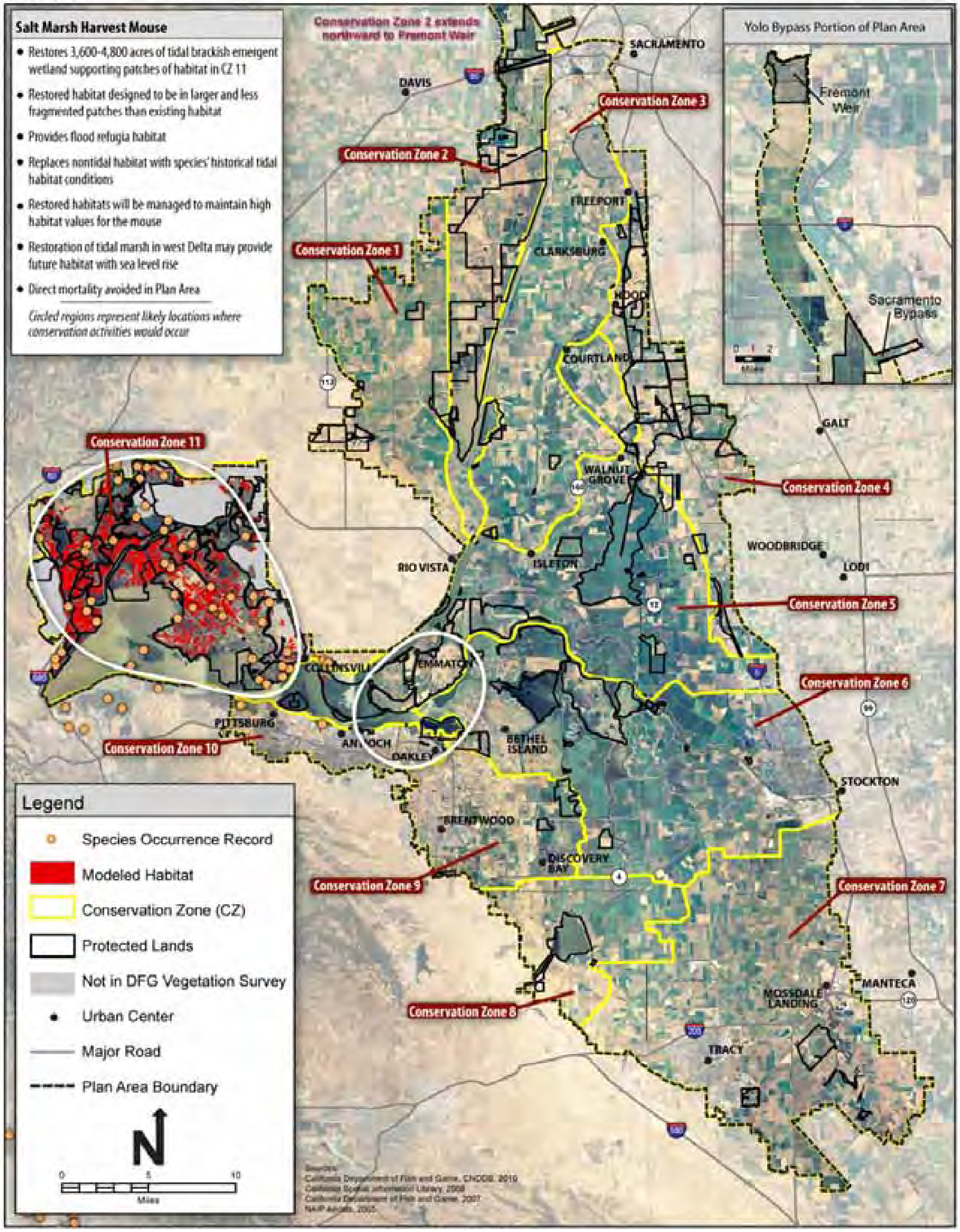

Figure 3-16. Salt Marsh Harvest Mouse Habitat Distribution and Conservation Strategy

3.3.2.4.4 Riparian Brush Rabbit

One of eight subspecies of brush rabbit in California, the riparian brush rabbit (*Sylvilagus bachmani riparius*) occupies a range that is disjunct from that of other brush rabbits, near sea level on the floor of the San Joaquin Valley (USFWS 1998a). Riparian brush rabbits inhabit valley riparian forests or forest patches, where they are closely associated with dense shrub vegetation (Williams et al. 2008). Occupied sites tend to be in riparian settings with an open overstory canopy of valley oak (*Quercus lobata*) or savannah-like settings that support extensive patches of low-growing willow (*Salix* spp.), wild rose (*Rosa californica*), wild grape (*Vitis californica*), or blackberry (*Rubus* spp.) (Williams et al. 2008). The brush rabbits move through the dense brush and thickets by creating tunnels through the vegetation. Seasonally available weedy/ruderal cover, including patches of tall grass, forbs, and pepperweed (*Lepidium latifolium*) is also used, particularly where it connects to more suitable woody cover (Williams et al. 2008). Generally, riparian forests that support a closed overstory canopy lack sufficient understory shrubs to support riparian brush rabbits (USFWS 1998a). Small herbaceous openings in close proximity to cover are also required for foraging, and higher elevation areas are required to sustain populations during floods (USFWS 1998a).

Due to drastic declines in brush rabbit numbers since the 1940s, the riparian brush rabbit (*Sylvilagus bachmani riparius*) is listed as endangered under the state and federal endangered species acts. The riparian brush rabbit's historical distribution may have extended along portions of the San Joaquin River and its tributaries on the valley floor from at least as south as Stanislaus County to the Delta (Orr 1935 in USFWS 1998a). Populations are known to have historically occurred in riparian forests along the San Joaquin and Stanislaus rivers and some tributaries to the San Joaquin River on the valley floor (USFWS 1998a). One population estimate within this historical range was about 110,000 individuals (USFWS 1998). The dramatic decline of the riparian brush rabbit began with the building of dams constructed for irrigation and flood control, on the major rivers of the Central Valley. Protection from flooding resulted in conversion of floodplains to croplands and the consequent reduction and fragmentation of remaining riparian communities. By the mid-1980s, the riparian forest within the species' former range had been reduced to a few small and widely scattered fragments totaling about 5,189 acres (USFWS 1998a).

As a result of habitat loss, remaining populations of riparian brush rabbits occur in only two areas of San Joaquin County. The first is a patch of approximately 258 acres in Caswell Memorial State Park (CMSP) on the Stanislaus River. The second population, which was only confirmed in late 1998, occupies approximately 270 acres in several small, isolated or semi-isolated patches along Paradise Cut and Tom Paine Slough and channels of the San Joaquin River in the southern Plan Area (Williams et al. 2002a, Williams et al. 2008).

In 2005, a captive-bred population of approximately two-dozen animals was introduced to the Faith Ranch along the San Joaquin River in Stanislaus County adjacent to the San Joaquin River National Wildlife Refuge. The recovery plan for the brush rabbit (and other upland species of the San Joaquin Valley) is focused on riparian restoration and protection, together with population reintroductions.

Applicable Natural Community Goals and Objectives

Goal VRNC1: The expected outcome is restored large expanses and interconnected corridors of valley/foothill riparian natural community.

> **Objective VRNC1.1**: Restore or create 5,000 acres of valley/foothill riparian in Conservation Zones 1, 2, 4, 5, 6, 7, and/or 11.

Goal VRNC2: The expected outcome is biologically diverse valley/foothill riparian natural community that supports native species and is sustained by natural ecological processes.

> **Objective VRNC2.1**: Maintain and enhance the habitat and ecosystem functions of BDCP restored valley/foothill riparian and patches of riparian forest and scrub present on BDCP preserved lands over the term of the BDCP.

> **Objective VRNC2.3**: Restore connectivity of valley/foothill riparian corridors along linear watercourses to enhance habitat for covered species and facilitate wildlife movement.

Species-Specific Goals and Objectives

Goal RIBR1: The expected outcome is restored and protected habitat for riparian brush rabbit.

> **Objective RIBR1.1:** Of the 5,000 acres of riparian restoration, restore and manage at least 300 acres to meet the ecological requirements of the riparian brush rabbit in Conservation Zones 7 or 8.

Rationale and Conservation Approach

BDCP implementation will be congruent with and help achieve the goals of the recovery plan. Specifically, conservation within the Plan Area will be directed towards restoring riparian forest and scrub to provide habitat compatible with future reintroduction efforts or expansion of the existing riparian brush rabbit population into the Plan Area. Approaches for restoring riparian communities that support riparian brush rabbit habitat are described in the conservation approaches for conserving the Valley/foothill riparian natural community.

Conservation of riparian brush rabbit will be provided through restoration of 300 acres of riparian vegetation that supports brush rabbit habitat attributes within the species' historical range along Old River, Middle River, and/or the San Joaquin River or suitable tributaries in Conservation Zones 7 and 8 (Figure 3-17). Habitat will be restored in patches of at least 25 acres, which is believed to exceed the minimum habitat patch size requirements for the species.

Connectivity with currently occupied or potentially occupied habitat will be a primary factor in the selection of restoration sites. In addition to the species' limited distribution and abundance, flooding and predation are primary stressors on this species. The restored riparian brush rabbit habitat will be designed to incorporate flood refugia habitat (i.e., bunny mounds) and will be designed and managed to control predation. The extent of existing known occupied habitat is approximately 270 acres (Appendix A, *Covered Species Accounts*) and restoration of 300 acres of additional habitat located adjacent to occupied or potentially occupied habitat areas will result in a substantial increase in the extent of available habitat. Additionally, a portion of the remaining 4,500 acres riparian habitat to be restored and distributed amongst Conservation Zones 1, 4, 5, 7, and/or 11 is expected to also support riparian brush rabbit habitat over the term of the BDCP. Thus, the proposed restoration and management of riparian brush rabbit habitat are expected to sustain the existing population. Riparian habitat conservation efforts within Conservation Zones 7 and 8 will serve to accommodate any future expansion of the existing population or provide habitat for future introductions of the species.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM7 Riparian Habitat Restoration
- CM11 Natural Communities Enhancement and Management

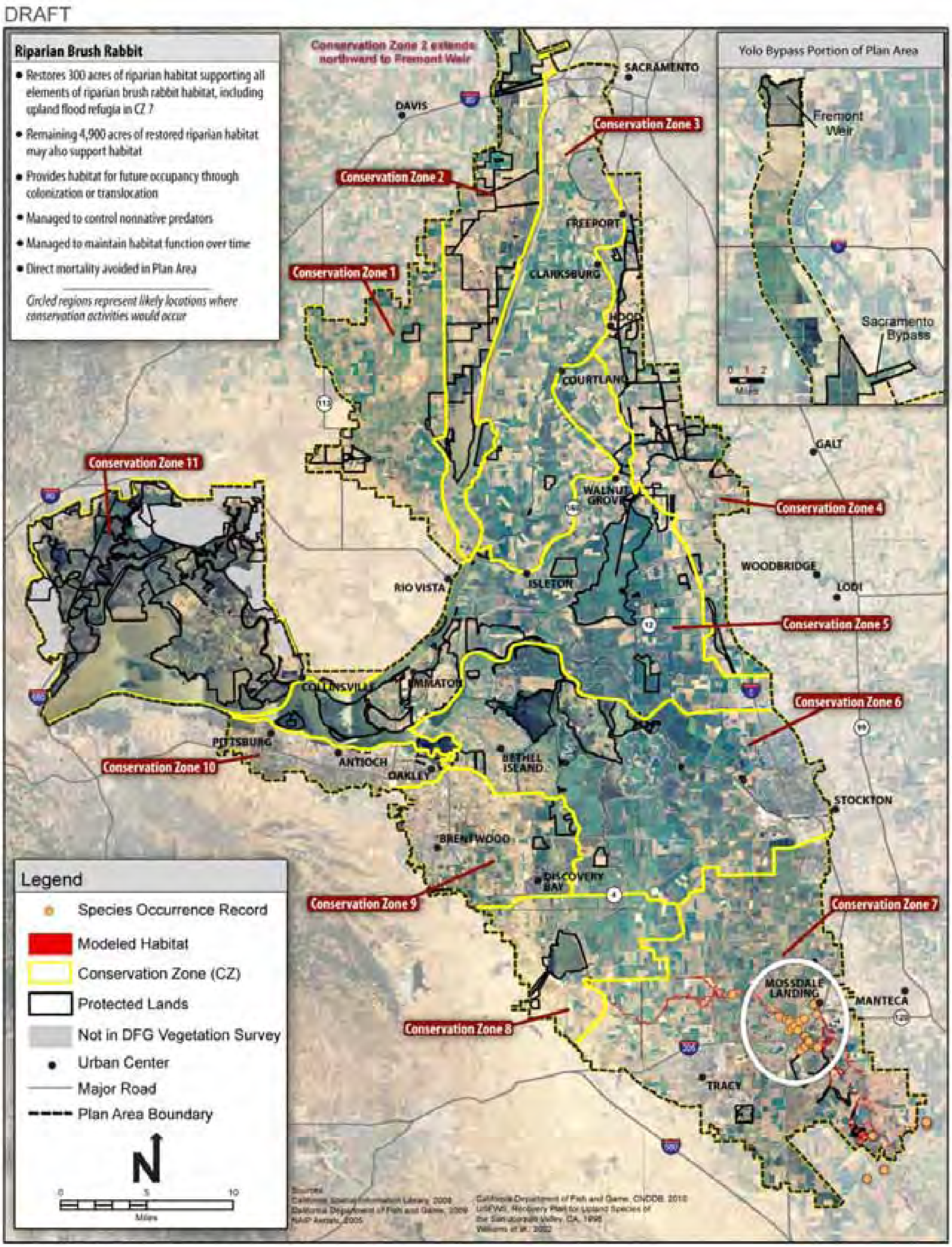

Figure 3-17. Riparian Brush Rabbit Habitat Distribution and Conservation Strategy

3.3.2.4.5 Townsend's Big-Eared Bat

Townsend's big-eared bat occurs in many habitats including active agricultural areas, riparian vegetation communities, coastal habitat types, oak woodland, conifer forest, desert scrub, and native prairies. Roosting habitat is mainly limited to caves, mines, tunnels, and other features that mimic caves, such as large tree hollows, abandoned buildings with cave-like attics, water diversion tunnels, and internal spaces in bridges. Pierson and Rainey (1998a) suggested that the species' distribution appears to be constrained primarily by the availability of suitable roosting sites and the degree of human disturbance at roosts.

According to Pierson and Rainey (1998a), there has been a 52 percent loss in the number of maternity colonies during the last 40 years, a 45 percent decline in the number of available roosts, a 54 percent decline in the total number of animals, and a 33 percent decrease in the average size of remaining colonies for the species as a whole across California. Townsend's big-eared bats have declined notably in San Francisco Bay area counties where native habitat and rural land have been converted to agriculture (i.e., wine production) or suburban/urban development. The cause of local population declines is most likely the disturbance and the destruction of roost sites. Vulnerability to human disturbance is indicated by findings that colonies have abandoned roost sites after human visitation (Humphrey and Kunz 1976). In addition to the disturbance or destruction of winter roosts, Pierson et al. (1999) also reported that Townsend's big-eared bats are threatened by the loss of clean water and the loss of roosting and foraging habitat. The impacts of pesticides and herbicides on insect prey availability may also threaten populations of this species.

No Townsend's big-eared bat has been documented in the Plan Area. However, the species is known to occur at nearby Central Valley locations and presumably could be present in the Plan Area (see Appendix A, *Covered Species Accounts*).

Applicable Natural Community Goals and Objectives

Goal VRNC1: The expected outcome is restored large expanses and interconnected corridors of valley/foothill riparian natural community.

> **Objective VRNC1.1**: Restore or create 5,000 acres of valley/foothill riparian in Conservation Zones 1, 2, 4, 5, 6, 7, and/or 11.

Goal ALNC1: The expected outcome is increased habitat functions for covered and other native species that are supported by agricultural land cover types and management practices.

> **Objective ALNC1.1**: Maintain and protect the functions of 4,600 acres of rice lands as habitat for giant garter snake, western pond turtle, tricolored blackbird, white-tailed kite, waterfowl, and migrant shorebirds in Conservation Zone 2. This objective may be partially or fully achieved by maintaining an equivalent extent of natural or managed lands that support habitat functions similar to rice lands for associated covered and other native wildlife species.

Objective ALNC1.2: Maintain and protect the functions of 12,020 to 28,040 acres of non-rice agricultural lands as foraging habitat for Swainson's hawk, white-tailed kite, and tricolored blackbird that are located within 8 miles of occupied Swainson's hawk nesting habitat.

Goal BMNC1: The expected outcome is restored large expanses and interconnected patches of tidal brackish emergent wetland natural community.

Objective BMNC1.1: Restore or create 3,600 to 4,800 acres of tidal brackish emergent wetland in the Suisun Marsh ROA (Conservation Zone 11).

Goal FMNC1: The expected outcome is restored large, interconnected patches of tidal freshwater emergent wetland natural community.

Objective FMNC1.1: Restore or create 13,900 to 21,600 acres of tidal freshwater emergent wetland in the Cache Slough, West Delta, Cosumnes-Mokelumne, and South Delta ROAs (Conservation Zones 1, 2, 4, 5, 6, and 7).

Goal GRNC1: The expected outcome is grassland comprised of large interconnected patches or contiguous expanses.

Objective GRNC1.1: Protect a minimum of 8,000 acres of grassland in Conservation Zones 1, 8, and 11. At least 1,000 acres will be protected in Conservation Zone 8, with the remainder distributed throughout these three Conservation Zones.

Rationale and Conservation Approach

Conservation of Townsend's big-eared bat under BDCP focuses on the restoration of valley/foothill riparian as roosting and primary foraging habitat. Woody vegetation is particularly important for foraging as well as for roosting because Townsend's big-eared bats forage through both aerial hawking and substrate gleaning. Restored areas of valley/foothill riparian are anticipated to be located primarily within Conservation Zones 1, 4, 7, and/or 11 (Figure 3-18). Secondary foraging habitats are comprised of all other land cover types present in the Plan Area (e.g., cultivated lands) and will be protected through actions that provide conservation for other covered species (e.g., preservation of Swainson's hawk foraging habitat) and the restoration of tidal emergent wetland, tidal perennial aquatic, nontidal wetland, and valley/foothill riparian. The production of flying insects and, consequently the function of restored habitats as bat foraging habitat is expected to be greater in restored habitats than in cultivated land foraging habitats. Restored habitats will provide a diversity of microhabitats conducive to a greater production and availability of flying insects compared to the homogenous microhabitat conditions associated with cultivated lands that are subject to routine application of pesticides. Additionally, protected and restored habitats will be monitored to assess occupancy by the species and managed to minimize human disturbances that could affect roosting bats.

Based on model projections, the restoration of valley/foothill riparian areas will increase the extent of Townsend's big-eared bat roosting and primary foraging habitat within the Plan Area by approximately 28 percent (see detailed description of habitat requirements and habitat model assumptions in Appendix A, *Covered Species Accounts*). The substantial increase in this species' core habitat in combination with the protection and enhancement of its secondary foraging habitats is expected to sustain the existing abundance and distribution of Townsend's big-eared bat and provide for the future growth of its population.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM7 Riparian Habitat Restoration
- CM11 Natural Communities Enhancement and Management

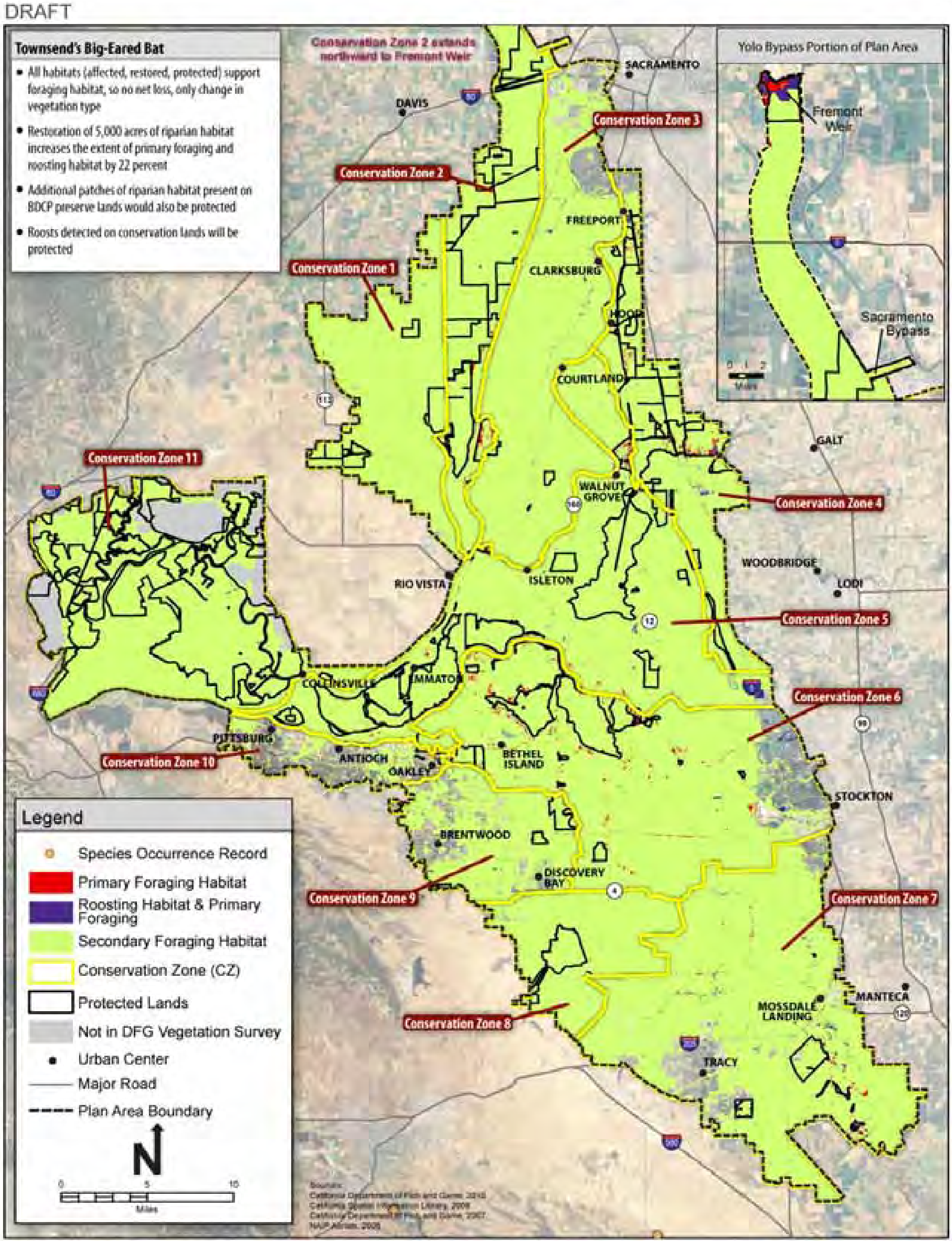

Figure 3-18. Townsend's Big-Eared Bat Habitat Distribution and Conservation Strategy

3.3.2.4.6 Suisun Shrew

The Suisun shrew is one of several subspecies of the ornate shrew and is endemic to the tidal saline and brackish salt marshes of Solano, Napa, and eastern Sonoma counties. Its current distribution is restricted to isolated remnants of natural tidal and brackish marshes along the northern borders of San Pablo and Suisun bays, including a number of locations in Suisun Marsh, Southampton Marsh, and the Napa Marshes, extending as far east as Grizzly Island and as far west as Sonoma Creek and Tubbs Island (Brown and Rudd 1981, Western Ecological Services 1986). There are no reported occurrences of Suisun shrew from within the Plan Area except in Suisun Marsh. Degradation of tidal marsh habitats continues to be the most significant threat to Suisun shrews and other tidal marsh species. Tidal marshes have been reduced by 84 percent since historical times (Dedrick 1989). The fragmentation of suitable habitats has isolated populations and reduced dispersal opportunities.

Applicable Natural Community Goals and Objectives

Goal BMNC1: The expected outcome is restored large expanses and interconnected patches of tidal brackish emergent wetland natural community.

> **Objective BMNC1.1:** Restore or create 3,600 to 4,800 acres of tidal brackish emergent wetland in the Suisun Marsh ROA (Conservation Zone 11).

Goal BMNC2: The expected outcome is biologically diverse tidal brackish emergent wetland that is enhanced for native species and sustained by natural ecological processes.

> **Objective BMNC2.1:** Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal brackish emergent wetland for covered and other native species over the term of the BDCP.

Rationale and Conservation Approach

Because the primary stressor on the Suisun shrew is loss of its tidal marsh habitat, Suisun shrew conservation and recovery efforts are aimed at protecting and restoring tidal marsh habitat (e.g., CALFED Bay-Delta Program 2000). Congruent with those conservation efforts, BDCP will restore tidal marsh habitat to provide for the conservation of the Suisun shrew. Suisun shrew inhabits tidal brackish emergent wetland. Much of Suisun shrew occupied habitat is supported by suitable patches of vegetation within nontidal managed wetland complex that the mouse has adapted to following the reclamation of historical Suisun Bay tidal marshes. Conservation will be directed towards restoring tidal brackish emergent wetland, on which the species was historically dependent to produce a net increase in Suisun shrew habitat. Because restoration of tidal brackish emergent wetland will remove and degrade patches of nontidal managed wetland complex that are currently occupied by Suisun shrew, restoration will be sequenced and located in a manner that minimizes the extent of any temporary loss of habitat. Approaches for restoring tidal brackish emergent wetland to support Suisun shrew habitat are described in the conservation approach for conserving the tidal brackish emergent wetland natural community.

In the Plan Area, the Suisun shrew is only present in Suisun Marsh in Conservation Zone 11. Conservation of Suisun shrew will be provided through the restoration and management of tidal brackish emergent wetland in Suisun Marsh and associated preserved upland refugia habitats. A total of between 3,600 and 4,800 acres[25] of tidal wetland and 350 to 700 acres of associated upland habitat is expected to be restored in the Suisun Marsh (Conservation Zone 11) and provide high value habitat for the Suisun shrew (Figure 3-19). Restored marsh plain habitats will be designed to the maximum extent practicable within site constraints to provide the full range of tidal exchange that occurred under historical Suisun Bay conditions. This approach is expected to result in the establishment of patches of Suisun shrew habitat within a mosaic of larger marsh plain habitats. Restoration designs will also include the preservation and enhancement of adjacent uplands in sufficient quantity and width to function as flood refugia habitat during high tidal events. This upland habitat will be designed and managed to minimize exposure to predation during flood events. The proposed restoration of tidal brackish emergent wetland in Suisun Marsh is consistent with and helps achieve the Suisun shrew objectives of the draft tidal marsh ecosystems recovery plan (USFWS 2010) and the objectives of the Suisun Marsh Restoration Plan (under development).

Suisun shrew habitat will be restored in a sequenced manner that minimizes disturbance of existing habitat between the time that restoration actions are initiated and when restored tidal brackish emergent wetland develops as Suisun shrew habitat. Direct removal of existing tidal brackish emergent wetland will be minimized to be consistent with achieving overall BDCP wetland restoration objectives, although some existing tidal brackish emergent wetland is expected to be desiccated or inundated as a result of changes in the existing tidal range following the breaching of dikes and levees. It is anticipated that following completion of all tidal habitat restoration in Suisun Marsh, tidal brackish emergent wetland will be restored in larger patches than the existing patches of habitat that are currently fragmented by dikes, roads, unsuitable habitat areas, and other infrastructure. These larger, unfragmented patches are expected to provide higher-value habitat that will facilitate the expansion and growth of Suisun shrew populations in the Suisun Marsh.

Applicable Conservation Measures

- CM3 Natural Communities Protection;
- CM4 Tidal Habitat Restoration; and
- CM11 Natural Communities Enhancement and Management

[25] Restored tidal habitat acreage ranges are a component of the 65,000 acre target for restored tidal habitat. Acreage ranges are based on the results of hydrodynamic modeling of realistic hypothetical restoration designs. While these ranges are not the acreage targets for restored tidal habitats, but rather the results of modeling, the hypothetical designs provided verification of the practicability of achieving restoration targets.

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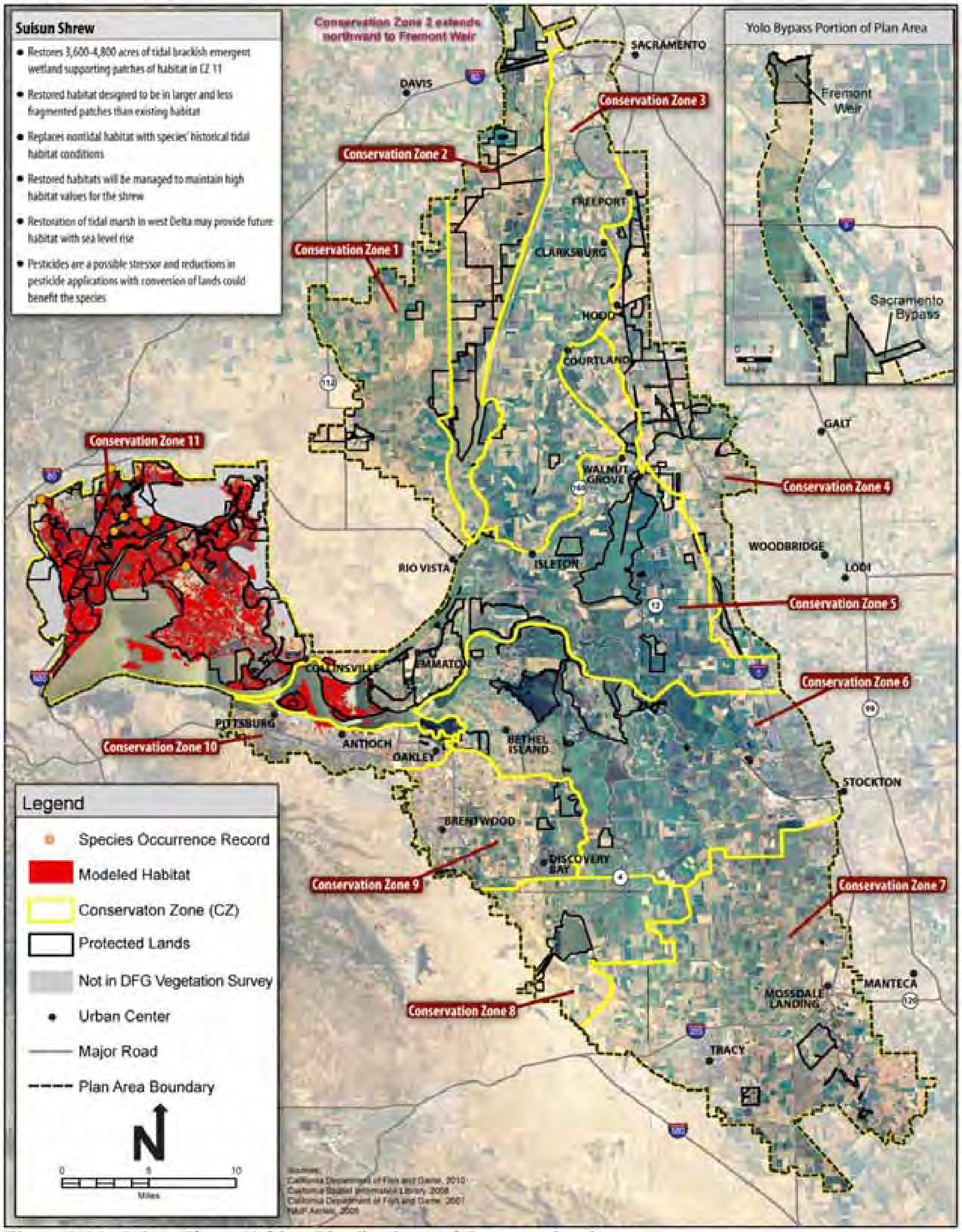

Figure 3-19. Suisun Shrew Habitat Distribution and Conservation Strategy

3.3.2.4.7 Tricolored Blackbird

Tricolored blackbirds form the largest colonies of any North American passerine bird (Beedy and Hamilton 1999) and are largely endemic to California. The state is home to more than 95 percent of the global population and more than 75 percent of the breeding population occurs in the Central Valley in any given year (Hamilton 2000). Tricolored blackbirds nest in areas with open accessible water, a protected nesting substrate (e.g., flooded, thorny, or spiny vegetation), and suitable foraging habitat (e.g., pastures, dry seasonal pools, agricultural fields such as alfalfa and rice, feedlots, and dairies) providing adequate insect prey within a few miles of the nesting colony. As many as 30,000 nests have been recorded in cattail (Typha spp.) marshes of 10 acres or less (Neff 1937, DeHaven et al. 1975). The Bay Delta is recognized as a major wintering area for tricolored blackbirds (Hamilton 2004, Beedy 2008), though there are few records of breeding colonies in the Delta (see Appendix A, *Covered Species Accounts*).

While the overall range of the species is largely unchanged since the 1930s (Neff 1937, DeHaven et al. 1975, Beedy et al. 1991, Hamilton 1998), there are now large gaps in the species' former range encompassing entire counties (e.g., Kings, San Joaquin, Riverside, San Bernardino counties). Recent surveys (Hamilton et al. 1995, Beedy and Hamilton 1997, Hamilton 2000) indicate a significant declining trend in populations in California since the 1930s and a particularly dramatic decline since 1994. Hamilton (2000) reports a 56 percent statewide decline between 1994 and 2000 (from 369,359 to 162,508 adults), and a 69 percent decline in the Sacramento Valley during that period (from 98,362 to 30,979 adults). The most significant historical and ongoing threat to the tricolored blackbird is habitat loss and alteration (e.g., (Cook 1999, DeHaven 2000, Hamilton 2004, Yolo Natural Heritage Program 2008). The initial conversion from native landscapes to agriculture removed vast wetland areas in the state and caused initial declines in populations. The more recent conversion of suitable agricultural lands to urbanization has permanently removed historical breeding and foraging habitat for this species. In urbanizing areas, habitat fragmentation and proximity to human disturbances has also led to abandonment of large historical colonies (Beedy and Hamilton 1999).

Applicable Natural Community Goals and Objectives

Goal FMNC1: The expected outcome is restored large, interconnected patches of tidal freshwater emergent wetland natural community.

> **Objective FMNC1.1:** Restore or create 13,900 to 21,600 acres of tidal freshwater emergent wetland in the Cache Slough, West Delta, Cosumnes-Mokelumne, and South Delta ROAs (Conservation Zones 1, 2, 4, 5, 6, and 7).

Goal NWNC1: The expected outcome is nontidal freshwater perennial emergent wetland natural community that supports habitat for covered and other native species.

> **Objective NWNC1.1**: Create 400 acres of nontidal freshwater marsh (including components of nontidal perennial aquatic and perennial emergent wetland communities)

that functions as habitat for the giant garter snake, tricolored blackbird, and western pond turtle within or adjacent to habitat occupied by the Caldoni Marsh/White Slough giant garter snake subpopulation in Conservation Zone 4 and the Yolo/Willow Slough giant garter snake subpopulation in Conservation Zone 2.

Goal GRNC1: The expected outcome is grassland comprised of large interconnected patches or contiguous expanses.

Objective GRNC1.1: Protect a minimum of 8,000 acres of grassland in Conservation Zones 1, 8, and 11. At least 1,000 acres will be protected in Conservation Zone 8, with the remainder distributed throughout these three Conservation Zones.

Goal ALNC1: The expected outcome is increased habitat functions for covered and other native species that are supported by agricultural land cover types and management practices.

Objective ALNC1.1: Maintain and protect the functions of 4,600 acres of rice lands as habitat for giant garter snake, western pond turtle, tricolored blackbird, white-tailed kite, waterfowl, and migrant shorebirds in Conservation Zone 2. This objective may be partially or fully achieved by maintaining an equivalent extent of natural or managed lands that support habitat functions similar to rice lands for associated covered and other native wildlife species.

Objective ALNC1.2: Maintain and protect the functions of 12,020 to 28,040 acres of non-rice agricultural lands as foraging habitat for Swainson's hawk, white-tailed kite, and tricolored blackbird that are located within 8 miles of occupied Swainson's hawk nesting habitat.

Rationale and Conservation Approach

Because the primary stressor on tricolored blackbird is the loss of its wetland nesting habitat due to urban and agricultural expansion (e.g., DeHaven et al. 1975, Cook and Toft 2005), restoration of wetland nesting habitat likely represents the most effective approach to the species' long-term conservation. Conservation of tricolored blackbird within the Plan Area is directed at substantially increasing the extent of its tidal and nontidal emergent wetland nesting habitat in conjunction with protection of nearby foraging habitats (Figure 3-20). Restoration of brackish and freshwater tidal emergent wetland is expected to support large patches of emergent vegetation suitable for nesting within Conservation Zones 1, 2, 4, 5, 6, 7, and 11. Because nesting habitat will be restored in large contiguous patches in these areas, restored nesting habitat is expected to provide higher nesting habitat functions than existing patches of nesting habitat, which are generally small, fragmented, and subject to disturbance during the breeding season. The proposed restoration of up to between 17,500 to 26,400 acres of tidal emergent wetland and 400 acres of nontidal marsh habitat suitable for tricolored blackbird nesting and foraging is expected to increase the extent of available nesting habitat in the Plan Area several-fold.

Protection of foraging habitats within a few miles of nesting habitat will provide food resources necessary for successful rearing and fledging of young and all protected foraging habitats will support wintering birds. The proposed protection of agricultural habitat, grassland, and vernal pool complex foraging habitat will increase the extent of currently preserved habitat from 19 percent to up to approximately 26 percent within the Plan Area.

The protection of active nesting colonies is also essential for successful breeding. Tricolored blackbirds are sensitive to human disturbances, and establishing no-disturbance buffers around nesting colonies during the breeding season will increase the opportunities for reproductive success. No disturbance buffers will be established through implementation of Avoidance and Minimization Measures (See AMM13).

In summary, proposed BDCP restoration of nesting habitat and protection of foraging habitats are expected to be sufficient to sustain the existing breeding and wintering population(s) of tricolored blackbirds in the Plan Area. Because the Plan Area corresponds to a major wintering area yet supports only a small number of nesting colonies (largely or mainly in the Yolo Bypass; see Appendix A, *Covered Species Accounts*), restoration of wetland nesting habitat in particular has the potential to provide for future increases in of tricolored blackbird abundance and distribution.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM8 Grassland Communities Restoration
- CM9 Vernal Pool Complex Restoration
- CM11 Natural Communities Enhancement and Management

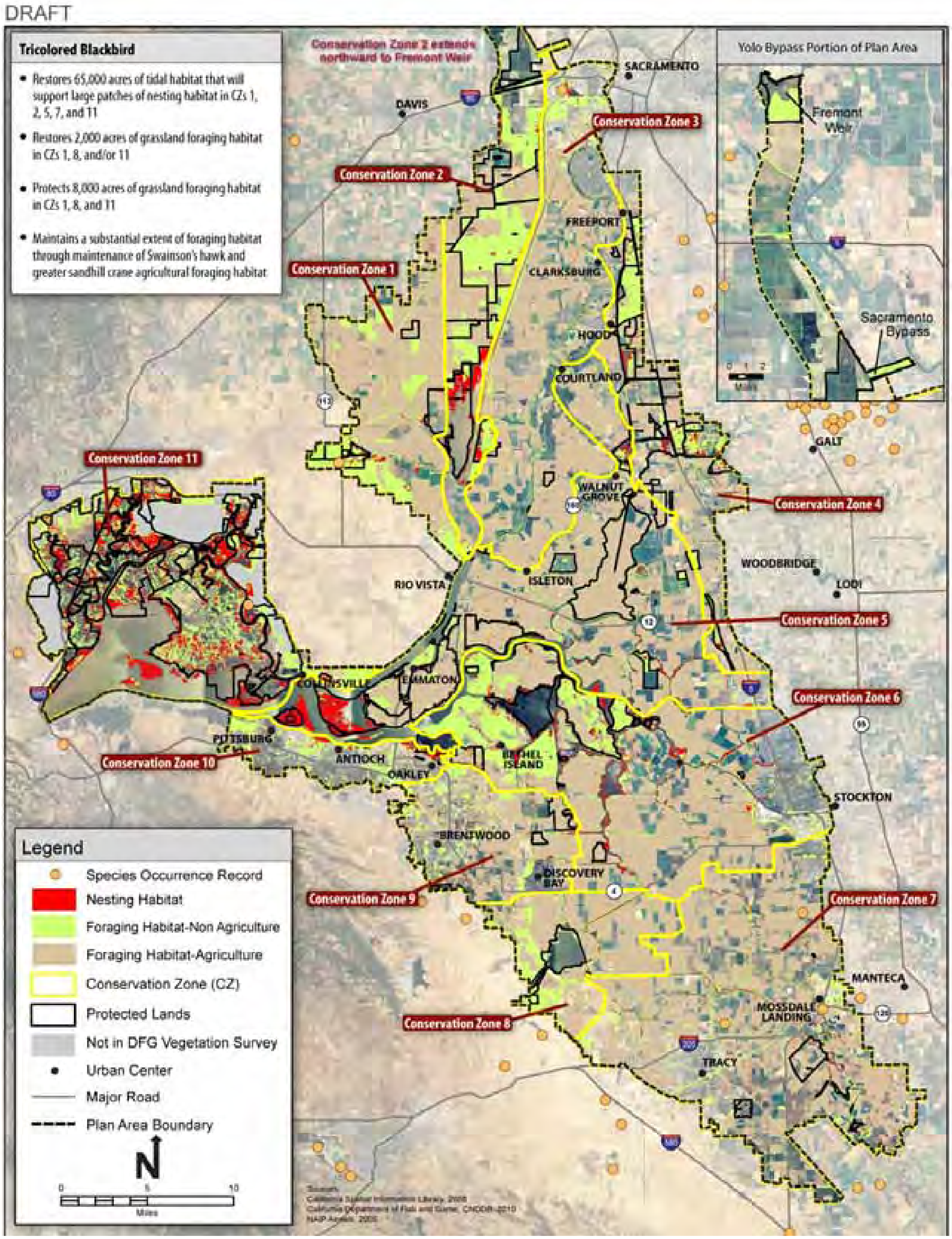

Figure 3-20. Tricolored Blackbird Habitat Distribution and Conservation Strategy

3.3.2.4.8 Suisun Song Sparrow

The Suisun song sparrow is endemic to the salt marshes of Suisun Bay and while it has been confirmed to be phenotypically distinct from neighboring subspecies (Patten 2001), genetic differentiation has not been confirmed (Chan and Arcese 2002). The Suisun song sparrow is associated with tidal marsh habitats characterized by dense vegetation with bare areas that support foraging. Its distribution extends into the Plan Area to approximately Kimbal Island; however, the majority of the range of the species is included within the Suisun Marsh. Spautz and Nur (2008), citing unpublished data from the Point Reyes Bird Observatory (PRBO), estimate the total population of Suisun song sparrows as 43,000 to 66,000 breeding pairs, approximately one-third of the estimated historical population size (Spautz and Nur 2008). Habitat loss and fragmentation, caused by diking, levee construction, channelization, invasive species, and urbanization, is considered the primary threat to the continued existence of the Suisun marsh sparrow (Larsen 1989, Spautz and Nur 2008). Throughout most of the Suisun Marsh, tidal marsh has been reduced to small fragments that are separated by dispersal barriers or only connected by very narrow strips of vegetation remaining along the banks of tidal sloughs, reducing dispersal, gene flow, and reproduction (Larsen 1989).

Applicable Natural Community Goals and Objectives

Goal BMNC1: The expected outcome is restored large expanses and interconnected patches of tidal brackish emergent wetland natural community.

> **Objective BMNC1.1:** Restore or create 3,600 to 4,800 acres of tidal brackish emergent wetland in the Suisun Marsh ROA (Conservation Zone 11).

Goal BMNC2: The expected outcome is biologically diverse tidal brackish emergent wetland that is enhanced for native species and sustained by natural ecological processes.

> **Objective BMNC2.1:** Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal brackish emergent wetland for covered and other native species over the term of the BDCP.

Rationale and Conservation Approach

Because the primary stressor on the Suisun song sparrow is loss of tidal marsh habitat, the restoration of this habitat type is considered the most effective approach to the conservation of the sparrow. Under BDCP, the conservation of Suisun song sparrow will be provided through restoration and management of brackish tidal emergent wetland habitats that historically supported Suisun song sparrow habitat in Suisun Marsh (Figure 3-21). Much of the still-existing Suisun song sparrow habitat consists of patches of nontidal managed wetlands that the sparrow has adapted to following reclamation of historically Suisun Bay tidal marshes. Because restoration of tidal brackish emergent wetland will remove and degrade patches of nontidal managed wetlands that are currently occupied by Suisun song sparrow, restoration will be sequenced and located in a manner that minimizes any temporary, initial loss of habitat.

Direct removal of existing tidal brackish emergent wetland will be minimized consistent with achieving overall wetland restoration objectives, although some existing tidal brackish emergent wetland is expected to be desiccated or inundated as a result of changes in the existing tidal range following the breaching of dikes and levees. Approaches for restoring tidal brackish emergent wetland to support Suisun song sparrow habitat are described in the conservation approach for conserving the tidal brackish emergent wetland natural community.

Suisun Marsh is included in Conservation Zone 11. Restored marsh plain habitat in Conservation Zone 11 (3,600 to 4,800 acres[26]) will be designed to the maximum extent practicable within site constraints to provide the full range of tidal conditions that were associated with historical Suisun Bay tidal marsh. This approach is expected to result in restoration of patches of sparrow habitat within a mosaic of extensive brackish tidal emergent wetland.

Restored habitat will be designed to include channel habitat edges that support high functioning Suisun song sparrow nesting habitat and tidal brackish emergent wetland away from channels that is dominated by *Salicornia*, *Spartina*, and *Grindelia*.

Nonnative predators (e.g., feral cats) are believed to be an important stressor on the Suisun song sparrow. The design and management of restored habitat will include the control of nonnative predators to help maintain the species abundance (e.g., through direct removal of predators or through the design of restored habitats that minimize access of predators into occupied habitats).

The proposed restoration of tidal brackish emergent wetland in Suisun Marsh is consistent with and helps achieve the Suisun song sparrow objectives of the draft tidal marsh ecosystems recovery plan (USFWS 2010) and the objectives of the Suisun Marsh Restoration Plan (under development). It is anticipated that following completion of all tidal habitat restoration in Suisun Marsh, tidal brackish emergent wetland will be restored in larger patches than the existing patches of habitat currently fragmented by dikes, roads, infrastructure, or other unsuitable habitat. These larger unfragmented patches are expected to provide higher-value habitat and facilitate the expansion and growth of Suisun song sparrow populations in Suisun Marsh.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM4 Tidal Habitat Restoration
- CM11 Natural Communities Enhancement and Management

[26] Restored tidal habitat acreage ranges are a component of the 65,000 acre target for restored tidal habitat. Acreage ranges are based on the results of hydrodynamic modeling of realistic hypothetical restoration designs. While these ranges are not the acreage targets for restored tidal habitats, but rather the results of modeling, the hypothetical designs provided verification of the practicability of achieving restoration targets.

Figure 3-21. Suisun Song Sparrow Habitat Distribution and Conservation Strategy

3.3.2.4.9 Yellow-breasted Chat

The Yellow-breasted chat is a neotropical migrant that breeds throughout much of North America and winters primarily in Mexico and Central America, with a few birds also wintering in California (Small 1994). According to Grinnell and Miller (1944), the species' breeding distribution included the entire length and breadth of California exclusive of the higher mountains and coastal islands. The yellow-breasted chat is still present in most of its historical range with the exception of most of the Central Valley (Comrack 2008). In particular, nesting populations have been extirpated from the San Joaquin and Sacramento valleys except along foothill tributaries. The yellow-breasted chat occurs in the Plan Area mainly as a spring and fall migrant. During the breeding season, however, it is sparsely distributed across the Plan Area (Appendix A, *Covered Species Accounts*).

Yellow-breasted chats nest and forage in streamside, shrubby thickets of willows, vines, and brush (Small 1994). The species has been classified as an open-canopy obligatory species (i.e., preferred open overstory and brushy understory), with population density directly related to shrub density to a height of 4.5 meters (14.8 feet) (Crawford et al. 1981). Habitat loss is implicated in yellow-breasted chat population declines throughout much of the species' range (e.g., Remsen 1978, Rosenberg et al. 1991). Shuford and Gardali's (2008) list of management recommendations includes the preservation of existing, healthy riparian habitat and the restoration of degraded riparian habitat. Also listed by Shuford and Gardali (2008) is the need to maintain and/or promote a dense shrub layer in riparian habitat and create a shrub layer in the early stages of restoration projects. Zeiner et al. (1990) report that yellow-breasted chat territory size ranges from 0.3 to 3.2 acres (0.1 – 1.3 hectare). Small territory size suggests the potential for large-scale restoration of valley/foothill riparian to promote the establishment of sizeable chat populations.

Applicable Natural Community Goals and Objectives

Goal VRNC1: The expected outcome is restored large expanses and interconnected corridors of valley/foothill riparian natural community.

> **Objective VRNC1.1**: Restore or create 5,000 acres of valley/foothill riparian in Conservation Zones 1, 2, 4, 5, 6, 7, and/or 11.

Goal VRNC2: The expected outcome is biologically diverse valley/foothill riparian natural community that supports native species and is sustained by natural ecological processes.

> **Objective VRNC2.1**: Maintain and enhance the habitat and ecosystem functions of BDCP restored valley/foothill riparian and patches of riparian forest and scrub present on BDCP preserved lands over the term of the BDCP.

Objective VRNC2.2: Establish seasonal buffers around riparian habitats occupied by covered species to minimize disturbance during the breeding season.

Objective VRNC2.3: Restore connectivity of valley/foothill riparian corridors along linear watercourses to enhance habitat for covered species and facilitate wildlife movement.

Rationale for Conservation Approach

Within the Plan Area, modeled yellow-breasted chat habitat is divided into primary and secondary habitat based on a qualitative assessment of shrub and tree densities in riparian areas. Primary habitat includes a dense shrub layer such as typically found within chat breeding territories (Figure 3-22). Secondary habitat is riparian habitat with a less developed shrub layer. BDCP yellow-breasted chat conservation is directed at increasing the extent of primary and secondary riparian nesting and migratory habitats to ensure that: (1) chat numbers in the Plan Area at a minimum remain stable; and (2) sufficient valley/foothill riparian habitat is maintained to support potential future increases in the species' abundance and distribution.

Of the 5,000 acres of BDCP riparian habitat to be restored, it is expected that a substantial amount will provide the structure, species composition, and overstory suitable as yellow-breasted chat breeding habitat. It is also anticipated that much of the restored valley/foothill riparian habitat will be restored in large patches that will minimize the potential for cowbird nest parasitism, which is believed to be a stressor on the species (see Appendix A, *Covered Species Accounts*). The proposed restoration of yellow-breasted chat riparian habitat is expected to increase the extent of available habitat in the Plan Area by approximately 35 percent and, following BDCP implementation, approximately 51 percent of the species' habitat is expected to be under protected status.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM7 Riparian Habitat Restoration
- CM11 Natural Communities Enhancement and Management

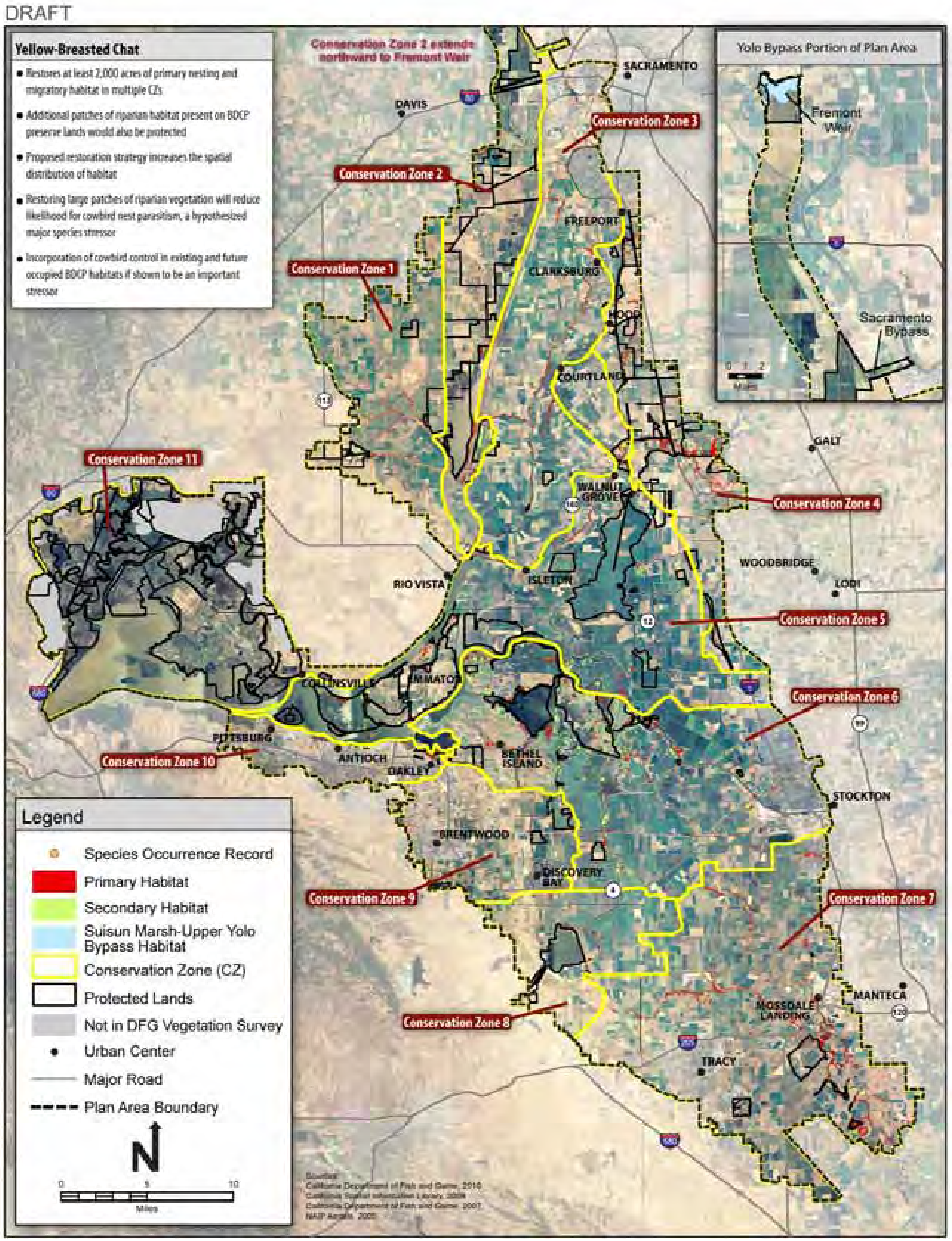

Figure 3-22. Yellow-Breasted Chat Habitat Distribution and Conservation Strategy

3.3.2.4.10 Least Bell's Vireo

A neotropical migrant, the least Bell's vireo is the only subspecies of the Bell's vireo that breeds entirely in California and northern Baja California. The least Bell's vireo's historical breeding distribution once extended from coastal southern California through the San Joaquin and Sacramento valleys as far north as Tehama County near Red Bluff. The Sacramento and San Joaquin valleys were considered the center of the species' historical breeding range supporting 60-80 percent of the historical population (51 FR 16474). Coinciding with widespread loss of riparian vegetation throughout California (Katibah 1984), Grinnell and Miller (1944) began to detect population declines in the Sacramento and San Joaquin Valley region by the 1930s. Surveys conducted in late 1970s (Goldwasser et al. 1980) detected no least Bell's vireos in the Sacramento-San Joaquin Valleys, and the species was considered extirpated from the region. By 1986, the USFWS determined that least Bell's vireo had been extirpated from most of its historical range and numbered approximately 300 pairs statewide (51 FR 16474). However, recent occurrences have suggested a northward expansion of the breeding range, including nest sites reported from the San Joaquin River National Wildlife Refuge and recent (2010) occurrences from the Yolo Bypass Wildlife Area.

The least Bell's vireo is an obligate riparian breeder that typically inhabits structurally diverse woodlands, including cottonwood-willow woodlands/forests, oak woodlands, and mule fat scrub (USFWS 1998b). Two features appear to be essential for breeding habitat: (1) the presence of dense cover within 3-6 ft. (1-2 m.) of the ground, where nests are typically placed; and (2) a dense stratified canopy for foraging (Goldwasser 1981, Gray and Greaves 1981, Salata 1981 & 1983, RECON 1989). While least Bell's vireo typically nests in willow-dominated areas, plant species composition does not seem to be as important a factor as habitat structure. Least Bell's vireo territories can range in size from 0.5-7.2 acres, but common territory sizes in Southern California range from 1.5-2.5 acres.

Critical habitat for this state and federally endangered species was designated in 1994, and a Draft Recovery Plan emphasizing the need for habitat protection and restoration was published in 1998 (USFWS 1998b). Riparian habitat creation and restoration are underway throughout California (RHJV 2004), and the least Bell's vireo is listed as a covered species in 16 Habitat Conservation Plans (HCPs), including the Coachella Valley Multi-species HCP, San Diego MSCP, Orange County NCCP/HCP, and Western Riverside MSHCP. Conservation actions under all of those habitat conservation plans and BDCP have the potential to act in synergy toward partial recovery of the vireo. The recent documentation of the species in the Yolo Bypass has heightened awareness of the species' conservation potential within the Plan Area.

Applicable Natural Community Goals and Objectives

Goal VRNC1: The expected outcome is restored large expanses and interconnected corridors of valley/foothill riparian natural community.

> **Objective VRNC1.1**: Restore or create 5,000 acres of valley/foothill riparian in Conservation Zones 1, 2, 4, 5, 6, 7, and/or 11.

Goal VRNC2: The expected outcome is biologically diverse valley/foothill riparian natural community that supports native species and is sustained by natural ecological processes.

> **Objective VRNC2.1**: Maintain and enhance the habitat and ecosystem functions of BDCP restored valley/foothill riparian and patches of riparian forest and scrub present on BDCP preserved lands over the term of the BDCP.

> **Objective VRNC2.2**: Establish seasonal buffers around riparian habitats occupied by covered species to minimize disturbance during the breeding season.

> **Objective VRNC2.3**: Restore connectivity of valley/foothill riparian corridors along linear watercourses to enhance habitat for covered species and facilitate wildlife movement.

Rationale and Conservation Approach

Because the primary stressor on the least bell's vireo is loss and fragmentation of its riparian habitat through urban and agricultural expansion, the protection and restoration of riparian areas is considered the most effective approach to the vireo's conservation. In the Plan Area, the conservation of least Bell's vireo will be provided through the restoration of 5,000 acres of valley/foothill riparian (of which more than 2,000 acres is expected to support least Bell's vireo) (Table 3-5) (Figure 3-23).

The least Bell's vireo is not known to presently breed in the Plan Area, but two singing males were detected in the Yolo Bypass Wildlife Area in mid-April 2010. A single breeding pair recently nested for multiple years immediately south of the Plan Area along the San Joaquin River, and because the Plan Area may support suitable riparian habitat, the species may re-establish itself within the Plan Area. Approaches for restoring valley/foothill riparian communities that support least Bell's vireo habitat are described in the conservation approaches for conserving the valley/foothill riparian natural community.

Patches of least Bell's vireo habitat are expected to be restored as a component of BDCP actions to restore 5,000 acres of valley/foothill riparian. A substantial amount of willow-dominated riparian is expected to be restored that will meet the ecological requirements of the least Bell's vireo. It is anticipated that much of the restored riparian habitat will occur in large wide patches that will minimize the potential for cowbird nest parasitism, which is a stressor on the species (see Appendix A, *Covered Species Accounts*). Given the relatively small territory size of least Bell's vireo and the large acreage of riparian habitat to be restored, BDCP riparian restoration efforts have the potential to significantly increase the likelihood of population re-establishment in the region.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM7 Riparian Habitat Restoration
- CM11 Natural Communities Enhancement and Management

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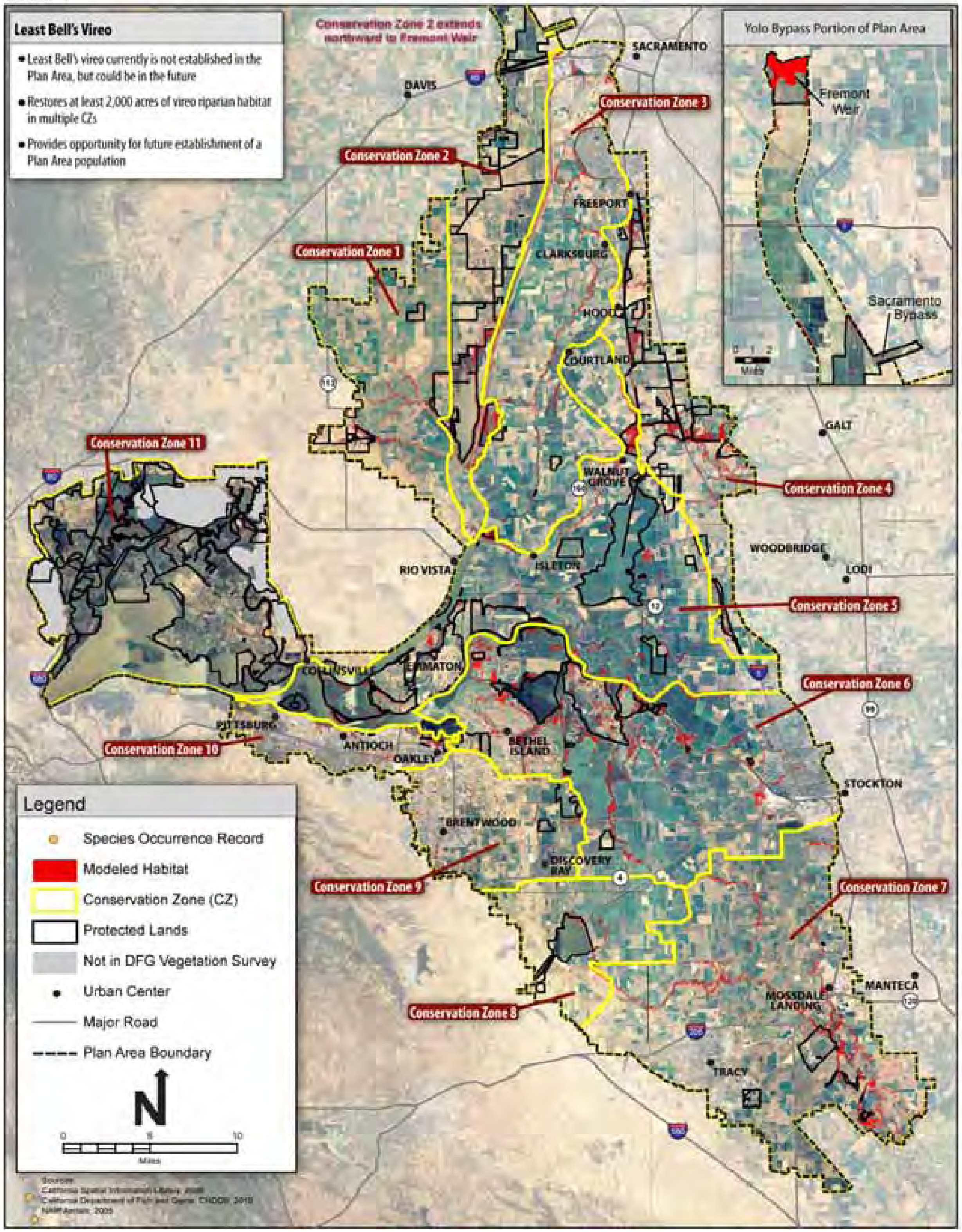

Figure 3-23. Least Bell's Vireo Habitat Distribution and Conservation Strategy

3.3.2.4.11 Western Burrowing Owl

Western burrowing owl occurrences in the Plan Area are a mix of year-round and winter residents, where habitat consists of grasslands, managed wetlands, and cultivated lands (see Appendix A, *Covered Species Accounts*). Throughout much of the species' range, and including in California, burrowing owl populations have been declining largely as a result of loss, degradation, or fragmentation of foraging and nesting habitat (Zarn 1974, Haug et al. 1993, Klute et al. 2003, DeSante et al. 2007, Desmond 2010). Causal factors are numerous, ranging from urbanization to poisoning of sciurid rodents whose burrows are used by the owls (Klute et al. 2003, DeSante et al. 2007, Desmond 2010). The majority of burrowing occurrences in the Plan Area are from the grassland/pastureland/cultivated matrix in Conservation Zones 1 and 2. However, the species is known to persist in low densities in more isolated locations where suitable burrowing habitat exists, including grassy levee slopes, remnant patches of grassland, and debris piles, roadside edges, and field edges in cultivated landscapes. The focus of BDCP on habitat for the western burrowing owl directly addresses the primary regional threat to the species (DeSante et al. 2007).

Applicable Natural Community Goals and Objectives

Goal GRNC1: The expected outcome is grassland comprised of large interconnected patches or contiguous expanses.

> **Objective GRNC1.1**: Protect a minimum of 8,000 acres of grassland in Conservation Zones 1, 8, and 11. At least 1,000 acres will be protected in Conservation Zone 8, with the remainder distributed throughout these three Conservation Zones.

> **Objective GRNC1.2**: Restore 2,000 acres of grassland to connect fragmented patches of protected grassland.

Goal GRNC2: The expected outcome is biologically diverse grassland managed to enhance native species and sustained by natural ecological processes.

> **Objective GRNC2.4**: Increase burrow availability for burrow-dependent species.

> **Objective GRNC2.5**: Increase prey, especially small mammals and insects, for grassland-foraging species.

Goal ALNC1: The expected outcome is increased habitat functions for covered and other native species that are supported by agricultural land cover types and management practices.

> **Objective ALNC1.3**: Of the maintained 12,020 to 28,040 acres of non-rice agricultural lands, maintain at least 3,000 acres of pasture that supports western burrowing owl foraging habitat. This objective may be partially or fully achieved through preservation

of other land cover types that provide moderate-value or greater habitat function for the western burrowing owl.

Objective ALNC1.8: Maintain and protect the small patches of important wildlife habitats associated with agricultural lands that occur within BDCP conserved agricultural lands, including isolated valley oak trees, trees and shrubs along field borders and roadsides, remnant groves, riparian corridors, water conveyance channels, grasslands, and wetlands.

Rationale and Conservation Approach

Conservation of western burrowing owl focuses on maintaining a landscape of suitable habitat across the Plan Area and on adjacent lands through strategic acquisition and management of grassland and agricultural preserves (Figure 3-24). In terms of burrowing owl habitat, the Plan Area's grasslands, managed wetlands, and cultivated lands range in value (or quality) from high to low (see Appendix A, *Covered Species Accounts*). Specifically, BDCP implementation will result in the protection and restoration of large patches of moderate-to-high-value natural grassland foraging and breeding habitats.

Protected grassland will also be connected to burrowing owl habitats adjacent to the Plan Area to preclude further fragmentation of important habitats. The distribution of high and moderate value habitat in the Plan Area is consistent with the observed current distribution of burrowing owls. Few western burrowing owls have been documented from low-value habitat areas. Habitat will be protected in large patches that are connected to existing protected habitats and located within or near known occupied habitat. It will also be managed to increase the availability of nesting burrows and prey species through a combination of measures (e.g., discontinued use of pesticides, manipulation of topography, mowing). An estimated 33 percent of the high-value habitat, 31 percent of the moderate-value habitat, and 11 percent of the low-value habitat are currently protected, respectively. Following BDCP implementation, 46 percent of the highest value existing habitat and 39 percent of the moderate value habitat in the Plan Area will be protected. The implementation of the proposed conservation actions is expected to sustain existing burrowing owl populations within and adjacent to the Plan Area and to provide an acreage of suitable habitat large enough to allow for any future population growth.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM8 Grassland Communities Restoration
- CM9 Vernal Pool Complex Restoration
- CM11 Natural Communities Enhancement and Management

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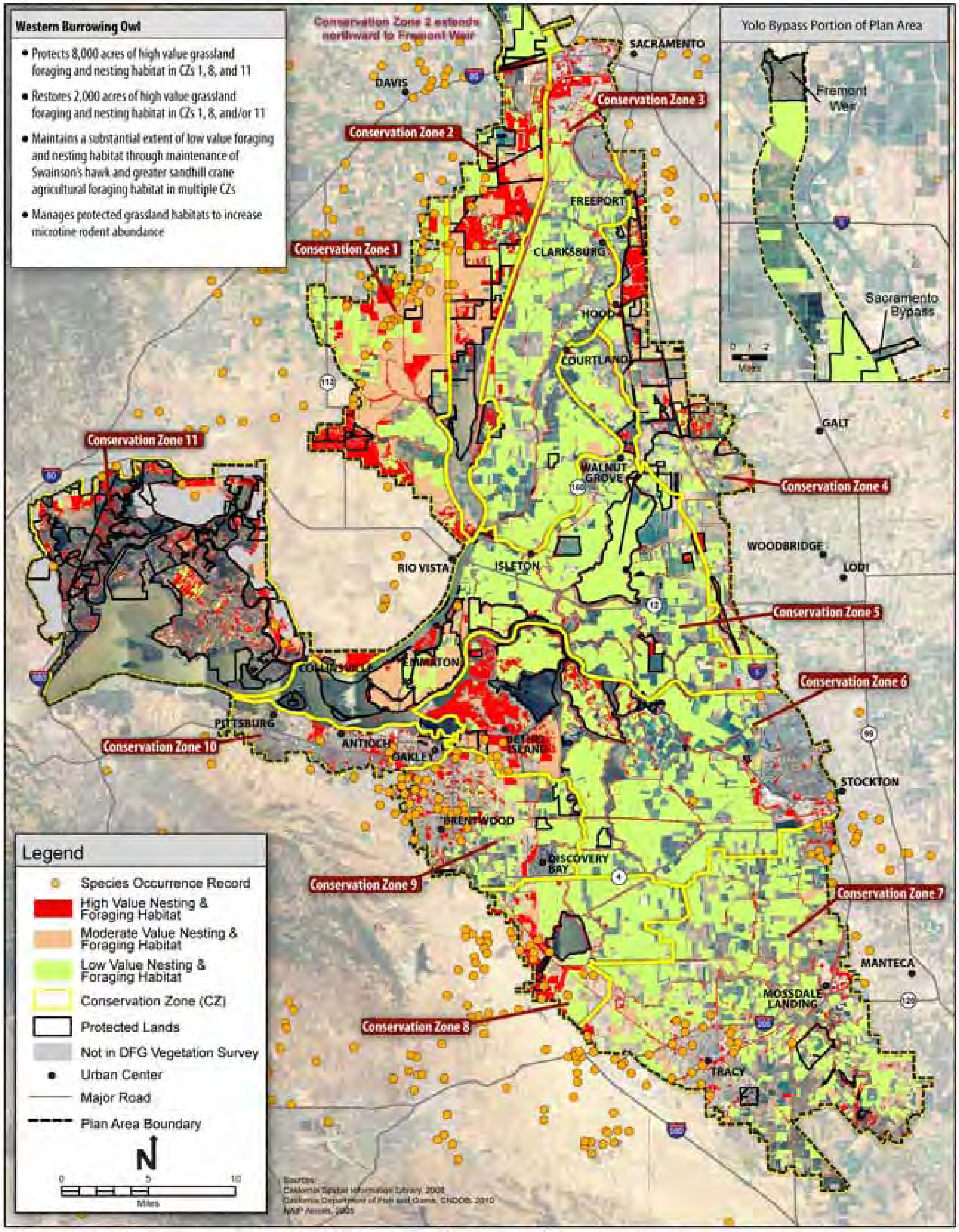

Figure 3-24. Western Burrowing Owl Habitat Distribution and Conservation Strategy

3.3.2.4.12 Western Yellow-billed Cuckoo

The yellow-billed cuckoo is a Neotropical migrant that breeds in North America and winters in South America. The range of the western yellow-billed cuckoo historically extended from southern British Columbia south to the Rio Grande in northern Mexico, and east to the Rocky Mountains (Bent 1940). Currently, the only known populations of breeding western yellow-billed cuckoo are in several disjunct locations in California, Arizona, and western New Mexico (Halterman 1991). Declines in numbers of the yellow-billed cuckoo in California are the result of the "removal widely of essential habitat conditions," as described by Grinnell and Miller (1944). Population declines in California have continued primarily in the San Joaquin Valley and along the north coast and central coast (where the populations had been extirpated by 1977) (Gaines and Laymon 1984), while the species was also nearly extirpated in the Lower Colorado River Valley by 1999. In the Sacramento Valley, only 1 percent of the species' historical habitat remains to support a small population estimated at only 50 pairs in 1987 and 19 pairs in 1989 (Laymon and Halterman 1989), most of these from Sutter, Yuba, and Butte Counties. There are no records of the species breeding in the Plan Area; however, an individual cuckoo was documented in the Central Delta during breeding season surveys conducted in 2009.

Estimates of yellow-billed cuckoo territory size on the south fork of the Kern River ranged from 8-40 hectares (20-100 acres) (Laymon and Halterman 1985), but on the Colorado River were as small as 4 hectares (10 acres) (Laymon and Halterman 1989). Patch size, type and quality of habitat, and prey abundance largely determine the size of territories (Halterman 1991). Laymon and Halterman (1989) classify a willow-cottonwood forest patch greater than 604 meters (1,980 ft) wide and greater than 81 hectares (200 acres) as optimum habitat.

Applicable Natural Community Goals and Objectives

Goal VRNC1: The expected outcome is restored large expanses and interconnected corridors of valley/foothill riparian natural community.

> **Objective VRNC1.1**: Restore or create 5,000 acres of valley/foothill riparian in Conservation Zones 1, 2, 4, 5, 6, 7, and/or 11.

Goal VRNC2: The expected outcome is biologically diverse valley/foothill riparian natural community that supports native species and is sustained by natural ecological processes.

> **Objective VRNC2.1**: Maintain and enhance the habitat and ecosystem functions of BDCP restored valley/foothill riparian and patches of riparian forest and scrub present on BDCP preserved lands over the term of the BDCP.

> **Objective VRNC2.2**: Establish seasonal buffers around riparian habitats occupied by covered species to minimize disturbance during the breeding season.

Objective VRNC2.3: Restore connectivity of valley/foothill riparian corridors along linear watercourses to enhance habitat for covered species and facilitate wildlife movement.

Rationale and Conservation Approach

The primary stressor on the yellow-billed cuckoo is the loss and fragmentation of its riparian habitat through urban and agricultural expansion, bank stabilization, and flood control projects; therefore, the restoration of this habitat type is considered to be the most effective approach to its conservation. In the Plan Area, the conservation of western yellow-billed cuckoo will be provided through the restoration of 5,000 acres of valley/foothill riparian habitat (Table 3-5) (Figure 3-25). The western yellow-billed cuckoo has been sighted several times migrating through the Plan Area, but there have been no recently confirmed nesting records in the Plan Area or vicinity. Since most riparian corridors in the Plan Area do not support sufficiently large riparian patches for cuckoo breeding, conservation will be directed towards restoring riparian forest within the Plan Area to provide habitat that could allow for the future reintroduction or expansion of the existing yellow-billed cuckoo population into the Plan Area. Approaches for restoring valley/foothill riparian that supports western yellow-billed cuckoo habitat are described in the conservation approaches for conserving the valley/foothill riparian natural community.

Western yellow-billed cuckoo nesting habitat is located in expansive stands of riparian cottonwood-willow forests, but other species such as alder (*Alnus rhombifolia*) and box elder (*Acer negundo*) may be an important habitat element in some areas (see Appendix A, *Covered Species Accounts*). Patches of this habitat are expected to be restored as a component of BDCP actions to restore 5,000 acres of valley/foothill riparian. The large amount of valley/foothill riparian that will be restored as a result of the BDCP is expected to significantly advance conservation for the western yellow-billed cuckoo. These restoration actions could increase the likelihood for the western yellow-billed cuckoo to continue to migrate through and potentially re-initiate breeding in the Plan Area.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM7 Riparian Habitat Restoration
- CM11 Natural Communities Enhancement and Management

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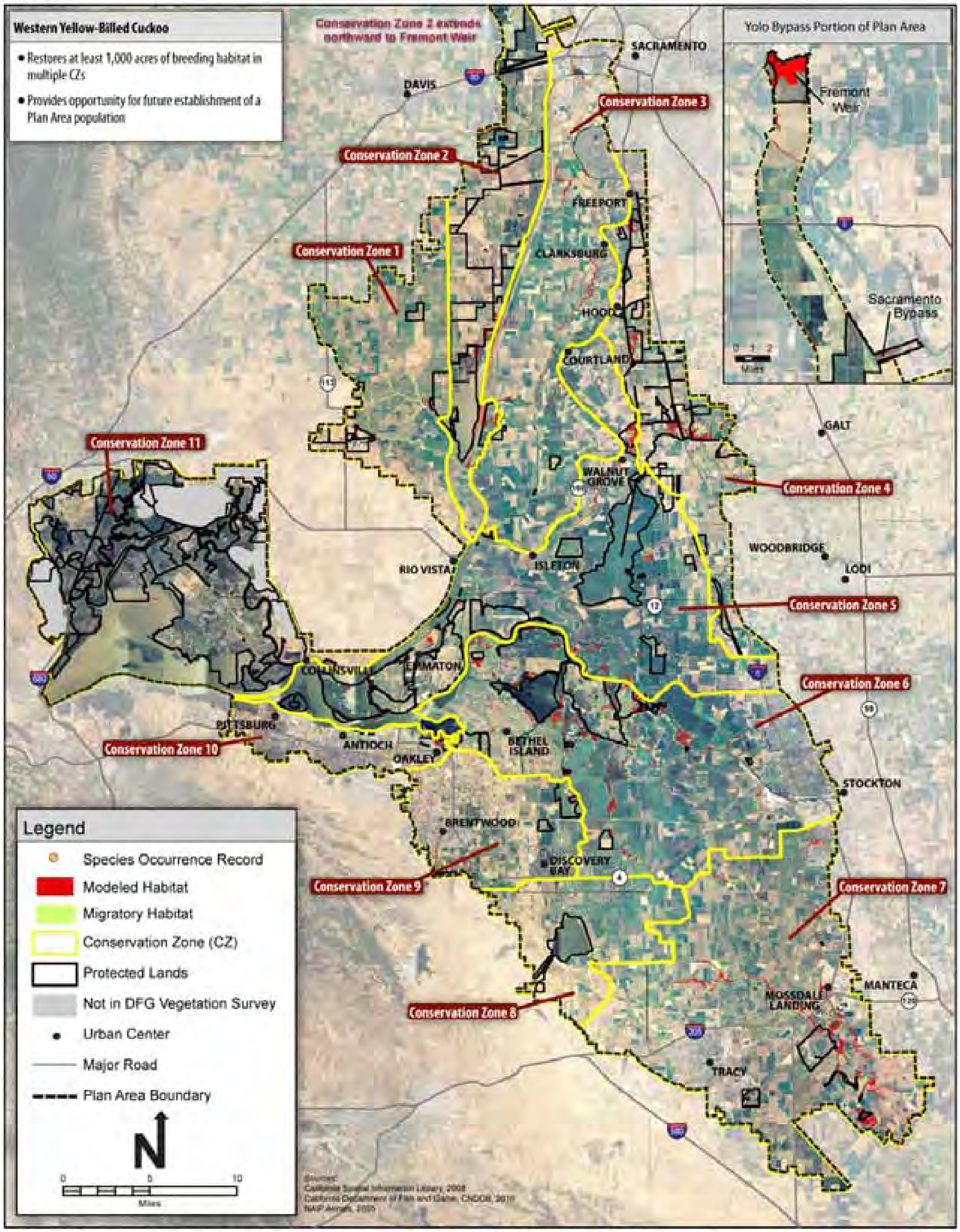

Figure 3-25. Western Yellow-Billed Cuckoo Habitat Distribution and Conservation Strategy

3.3.2.4.13 California Least Tern

California least tern is a migratory species present in California only during the breeding season; arriving in mid-April and departing in late September (Massey 1974, Cogswell 1977, Anderson and Rigney 1980, Patton 2002). Habitat loss is the primary reason for the population declines of California terns from historical levels (USFWS 2006). Since federal and state listing of the California least tern, nesting populations have increased dramatically from only a few pairs in the late 1960s to approximately 7,000 pairs at present (Marschalek 2009). However, the population size and distribution of the least California tern remains limited by the lack of natural nesting habitat (USFWS 2006). Two known breeding occurrences within the Plan Area are both on artificial substrates and virtually no natural breeding habitat exists within the Plan Area.

Applicable Natural Community Goals and Objectives

Goal TANC1: The expected outcome is tidal perennial aquatic natural community that supports habitats for covered and other native species and that supports aquatic food web processes.

> **Objective TANC1.1**: Restore or create 10,000 to 20,000 acres of tidal perennial aquatic in the BDCP Restoration Opportunity Areas (Conservation Zones 1, 2, 4, 5, 6, 7, and 11) that supports aquatic food production and habitat for covered and other native species.

Goal TANC2: The expected outcome is biologically diverse tidal perennial aquatic natural community that is enhanced for native species and sustained by natural ecological processes.

> **Objective TANC2.1:** Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal perennial aquatic community for covered and other native species over the term of the BDCP.

Species-Specific Goals and Objectives

Goal CALT1: The expected outcome is an expanded California least tern population in the Plan Area.

> **Objective CALT1.1:** Create two patches of California least tern nesting habitat during restoration of tidal marsh communities.

Rationale and Conservation Approach

BDCP conservation of California least tern is directed at expanding high value foraging habitat and protecting and creating future nesting sites in the Plan Area (Figure 3-26). Currently, there are only two nesting sites associated with the Plan Area, one at the Montezuma Wetlands and one in the City of Pittsburg (see Appendix A, *Covered Species Accounts*). Neither site consists of natural nesting habitat. Overall, there is little to no natural nesting habitat available in the Plan Area. While much of the tidal perennial aquatic habitat (open water) is suitable for tern foraging, nesting habitat is a function of the availability and suitability of artificial features, such as gravel piles or unused gravel roads in the immediately vicinity of open water habitats. Because of its rarity throughout its range and particularly within the Plan Area, protection and creation of least tern nesting habitat will aid in the expansion of this species' distribution and contribute to its recovery. Tidal habitat restoration in the ROAs is projected to result in the development of 24,913 to 31,622 acres[27] of subtidal aquatic habitat based on the hypothetical restoration designs (exceeding the objective of 10,000 to 20,000 acres), much of which will be suitable as least tern foraging habitat.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM11 Natural Communities Enhancement and Management

[27] Restored tidal habitat acreage ranges are a component of the 65,000 acre target for restored tidal habitat. Acreage ranges are based on the results of hydrodynamic modeling of realistic hypothetical restoration designs. While these ranges are not the acreage targets for restored tidal habitats, but rather the results of modeling, the hypothetical designs provided verification of the practicability of achieving restoration targets.

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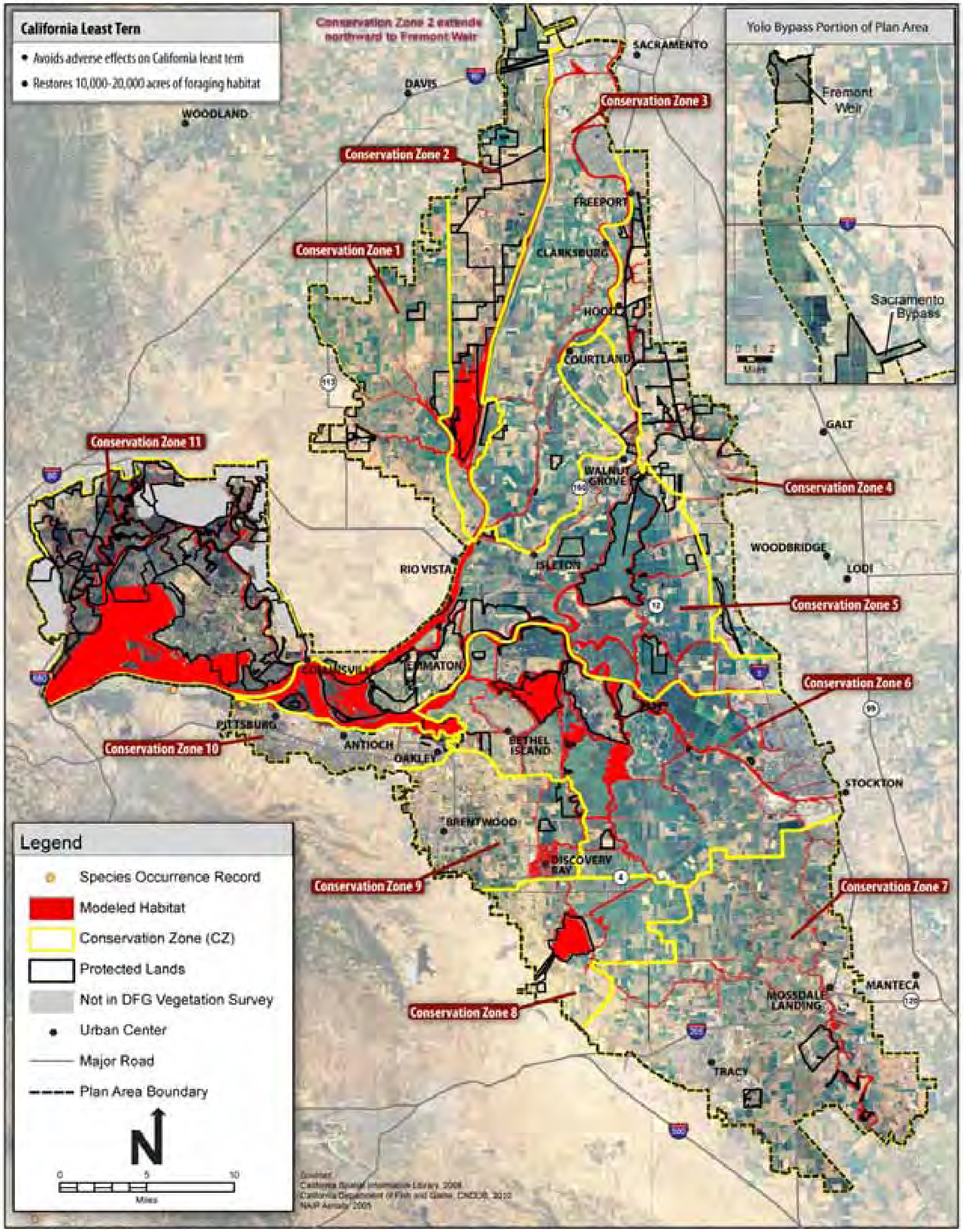

Figure 3-26. California Least Tern Habitat Distribution and Conservation Strategy

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3.3.2.4.14 Greater Sandhill Crane

There are an estimated 500,000 sandhill cranes in North America, of which an estimated 62,600 are greater sandhill cranes. An estimated 8,500 of these belong to the Central Valley Population (Littlefield and Ivey 2000). Greater sandhill cranes are winter residents in the Plan Area, where they depend on certain types of agricultural fields (e.g., corn stubble fields) and on grasslands and managed wetlands for foraging; field edges, levees, rice-checks, ditches, alfalfa fields, and pastures for loafing; and inundated fields and wetlands for roosting (Appendix A, *Covered Species Accounts*).

The most significant threat to wintering greater sandhill cranes is the loss of traditional winter habitat from urbanization and agricultural conversion (Littlefield and Ivey 2000). While relatively limited urbanization has occurred to date within key crane areas, surrounding development and increased levels of human disturbances may threaten the long-term sustainability of important wintering lands. In the Delta region, the conversion of suitable agricultural foraging and roosting habitats to unsuitable cover types, particularly orchards and vineyards, has removed key habitats and altered the distribution and behavior of wintering greater sandhill cranes.

Applicable Natural Community Goals and Objectives

Goal ALNC1: The expected outcome is increased habitat functions for covered and other native species that are supported by agricultural land cover types and management practices.

> **Objective ALNC1.2**: Maintain and protect the functions of 12,020 to 28,040 acres of non-rice agricultural lands as foraging habitat for Swainson’s hawk, white-tailed kite, and tricolored blackbird that are located within 8 miles of occupied Swainson’s hawk nesting habitat.

> **Objective ALNC1.4**: Of the maintained 12,020 to 28,040 acres of non-rice agricultural lands, maintain at least 4,800 acres that supports greater sandhill crane foraging habitat within its Winter Use Area and within 2 miles of known roosting sites in Conservation Zones 3, 4, 5, and/or 6.

Goal MWNC2: The expected outcome is biologically diverse managed wetlands that are enhanced for native species.

> **Objective MWNC2.1**: Maintain and enhance the habitat functions of BDCP managed wetlands present on BDCP preserved lands over the term of the BDCP.

Goal FMNC1: The expected outcome is restored large, interconnected patches of tidal freshwater emergent wetland natural community.

> **Objective FMNC1.1:** Restore or create 13,900 to 21,600 acres of tidal freshwater emergent wetland in the Cache Slough, West Delta, Cosumnes-Mokelumne, and South Delta ROAs (Conservation Zones 1, 2, 4, 5, 6, and 7).

Goal FMNC2: The expected outcome is biologically diverse tidal freshwater emergent wetland that is enhanced for native species and sustained by natural ecological processes.

> **Objective FMNC2.1:** Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal freshwater emergent wetlands for covered and other native species over the term of the BDCP.

Species-Specific Goals and Objectives

Goal GSHC1: The expected outcome is expansion and protection of greater sandhill crane winter range.

> **Objective GSHC1.1**: Create 320 acres of seasonally managed greater sandhill crane roosting habitat within Conservation Zones 3, 4, 5, or 6.

Rationale and Conservation Approach

Conservation of greater sandhill crane proposed under BDCP is directed at preserving and restoring wintering habitat sufficient to sustain current wintering population numbers and provide for any future growth of the population. In particular, at least 4,800 acres of protected high functioning foraging habitat will be located within the winter use area.

Protected foraging habitat will primarily be comprised of agricultural habitats with high crane foraging value (e.g., corn, grains, irrigated pasture, alfalfa), but may include grassland and managed wetlands. Protected lands will be managed to provide high-quality foraging habitat and to minimize human disturbances during the crane's wintering period. A total of at least 4,800 acres of high value foraging habitat will be preserved and protected in Conservation Zones 3, 4, 5 and/or 6 (Figure 3-27). Preserved foraging habitat patches will be at least 160 acres in size (or less if adjacent to other protected habitat) to minimize the potential effects of human-associated visual and noise disturbances adjacent to preserved foraging habitat. The majority of foraging habitat within the winter use area is located below sea level and potentially subject to future loss with levee failures. As part of the conservation strategy, the BDCP Implementation Office will therefore consider opportunities for acquisition of lands at elevations above sea level.

In addition, the conversion from agricultural lands with uncertain or variable suitability (due to crop rotations or that are subject to conversion to unsuitable perennial crops such as orchards and vineyards) to tidal freshwater wetlands is expected to increase the habitat value of the restored lands. Restored tidal freshwater wetlands within the crane's primary use area (2,100 acres in

Conservation Zone 4) will include shallow water habitats, berms, and grassland edges and may provide suitable roosting and foraging habitat for greater sandhill cranes. Additional restored tidal freshwater wetlands south of the crane's primary use area (5,000 acres in Conservation Zone 7) is expected to provide suitable roosting, resting, and foraging habitat that may facilitate expansion of the wintering range.

Additional agricultural land preserved for other covered species including Swainson's hawk and white-tailed kite (primarily alfalfa and irrigated pasture cover types) within the crane use area will also be available to wintering greater sandhill cranes. Following implementation of BDCP actions, more than 19 percent of greater sandhill crane foraging habitat will be protected (Table 3-5). Protection and management of existing foraging habitats and restoration and management of roost sites are expected to ensure that the existing abundance of wintering cranes in the Plan Area is maintained and are expected to provide sufficient wintering habitat to accommodate potential future expansions of the crane population.

Greater sandhill crane winter roosting habitats are limited within the Plan Area and roosting cranes are intolerant of disturbances and readily will abandon roosts if disturbed. Lack of permanent roosting habitat limits the ability of cranes to use foraging habitats. To address this species' requirement, 320 acres of land will be managed specifically to meet the ecological requirements of greater sandhill crane roosting habitat will be created to ensure the future availability of sufficient winter roosting habitat. Roost sites will be at least 80 acres in size (or less if adjacent to other existing roosting habitat or otherwise meet criteria for roosting and are considered to have exceptionally high value) and will be located within the Delta winter range of the species, but with consideration of the potential for sea level rise. Roost sites will be located in areas that are not subject to disturbances and will be designed to minimize predator accessibility. Location of roost sites will also consider opportunities for expanding the range of the species by placing roosts within suitable, but underused foraging habitats due to the lack of roost sites.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM11 Natural Communities Enhancement and Management

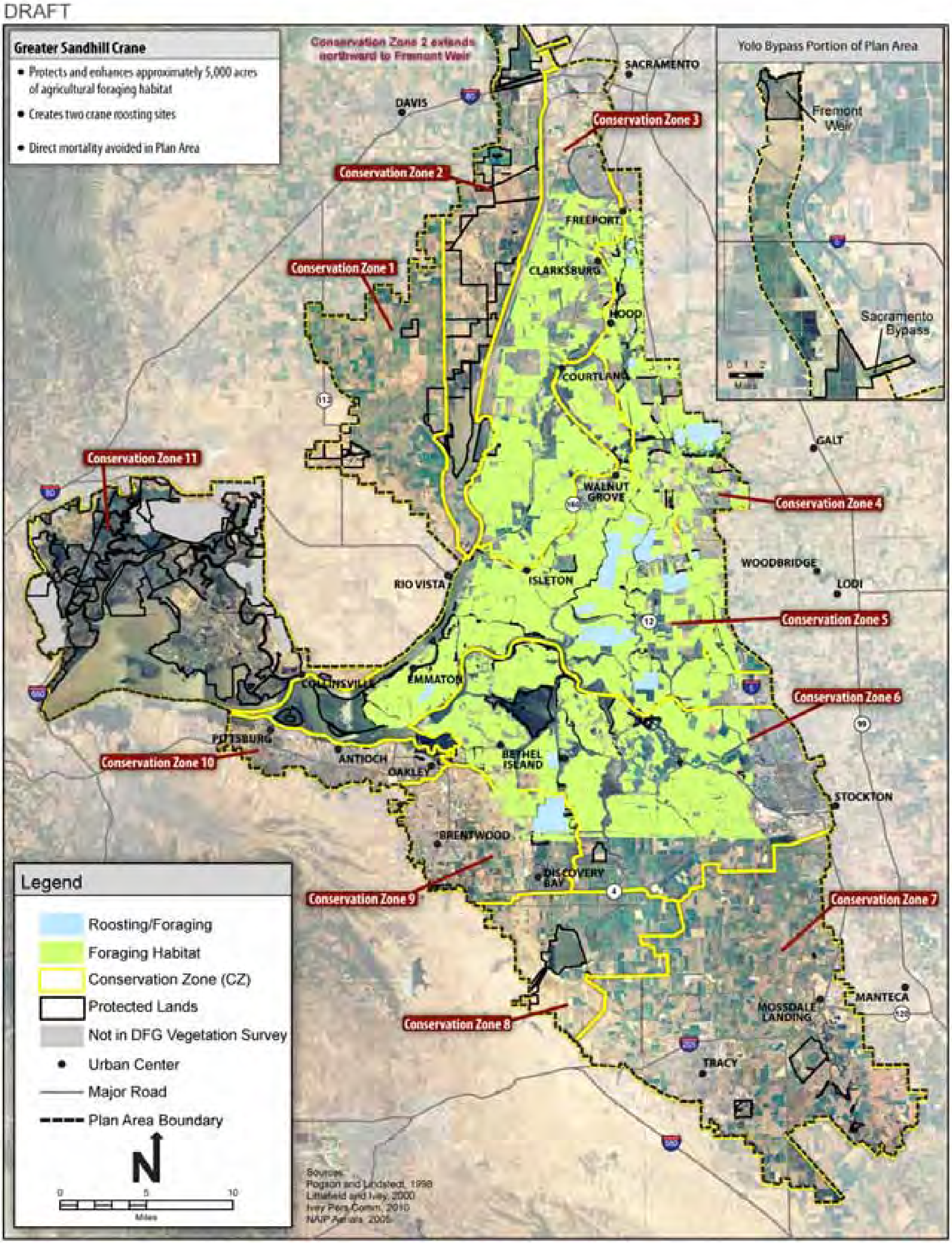

Figure 3-27. Greater Sandhill Crane Habitat Distribution and Conservation Strategy

3.3.2.4.15 California Black Rail

California black rail inhabits tidal saltwater, tidal brackish, and tidal freshwater marshes (Grinnell and Miller 1944, Manolis 1978, Spautz et al. 2005). Declines in populations of the California black rail in California and the extirpation of the rail from much of its historical coastal range are the result of tidal marsh habitat loss and degradation along with an increase in exotic predators such as black rats and red foxes (Manolis 1978, Garrett and Dunn 1981 as cited in DWR 2001, Evens et al. 1991). Currently, the species is confined to mostly pristine remnants of historical tidal marshlands, including throughout parts of Suisun Bay, which serves as one of the last large refuge areas for a viable population (Evens et al. 1991, Spautz et al. 2005). The proposed restoration of California black rail habitat in the Plan Area is consistent with and helps achieve the California black rail objectives of the draft tidal marsh ecosystems recovery plan (USFWS 2010) and objectives of the Suisun Marsh Restoration Plan (under development). Black rails also occur in lower densities in the patches of tidal freshwater marsh found along the margins of waterways in the Central Delta.

Applicable Natural Community Goals and Objectives

Goal BMNC1: The expected outcome is restored large expanses and interconnected patches of tidal brackish emergent wetland natural community.

> **Objective BMNC1.1:** Restore or create 3,600 to 4,800 acres of tidal brackish emergent wetland in the Suisun Marsh ROA (Conservation Zone 11).

Goal BMNC2: The expected outcome is biologically diverse tidal brackish emergent wetland that is enhanced for native species and sustained by natural ecological processes.

> **Objective BMNC2.1:** Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal brackish emergent wetland for covered and other native species over the term of the BDCP.

Goal FMNC1: The expected outcome is restored large, interconnected patches of tidal freshwater emergent wetland natural community.

> **Objective FMNC1.1:** Restore or create 13,900 to 21,600 acres of tidal freshwater emergent wetland in the Cache Slough, West Delta, Cosumnes-Mokelumne, and South Delta ROAs (Conservation Zones 1, 2, 4, 5, 6, and 7).

Goal FMNC2: The expected outcome is biologically diverse tidal freshwater emergent wetland that is enhanced for native species and sustained by natural ecological processes.

> **Objective FMNC2.1:** Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal freshwater emergent wetlands for covered and other native species over the term of the BDCP.

Rationale and Conservation Approach

Under BDCP, the conservation of the California black rail is directed at restoring tidal marsh conditions that historically supported habitat in the Plan Area (Figure 3-28). Outside of Suisun Marsh, existing habitat is limited primarily to small and isolated remnant patches of tidal emergent wetland vegetation along Delta channels. Because opportunities for conserving species habitats along existing tidal channels are limited by levees, conservation will be provided through the restoration of large tracts of brackish and freshwater tidal emergent wetland throughout Suisun Marsh and elsewhere in the Plan Area where such restoration is practicable. A total of between 17,500 and 26,400 acres of tidal emergent wetland (freshwater and brackish) will be restored in Conservation Zones 1, 2, 4, 5, 6, 7, and 11. Restored tidal brackish emergent wetland and tidal freshwater emergent wetland will be designed to the extent practicable within site constraints to provide the full range of environmental gradients from tidal areas to uplands that existed under historical conditions in Suisun Bay and the Delta. This approach is expected to result in restoration of patches of rail habitat within a mosaic of larger marsh plain habitats. Approaches for restoring habitat to support California black rail habitat are described in the conservation approaches for conserving the tidal brackish emergent wetland and the tidal freshwater emergent wetland natural communities.

In Suisun Marsh, tidal emergent wetland will be restored in a sequenced manner that minimizes the disturbance of existing habitats between the initiation of restoration actions and the point at which restored tidal emergent wetland develops as California black rail habitat. Direct removal of existing tidal brackish emergent wetland will be minimized consistent with achieving overall wetland restoration objectives, although some tidal brackish emergent wetland is expected to be desiccated or inundated as a result of changes in the existing tidal range following the breaching of dikes and levees. It is anticipated that following completion of all tidal habitat restoration in Suisun Marsh, tidal brackish emergent wetland will be restored in larger patches than the existing patches of habitat that are currently fragmented by dikes, roads, unsuitable habitat areas, and other infrastructure. These larger unfragmented patches are expected to provide higher-value habitat and facilitate population expansion and growth of California black rail populations in Suisun Marsh.

Restoration of tidal freshwater emergent wetland in the Delta will occur primarily on existing agricultural land and is expected to expand the range of suitable California black rail habitat. Nonnative predators (e.g., feral cats) are believed to be an important stressor on the California black rail. The design and management of restored habitat will include control of nonnative predators to help maintain the species abundance (e.g., through direct removal of predators or through design of restored habitats that minimize access of predators into occupied habitats).

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM4 Tidal Habitat Restoration
- CM10 Nontidal Marsh Restoration
- CM11 Natural Communities Enhancement and Management

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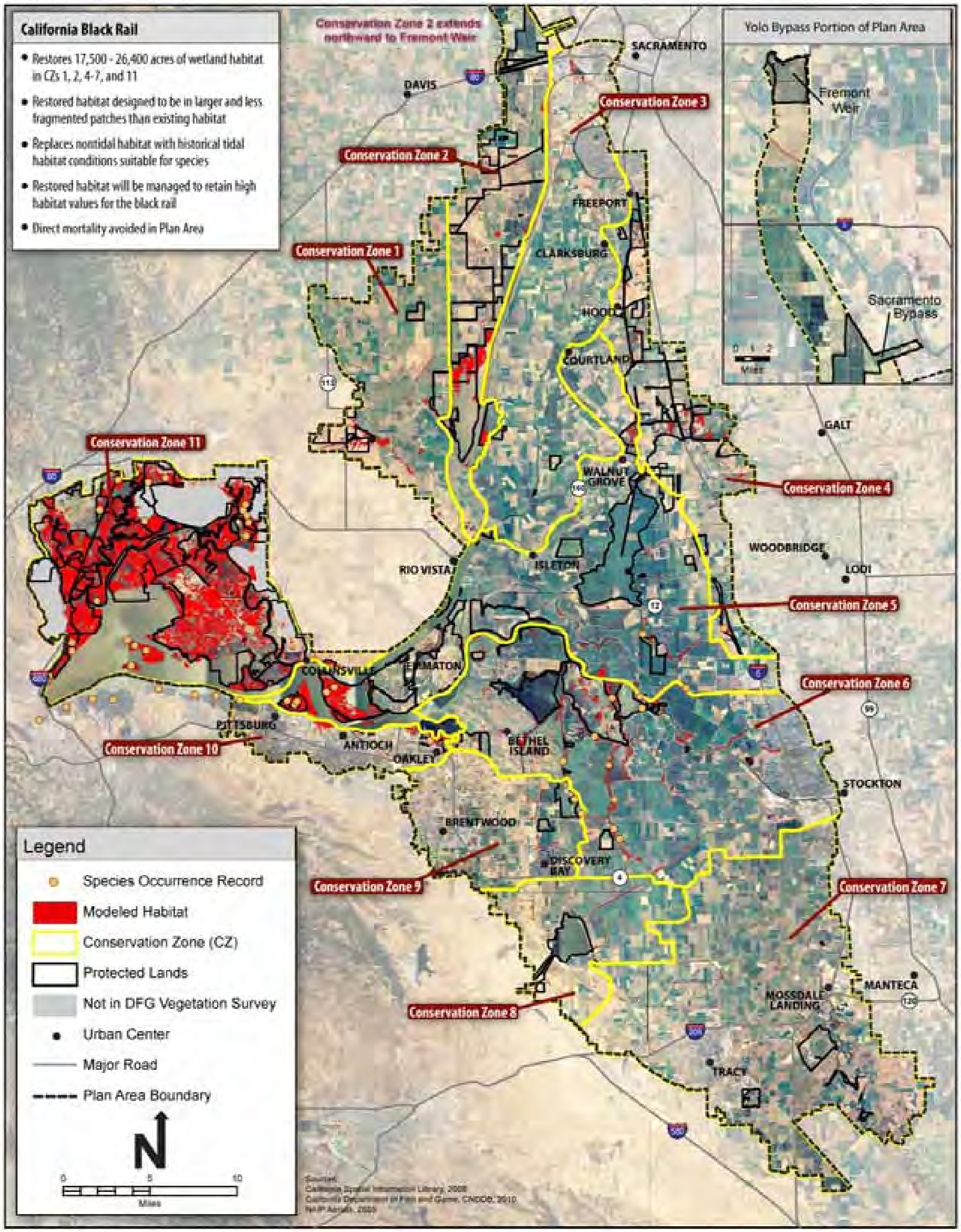

Figure 3-28. California Black Rail Habitat Distribution and Conservation Strategy

3.3.2.4.16 California Clapper Rail

The California clapper rail is a year-round resident of tidal salt and brackish marshes (Albertson 1995 as cited in LSA 2007, USFWS 1998c), occurring in higher population densities where habitat exceeds 100 ha (247 acres) in size (LSA 2007). Its current range is limited to the San Francisco Bay (extending to Suisun Bay), but the California clapper rail once ranged over much of coastal northern California (DWR 1994, USFWS 1998c, LSA 2007). The main significant threat to the California clapper rail continues to be the degradation of its tidal marsh habitat (Williams 1985, Ohlendorf and Fleming 1988, Ohlendorf et al. 1989, Harvey 1990, Lonzarich et al. 1990, Foerster and Takekawa 1991, Leipsic-Baron 1992, DFG 2000 as cited in LSA 2007). Tidal marsh habitat has been reduced by up to 84 percent in the San Francisco Bay since the mid-1800s (Dedrick 1989).

Applicable Natural Community Goals and Objectives

Goal BMNC1: The expected outcome is restored large expanses and interconnected patches of tidal brackish emergent wetland natural community.

> **Objective BMNC1.1:** Restore or create 3,600 to 4,800 acres of tidal brackish emergent wetland in the Suisun Marsh ROA (Conservation Zone 11).

Goal BMNC2: The expected outcome is biologically diverse tidal brackish emergent wetland that is enhanced for native species and sustained by natural ecological processes.

> **Objective BMNC2.1:** Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal brackish emergent wetland for covered and other native species over the term of the BDCP.

Rationale and Conservation Approach

The primary focus of the Recovery Plan for the California clapper rail (USFWS 1984b) is to restore and enhance tidal marsh habitat as a means to increase population numbers and expand the distribution of the rail. BDCP implementation will tie in with existing conservation and enhancement efforts for Suisun Marsh, where more extensive patches of suitable habitat should support larger rail numbers.

The tidal brackish emergent wetland habitat of the California clapper rail is primarily in Suisun Marsh, which is encompassed by Conservation Zone 11. A small portion of the western edge of Conservation Zone 5 (western edge of Sherman Island) is also considered potential habitat for California clapper rail, although no occurrences have been documented there (Appendix A, *Covered Species Accounts*). Conservation will be directed towards restoring tidal brackish emergent wetland in Conservation Zone 11 such that of 3,600 to 4,800 acres[28] of restored tidal

[28] Restored tidal habitat acreage ranges are a component of the 65,000 acre target for restored tidal habitat. Acreage ranges are based on the results of hydrodynamic modeling of realistic hypothetical restoration designs. While these ranges are not the acreage targets for restored tidal habitats, but rather the results of modeling, the hypothetical designs provided verification of the practicability of achieving restoration targets.

habitat will serve as California clapper rail habitat based on the analysis of the hypothetical restoration design (Figure 3-29). Tidal habitat restoration that will be implemented in the West Delta ROA (see Conservation Measure CM4, Tidal Habitat Restoration), may also support California clapper rail in future years with sea level rise if salinity increases in the west Delta such that freshwater tidal habitats convert to brackish tidal habitat.

Because restoration of tidal habitat will remove and degrade patches of tidal brackish emergent wetland that are currently occupied by California clapper rail, restoration will be sequenced and located in a manner that minimizes any initial, temporary loss of habitat. Approaches for restoring tidal habitat to support California clapper rail habitat are described in Conservation Measure CM4 Tidal Habitat Restoration. Restored tidal habitats will be designed to the extent practicable within site constraints to provide the full range of environmental gradients from tidal areas to uplands that existed under historical conditions in Suisun Bay. This approach is expected to result in the restoration of patches of California clapper rail habitat within a mosaic of tidal emergent wetland. It is anticipated that following completion of all tidal habitat restoration in Suisun Marsh, tidal emergent wetland will be restored in larger patches than the existing patches of habitat that are currently fragmented by dikes, roads, unsuitable habitat areas, and other infrastructure. These larger unfragmented patches are expected to provide higher ecological value that will facilitate the expansion and growth of California clapper rail populations in the Suisun Marsh. The transitional upland component of restored tidal habitats will be designed to provide flood refugia habitat during high water events.

Nonnative predators (e.g., feral cats) are believed to be an important stressor on the California clapper rail. The design and management of restored habitat will include control of nonnative predators to help maintain the species abundance (e.g., through design of restored habitats that minimize access of predators to occupied habitats and/or through direct removal of predators or). Restored habitat will also be monitored to assess the status of the species and will be adaptively managed to ensure high habitat function for the clapper rail is maintained over time. The proposed restoration of tidal habitat in Suisun Marsh is consistent with and helps achieve the California clapper rail objectives of the draft tidal marsh ecosystems recovery plan (USFWS 2010) and objectives of the Suisun Marsh Restoration Plan (under development).

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM4 Tidal Habitat Restoration
- CM10 Nontidal Marsh Restoration
- CM11 Natural Communities Enhancement and Management

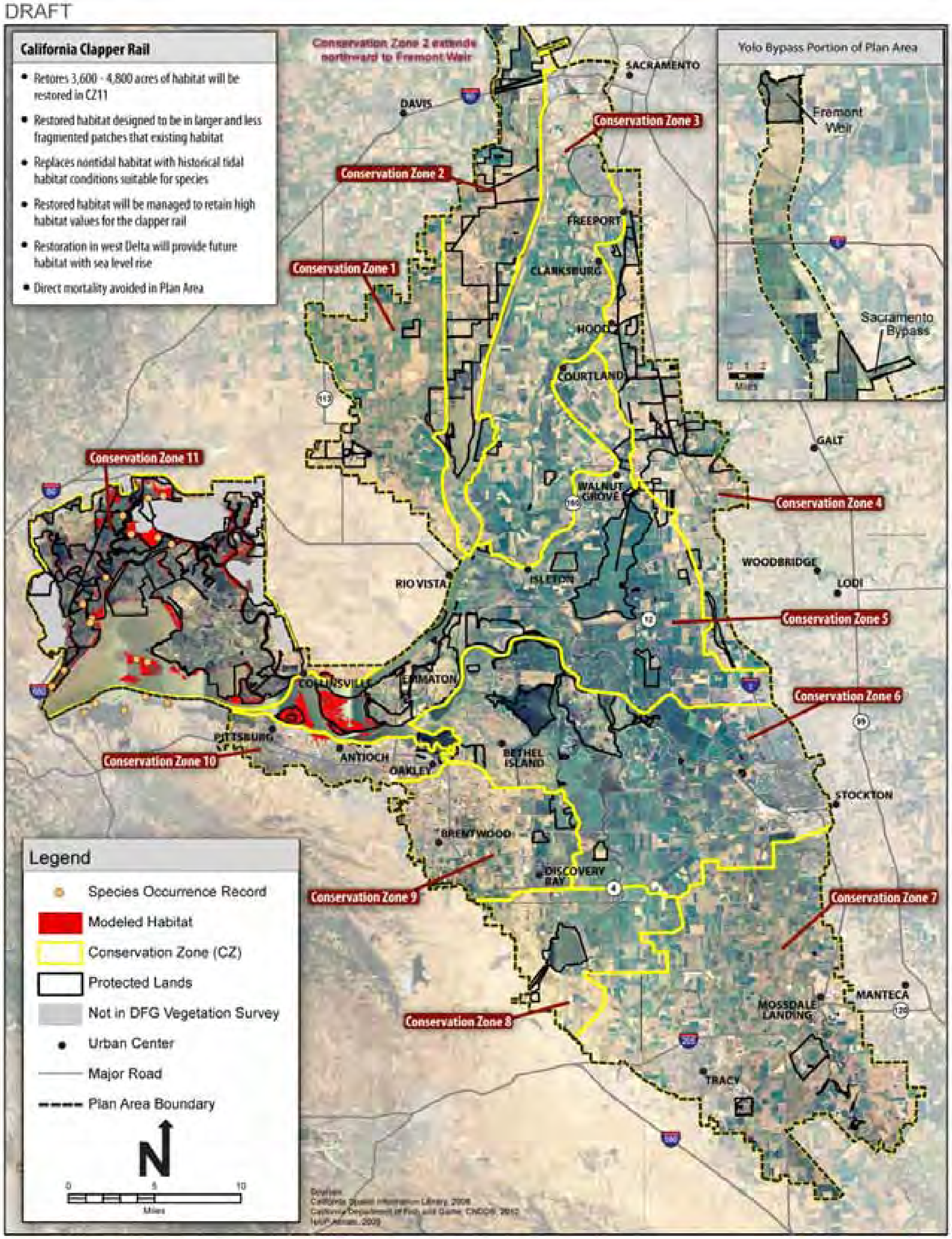

Figure 3-29. California Clapper Rail Habitat Distribution and Conservation Strategy

3.3.2.4.17 Swainson's Hawk

Nesting Swainson's hawks are widely distributed throughout the Plan Area and surrounding lands (Figure 3-30). Of the 314 nesting records since 2000, at least 220 of these are considered independent and are potentially active in any given year. They hunt primarily for rodent prey in agricultural and grassland habitats, and they nest in trees, mainly along stringers of remnant riparian forest along drainages (Estep 1984, Schlorff and Bloom 1984, England et al. 1997) as well as in isolated trees, tree rows, and other nesting habitats. Swainson's hawk population declines in California are thought to be the result of the loss of nesting and foraging habitat due to urban development and conversion to unsuitable agriculture, such as orchards and vineyards (Schlorff and Bloom 1984, England et al. 1995, 1997). Within the Bay/Delta region, high densities of nesting Swainson's hawk nesting pairs have been reported from remnant habitat patches, indicating the potential for large-scale riparian restoration to be of substantial benefit to the species (Estep 1989, 2008).

Applicable Natural Community Goals and Objectives

Goal VRNC1: The expected outcome is restored large expanses and interconnected corridors of valley/foothill riparian natural community.

> **Objective VRNC1.1**: Restore or create 5,000 acres of valley/foothill riparian in Conservation Zones 1, 2, 4, 5, 6, 7, and/or 11.

Goal VRNC2: The expected outcome is biologically diverse valley/foothill riparian natural community that supports native species and is sustained by natural ecological processes.

> **Objective VRNC2.1**: Maintain and enhance the habitat and ecosystem functions of BDCP restored valley/foothill riparian and patches of riparian forest and scrub present on BDCP preserved lands over the term of the BDCP.

> **Objective VRNC2.2**: Establish seasonal buffers around riparian habitats occupied by covered species to minimize disturbance during the breeding season.

> **Objective VRNC2.3**: Restore connectivity of valley/foothill riparian corridors along linear watercourses to enhance habitat for covered species and facilitate wildlife movement.

Goal GRNC1: The expected outcome is grassland comprised of large interconnected patches or contiguous expanses.

> **Objective GRNC1.1**: Protect a minimum of 8,000 acres of grassland in Conservation Zones 1, 8, and 11. At least 1,000 acres will be protected in Conservation Zone 8, with the remainder distributed throughout these three Conservation Zones.

Goal GRNC2: The expected outcome is biologically diverse grassland managed to enhance native species and sustained by natural ecological processes.

> **Objective GRNC2.5**: Increase prey, especially small mammals and insects, for grassland-foraging species.

Goal ALNC1: The expected outcome is increased habitat functions for covered and other native species that are supported by agricultural land cover types and management practices.

> **Objective ALNC1.2**: Maintain and protect the functions of 12,020 to 28,040 acres of non-rice agricultural lands as foraging habitat for Swainson's hawk, white-tailed kite, and tricolored blackbird that are located within 8 miles of occupied Swainson's hawk nesting habitat.

> **Objective ALNC1.8**: Maintain and protect the small patches of important wildlife habitats associated with agricultural lands that occur within BDCP conserved agricultural lands, including isolated valley oak trees, trees and shrubs along field borders and roadsides, remnant groves, riparian corridors, water conveyance channels, grasslands, and wetlands.

Rationale and Conservation Approach

The conservation of Swainson's hawk will be provided by restoring 5,000 acres of valley/foothill riparian nesting habitat, a substantial amount of which is expected to provide suitable nesting habitat for Swainson's hawk; and by preserving 20,020 to 36,040 acres of agricultural and grassland foraging habitat (Figure 3-30). These actions are expected to sustain the current local Swainson's hawk population and provide for any future increases in Swainson's hawk numbers in the Plan Area. Breeding densities are high in some areas, particularly the north, east, and south Delta, and less so in the Central Delta and south Yolo Bypass. Nesting occurs in riparian habitats as well as roadside trees, isolated trees, and groves where trees support appropriate height and structure (see Appendix A, *Covered Species Accounts*).

The majority of the land within the Plan Area supports Swainson's hawk foraging habitat; however, habitat value varies in agricultural habitats depending on annual and seasonal crop patterns and practices, which influences prey accessibility due to the growth and structure of vegetation, and prey abundance. Because of the dynamic nature of the agricultural landscape and the variability of crop patterns and conditions seasonally and annually, only a proportion of the agricultural landscape is suitable or available for foraging in any given season or year. To account for this variability and to more accurately represent the value of Plan Area-wide foraging habitat, acres of Swainson's hawk foraging habitat were converted to habitat units by placing different crop types and other foraging habitats that traditionally occur in the Plan Area into crop value classes and assigning relative values to those classes (See Species Model in Appendix A, *Covered Species Accounts*). This approach, used to calculate foraging habitat impacts to Swainson's hawk, will also be used to ensure that similar habitat value or better is consistently maintained on BDCP protected lands during the permit period.

The majority of protected foraging habitat will be located at elevations above sea level to ensure that foraging habitat is maintained for Swainson's hawks should potential future Delta levee failures result in large-scale inundation. It is anticipated that all of the restored riparian habitat will be located within flight distance to protected foraging habitat, thus increasing the functions of both types of habitat for the species. Furthermore, patches of nesting habitat located within lands protected for other purposes will also be maintained and all protected habitats supporting active nest sites will be managed to minimize human disturbances during the breeding season.

Protected grassland and agricultural lands will be managed to provide high value Swainson's hawk foraging habitat. Conservation will occur in cooperation and in conjunction with neighboring and overlapping HCP/NCCPs to ensure that conservation actions are implemented where they most benefit the regional Swainson's hawk population and where they are compatible with conservation of other agricultural and riparian-associated species. It is also expected that ongoing agricultural land uses within and adjacent to the Plan Area will also continue to support foraging habitat for Swainson's hawks in the Plan Area.

An estimated 17 percent of Swainson's hawk foraging habitat within the Plan Area is currently protected on state and federal wildlife refuges, other state-owned lands, and mitigation banks and is expected to remain suitable Swainson's hawk foraging habitat. Following implementation of BDCP actions, between 22 and 26 percent of the total available foraging habitat will be preserved, and the extent of nesting habitat will be increased by approximately 28 percent. The proposed conservation is expected to sustain the existing population of Swainson's hawk and provide for future increases in its abundance and distribution within and adjacent to the Plan Area.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM7 Riparian Habitat Restoration
- CM8 Grassland Communities Restoration
- CM9 Vernal Pool Complex Restoration
- CM11 Natural Communities Enhancement and Management

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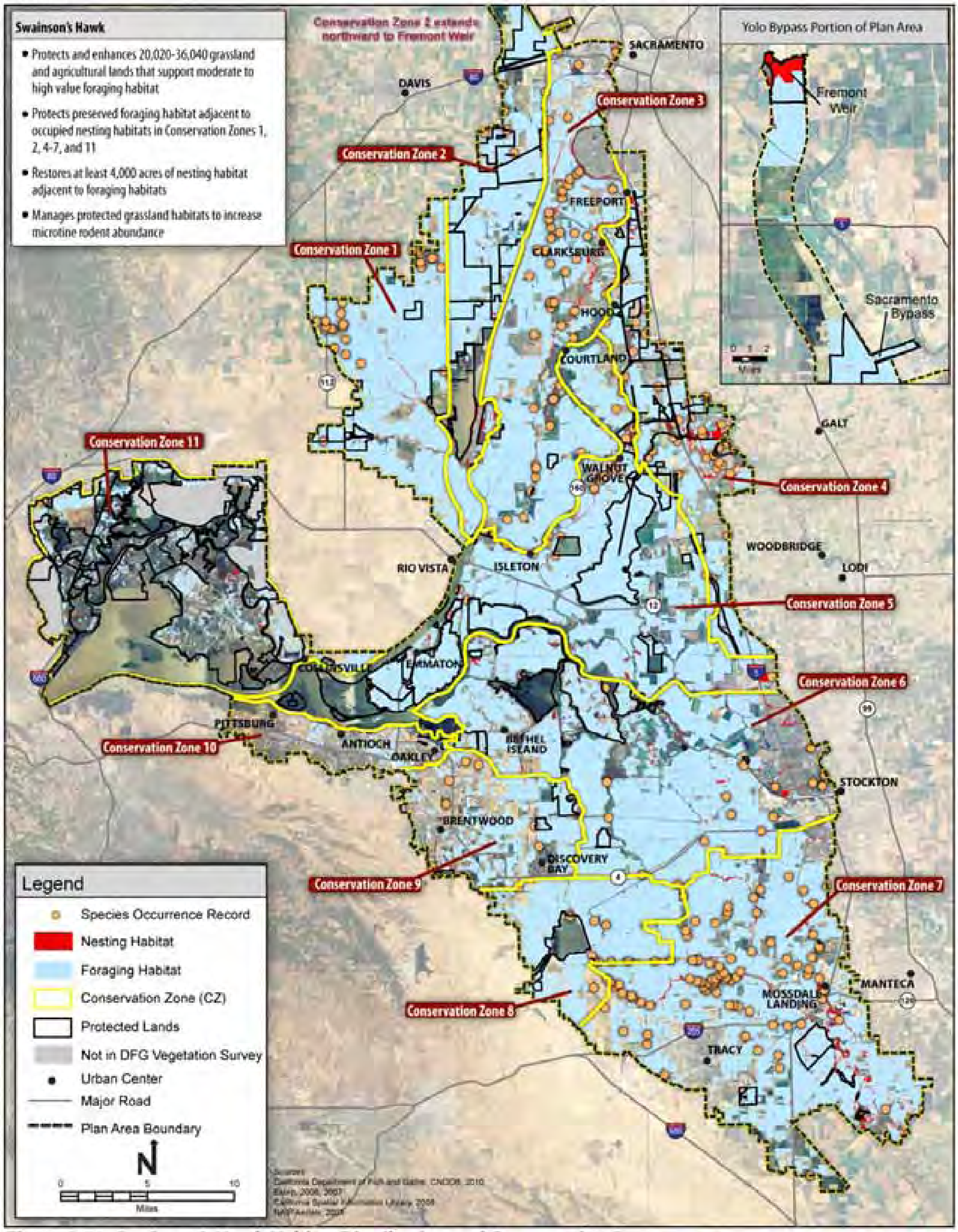

Figure 3-30. Swainson's Hawk Habitat Distribution and Conservation Strategy

3.3.2.4.18 White-Tailed Kite

The white-tailed kite inhabits or uses low elevation, open grasslands, savannah-like habitats, agricultural areas, wetlands, and oak woodlands (Dunk 1995). California is currently considered the stronghold of the white-tailed kite's breeding distribution in North America, with nearly all areas up to the western Sierra Nevada foothills and southeastern deserts occupied (Small 1994, Dunk 1995). It is an uncommon to common year-round resident in the Central Valley and other lowland valleys, and along the entire length of the coast (Dunk 1995). The white-tailed kite occurs year-round in the Plan Area, where it nests in trees, often in riparian areas, and forages in agricultural areas with accessible rodent prey populations (see Appendix A, *Covered Species Accounts*). It is designated as a state Fully Protected species pursuant to California Department of Fish and Game Code Section 3511.

Pronounced population declines and increases have been documented throughout the species' distribution in North America, in many cases the apparent result of changes in prey rodent densities caused by weather or anthropogenic habitat alteration (Ruth and Krueper 2010).

Applicable Natural Community Goals and Objectives

Goal VRNC1: The expected outcome is restored large expanses and interconnected corridors of valley/foothill riparian natural community.

> **Objective VRNC1.1**: Restore or create 5,000 acres of valley/foothill riparian in Conservation Zones 1, 2, 4, 5, 6, 7, and/or 11.

Goal VRNC2: The expected outcome is biologically diverse valley/foothill riparian natural community that supports native species and is sustained by natural ecological processes.

> **Objective VRNC2.1**: Maintain and enhance the habitat and ecosystem functions of BDCP restored valley/foothill riparian and patches of riparian forest and scrub present on BDCP preserved lands over the term of the BDCP.

> **Objective VRNC2.2**: Establish seasonal buffers around riparian habitats occupied by covered species to minimize disturbance during the breeding season.

> **Objective VRNC2.3**: Restore connectivity of valley/foothill riparian corridors along linear watercourses to enhance habitat for covered species and facilitate wildlife movement.

Goal GRNC1: The expected outcome is grassland comprised of large interconnected patches or contiguous expanses.

> **Objective GRNC1.1**: Protect a minimum of 8,000 acres of grassland in Conservation Zones 1, 8, and 11. At least 1,000 acres will be protected in Conservation Zone 8, with the remainder distributed throughout these three Conservation Zones.

Objective GRNC1.2: Restore 2,000 acres of grassland to connect fragmented patches of protected grassland.

Goal GRNC2: The expected outcome is biologically diverse grassland managed to enhance native species and sustained by natural ecological processes.

Objective GRNC2.5: Increase prey, especially small mammals and insects, for grassland-foraging species.

Goal ALNC1: The expected outcome is increased habitat functions for covered and other native species that are supported by agricultural land cover types and management practices.

Objective ALNC1.1: Maintain and protect the functions of 4,600 acres of rice lands as habitat for giant garter snake, western pond turtle, tricolored blackbird, white-tailed kite, waterfowl, and migrant shorebirds in Conservation Zone 2. This objective may be partially or fully achieved by maintaining an equivalent extent of natural or managed lands that support habitat functions similar to rice lands for associated covered and other native wildlife species.

Objective ALNC1.2: Maintain and protect the functions of 12,020 to 28,040 acres of non-rice agricultural lands as foraging habitat for Swainson's hawk, white-tailed kite, and tricolored blackbird that are located within 8 miles of occupied Swainson's hawk nesting habitat.

Objective ALNC1.8: Maintain and protect the small patches of important wildlife habitats associated with agricultural lands that occur within BDCP conserved agricultural lands, including isolated valley oak trees, trees and shrubs along field borders and roadsides, remnant groves, riparian corridors, water conveyance channels, grasslands, and wetlands.

Rationale and Conservation Approach

Habitat loss and fragmentation represent threats to the species in California (see Appendix A, *Covered Species Accounts*), and BDCP conservation of white-tailed kite is directed at maintaining a landscape of suitable nesting and foraging habitat across the Plan Area and adjacent lands. This goal is to be accomplished through strategic acquisition and management of between 22,000 and 40,000 acres of grassland and agricultural preserves (as foraging habitat) and through restoration of 5,000 acres of riparian habitat (Figure 3-31). The majority of protected foraging habitat will be located at elevations above sea level to ensure that foraging habitat is maintained for white-tailed kites should potential future Delta levee failures result in extensive, permanent inundation of the lowest-lying areas. It is anticipated that all of the restored valley/foothill riparian will be located within foraging flight distance to protected foraging habitat, thus increasing the value of both types of habitat for the species. Furthermore, patches of nesting habitat located within lands protected for other purposes will also be maintained and all protected habitats supporting active nest sites will be managed to minimize human disturbance during the breeding season.

Protected grasslands and agricultural lands will be managed to provide high value white-tailed kite foraging habitat. An estimated 21 percent of white-tailed kite foraging habitat within the Plan Area is currently protected on state and federal wildlife refuges, other state-owned lands, and mitigation banks and is expected to remain suitable white-tailed kite foraging habitat. Following implementation of BDCP actions, an estimated 26 to 31 percent of the total available foraging habitat will be protected, and the extent of nesting habitat will be increased by approximately 29 percent.

White-tailed kite conservation will occur in cooperation and in conjunction with neighboring and overlapping HCP/NCCPs to ensure that conservation actions occur where they most benefit the regional white-tailed kite population and where they are compatible with conservation of other agricultural and riparian-associated species. It is also expected that ongoing agricultural land uses within and adjacent to the Plan Area will continue to support foraging habitat for white-tailed kite nesting and wintering in the Plan Area. BDCP's proposed white-tailed kite conservation strategy is expected to sustain the existing population of white-tailed kites and provide for future increases in its abundance and distribution within and adjacent to the Plan Area.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM7 Riparian Habitat Restoration
- CM8 Grassland Communities Restoration
- CM9 Vernal Pool Complex Restoration
- CM11 Natural Communities Enhancement and Management

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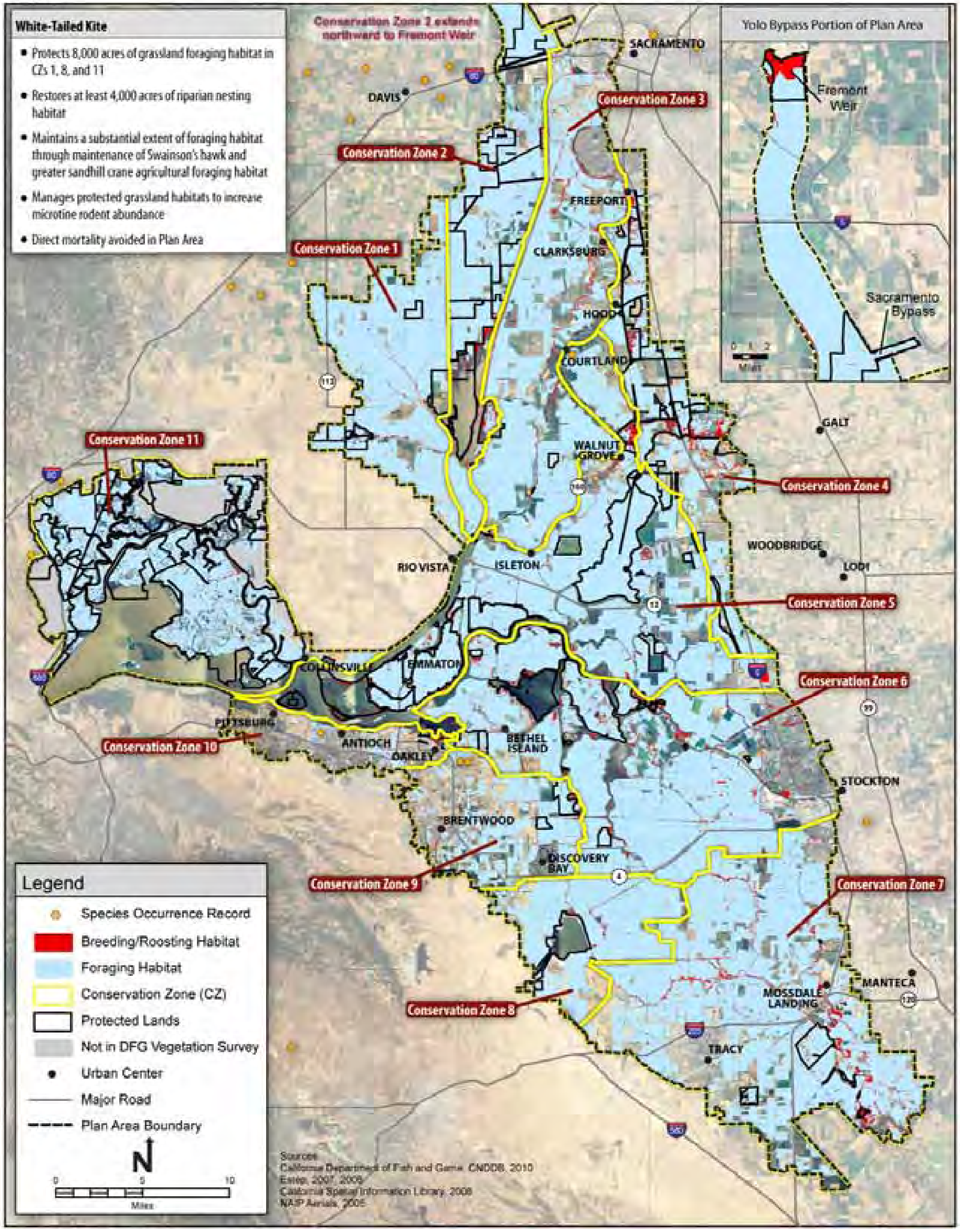

Figure 3-31. White-Tailed Kite Habitat Distribution and Conservation Strategy

3.3.2.4.19 Giant Garter Snake

The giant garter snake is endemic to wetlands in the Sacramento and San Joaquin valleys and was historically distributed throughout the San Joaquin Valley (Hansen and Brode 1980). The current distribution extends from near Chico in Butte County south to the Mendota Wildlife Area in Fresno County. The Plan Area is within the Mid-Valley Recovery Unit identified in the Draft Recovery Plan, and three of the thirteen giant garter snake populations identified by the USFWS occur within the Plan Area in Yolo Basin – Willow Slough, Yolo Basin – Liberty Farms, and Coldani Marsh – White Slough (USFWS 1999a).

Giant garter snakes utilize a wide variety of aquatic habitats including marshes, ponds, sloughs, small lakes, low gradient streams, and other waterways, including agricultural wetlands such as irrigation and drainage canals, rice fields, and the adjacent uplands. Important giant garter snake habitat elements include: adequate water during the snake's active season (early-spring through mid-fall) to provide food and cover, emergent herbaceous wetland vegetation accompanied by vegetated banks for escape cover and as foraging habitat during the active season, basking habitat of grassy banks and openings in waterside vegetation, and higher elevation uplands for cover and refuge from flood waters during the snake's dormant season in the winter. Home range size varies by location, with median home range estimates averaging 23 acres (range [10.3 to 203 ac], n = 8) (9 hectares, range = 4.2 to 82 ha) in a semi-native perennial marsh system and 131 acres (range [3.2 to 2,792 ac], n = 29) (53 hectares, range = 1.3 to 1130 ha) in a managed refuge (USFWS 1999a). Continued loss of wetland or other suitable habitat resulting from agricultural and urban development constitutes the greatest threat to this species' survival. Conversion of Central Valley wetlands for agriculture and urban uses has resulted in the loss of as much as 95 percent of historical habitat for the giant garter snake (Wylie et al. 1997).

Applicable Natural Community Goals and Objectives

Goal TANC1: The expected outcome is tidal perennial aquatic natural community that supports habitats for covered and other native species and that supports aquatic food web processes.

> **Objective TANC1.1**: Restore or create 10,000 to 20,000 acres of tidal perennial aquatic in the BDCP Restoration Opportunity Areas (Conservation Zones 1, 2, 4, 5, 7, and 11) that supports aquatic food production and habitat for covered and other native species.

Goal FMNC1: The expected outcome is restored large, interconnected patches of tidal freshwater emergent wetland natural community.

> **Objective FMNC1.1:** Restore or create 13,900 to 21,600 acres of tidal freshwater emergent wetland in the Cache Slough, West Delta, Cosumnes-Mokelumne, and South Delta ROAs (Conservation Zones 1, 2, 4, 5, 6, and 7).

Goal FMNC2: The expected outcome is biologically diverse tidal freshwater emergent wetland that is enhanced for native species and sustained by natural ecological processes.

Objective FMNC2.1: Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal freshwater emergent wetlands for covered and other native species over the term of the BDCP.

Goal NWNC1: The expected outcome is nontidal freshwater perennial emergent wetland natural community that supports habitat for covered and other native species.

Objective NWNC1.1: Create 400 acres of nontidal freshwater marsh (including components of nontidal perennial aquatic and perennial emergent wetland communities) that functions as habitat for the giant garter snake, tricolored blackbird, and western pond turtle within or adjacent to habitat occupied by the Caldoni Marsh/White Slough giant garter snake subpopulation in Conservation Zone 4 and the Yolo/Willow Slough giant garter snake subpopulation in Conservation Zone 2.

Goal NWNC2: The expected outcome is biologically diverse nontidal freshwater perennial emergent wetland communities that are enhanced for native species and sustained by ecological processes.

Objective NWNC2.1: Maintain and enhance the habitat functions of protected and created nontidal freshwater perennial emergent wetlands for covered and other native species over the term of the BDCP.

Goal NANC2: The expected outcome is biologically diverse nontidal perennial aquatic communities that are enhanced for native species and sustained by ecological processes.

Objective NANC2.1: Maintain and enhance the habitat functions of protected and created nontidal open water habitats for covered and other native species over the term of the BDCP.

Goal ALNC1: The expected outcome is increased habitat functions for covered and other native species that are supported by agricultural land cover types and management practices.

Objective ALNC1.1: Maintain and protect the functions of 4,600 acres of rice lands as habitat for giant garter snake, western pond turtle, tricolored blackbird, white-tailed kite, waterfowl, and migrant shorebirds in Conservation Zone 2. This objective may be partially or fully achieved by maintaining an equivalent extent of natural or managed lands that support habitat functions similar to rice lands for associated covered and other native wildlife species.

Objective ALNC1.2: Maintain and protect the functions of 12,020 to 28,040 acres of non-rice agricultural lands as foraging habitat for Swainson's hawk, white-tailed kite, and tricolored blackbird that are located within 8 miles of occupied Swainson's hawk nesting habitat.

Objective ALNC1.5: Of the maintained 12,020 to 28,040 acres of non-rice agricultural lands and 4,600 acres of rice lands, maintain and protect 1,000 acres within or adjacent to habitat occupied by the Yolo/Willow Slough giant garter snake subpopulation in Conservation Zone 2.

Objective ALNC1.6: Of the maintained 12,020 to 28,040 acres of non-rice agricultural lands, maintain and protect 1,000 acres within or adjacent to habitat occupied by the Caldoni Marsh/White Slough giant garter snake subpopulation in Conservation Zone 4.

Objective ALNC1.7: Target agricultural land conservation to provide connectivity between other protected lands.

Objective ALNC1.8: Maintain and protect the small patches of important wildlife habitats associated with agricultural lands that occur within BDCP conserved agricultural lands, including isolated valley oak trees, trees and shrubs along field borders and roadsides, remnant groves, riparian corridors, water conveyance channels, grasslands, and wetlands.

Species-Specific Goals and Objectives

Goal GGSN1: The expected outcome is high quality upland and aquatic habitat containing a mosaic of features provided for extant giant garter snake populations.

Objective GGSN1.1: Create functional landscapes on giant garter snake preserves that include a mosaic of restored freshwater marsh intermixed with protected agricultural lands and interconnected water conveyance canals and natural drainages.

Goal GGSN2: The expected outcome is protected giant garter snake corridors facilitating movement and linking populations.

Objective GGSN2.1: Establish connectivity between giant garter snake preserve lands, restored tidal wetlands, and protected agricultural lands in Conservation Zone 4 to facilitate movement into unoccupied portions of the Delta and with the Badger Creek subpopulation.

Objective GGNS2.2: Establish a giant garter snake north-south corridor that includes protected agricultural lands and restored tidal and nontidal wetlands between Coldani Marsh/White Slough and the Stone Lakes National Wildlife Refuge.

Rationale and Conservation Approach

Because the primary stressor on the giant garter snake is loss and fragmentation of its aquatic and terrestrial cover habitat through urban and agricultural expansion, the focus of this conservation strategy is to protect habitat, protect and restore connectivity, and enhance habitat function, key elements of the species' Recovery Plan (USFWS 1999a).

There are four components of giant garter snake conservation under BDCP (Figure 3-32):

- The establishment of agricultural land preserves that will include nontidal freshwater marsh restoration associated with two existing subpopulations in Conservation Zones 2 and 4;
- Protection of existing rice land values in Conservation Zone 2;
- Protection, connectivity, and management of non-rice agricultural habitats in the Plan Area; and
- Restoration of freshwater tidal marshes.

Protecting and expanding existing giant garter snake subpopulations is considered the most effective approach to conservation of this species in the Plan Area. The majority of the Plan Area is considered low value habitat for this species (Appendix A, *Covered Species Accounts*); however, extant subpopulations occur along the eastern edge of the Plan Area boundary in the vicinity of White Slough (Caldoni Marsh/White Slough subpopulation) and near the northwestern edge of the Plan Area in the vicinity of Willow Slough (Yolo/Willow Slough subpopulation).

The Caldoni Marsh/White Slough and Yolo/Willow Slough subpopulations support the highest densities of giant garter snakes in the Plan Area and habitat preservation, enhancement, and restoration actions for these populations are directed at securing habitats supporting these populations from potential threats (e.g., change in land uses), expanding and enhancing these habitat areas to allow for increases in their abundance and distribution, and to help to meet USFWS recovery goals for these designated subpopulations.

The Caldoni Marsh/White Slough subpopulation is centered within the White Slough Wildlife Area and is comprised of approximately 830 acres, of which approximately 50 acres represent core giant garter snake wetland habitat. The Yolo/Willow Slough subpopulation includes unprotected habitat areas and habitat preserved within the Yolo Wildlife Area.

The conservation strategy for these subpopulations includes creation of 400 acres of nontidal marsh that will be divided between two 1,000 acre agricultural preserves in each of these subpopulation areas to help ensure their continued existence. This additional restoration of nontidal marsh (comprised of a mix of nontidal perennial aquatic and nontidal permanent emergent communities) distributed between the two subpopulation habitat areas will substantially increase connectivity among existing occupied habitat areas and provide the basis for future expansion of their distribution and abundance.

Although dependent on the aquatic environment, the giant garter snake occurs within the agricultural landscape where it uses interconnected watercourses (primarily irrigation canals) and associated freshwater emergent wetland habitat and rice lands during the active season and adjacent uplands during the inactive season. Maintaining an agricultural matrix that includes suitable interconnected canals with reliable water, associated emergent vegetation and adjacent upland habitats is essential for conservation of this species. As these conservation areas are designed, agricultural parcels will be selected based on their proximity and connectivity to occupied sites and opportunities for restoration and enhancement. Restored marsh habitats will be created in appropriate patch sizes and within the existing agricultural matrix to maximize connectivity and the potential for expansion and dispersal. This approach is designed to protect the existing subpopulation centers and create opportunities for the expansion of these subpopulations.

Protected agricultural habitats will be managed to enhance habitat conditions for giant garter snake and to minimize potential adverse effects of agricultural operations on giant garter snake in occupied habitat areas (e.g., upland buffers adjacent to aquatic habitats; timing maintenance of agricultural ditches that support aquatic and movement habitat to periods the snake is not present). Protection and management of upland and agricultural habitat areas adjacent to core wetland habitats will also be aimed at preventing potential impacts associated with adjacent land uses. If site-specific planning to design the subpopulation preserves indicates that the extent of the proposed preservation is not necessary to sustain and expand these populations, some of the proposed preservation and restoration may be directed towards securing populations adjacent to the Plan Area (e.g., the Badger Creek population) consistent with achieving objectives of adjacent conservation plans.

In addition to the creation of the giant garter snake preserves, protection of other natural communities within the Plan Area will also benefit the giant garter snake. Lands protected for Swainson’s hawk and greater sandhill crane that occur within the range of the giant garter snake will provide additional protected landscape to support existing or future populations. These lands will include water conveyance systems, patches of freshwater marsh, and other aquatic habitats that will be managed to promote use by giant garter snake and other covered species. Protection of cultivated habitats in Zones 2 and 4 for Swainson’s hawk and greater sandhill crane conservation are expected to provide additional opportunities for enhancing north-south movement corridors for the Yolo/Willow Slough subpopulation within the Yolo Bypass and for the Caldoni Marsh/White Slough subpopulation between Stone Lakes National Wildlife Refuge and the Caldoni Marsh/White Slough area.

The restoration of freshwater tidal marsh habitat in the Plan Area is also expected to create or enhance habitat conditions for giant garter snake and provide potential for dispersal and expansion of populations. Restoration of 13,900-21,600 acres of tidal freshwater emergent wetland and portions of 10,000-20,000 acres of adjacent tidal aquatic habitat will provide opportunities for giant garter snake expansion into areas where they are currently absent (e.g., Conservation Zone 7). Restoration of tidal habitats, particularly in potentially occupied habitat areas in Conservation Zones 2 and 4 will increase the extent of suitable giant garter snake breeding and foraging habitat in locations with narrow tidal ranges. Restoration of tidal habitats in Conservation Zone 4 will also help in providing connectivity between the Caldoni Marsh/White Slough subpopulation and the Badger Creek subpopulation. Meeting the tidal marsh restoration objectives is expected to substantially increase aquatic and associated upland habitat for giant garter snake throughout the Plan Area.

Within the Yolo Bypass, preservation of the existing extent of rice lands that could be affected by proposed Fremont Weir operations or restoration of wetlands to replace any lost habitat functions of rice lands will sustain the abundance and distribution of snakes known to inhabit cultivated portions of the Bypass. Preservation of cultivated habitats will also preserve and enhance upland aestivation habitat for giant garter snake within its Primary Habitat Area.

Consistency with USFWS Draft Recovery Plan

Guidance in the USFWS draft giant garter snake recovery plan was used in the development of the giant garter snake conservation strategy. The following links recovery action priorities for the Southern Sacramento Valley recovery unit to individual goals and objectives for giant garter snake.

Protect Existing Populations. The following objectives address protection of existing populations.

- Objectives NWNC1.1 and 2.1; NANC2.1; ALNC1.1, 1.5,1.6, and GGSN1.1 will contribute to the priority need as identified in the Draft Recovery Plan by protecting and managing habitat currently occupied by the species. These objectives will shelter the population from potential threats, increase habitat quantity, and increase habitat quality; which will lead to increased population size of the Caldoni Marsh/White Slough and Yolo/Willow Slough subpopulations.
- Objectives FMNC2.1, NWNC2.1, NANC2.1, ALNC1.8, and GGNS1.1 will contribute to the priority need as identified in the Draft Recovery Plan by increasing the quality and functionality of managed lands in or adjacent to occupied habitat. Implementing management plans and guidelines for the species on managed lands is anticipated to reduce injury and mortality associated with incompatible land uses.
- Objectives ALNC1.5 and 1.6, NWNC1.1, TANC 1.1, FMNC1.1, and GGNS1.1 and 1.2 will contribute to the priority need as identified in the Draft Recovery Plan by protecting (previously unprotected) and/or enhancing corridor habitat. Increasing the connectivity between populations and within meta-populations is expected to enhance gene flow, increase distribution, and ultimately make the populations more resilient to catastrophic events.

Restore Habitat. The following objectives address restoration of giant garter snake habitat.

- Objectives TANC1.1 and FMNC1.1 will restore 10,000-20,000 acres of tidal perennial aquatic in Conservation Zones 1, 2, 4, 5, 6, 7, and 11 and 13,900-21,600 acres of tidal freshwater marsh to Conservation Zones 1, 2, 5, and 7. The majority of these lands are currently non-functional or low functioning lands for giant garter snake and will be restored to enhance existing conditions. Of the total acres of tidal marsh restoration, 1,500 acres is planned for Conservation Zone 4, which will provide additional habitat, contribute to connectivity, and facilitate movement between the Caldoni/White Slough subpopulation northward toward the Cosumnes River Preserve and Stone Lakes National Wildlife Refuge.

- Objective NWNC1.1 will restore 400 acres of nontidal freshwater marsh habitat in Conservation Zones 2 and 4 to support security and expansion of the Yolo/Willow Slough and Caldoni Marsh/White Slough subpopulations.
- Objectives FMNC2.1, NWNC2.1, NANC2.1, ALNC1.8, and GGNS1.1 will protect and manage essential habitat elements within restored habitats, including upland buffers, and ensure that management actions are consistent with giant garter snake protection.

Ensure dependable water supply. The following goals address ensuring a dependable water supply for restored giant garter snake habitats.

- Goals TANC1, FMNC1, and NWNC1 seek to meet the priority need identified in the Draft Recovery Plan to provide a dependable water supply for giant garter snake populations in the Delta region. Conservation actions will include provisions for a perennial water supply with particular importance placed on the active season.

Buffer land supporting giant garter snake populations from the effects of urbanization and highway expansion. The following objectives address protecting giant garter snake populations.

- Objectives FMNC2.1, NWNC2.1, NANC2.1, ALNC1.8, and GGNS1.1 will protect, enhance, and manage essential habitat elements within restored habitats to ensure protection of giant garter snake habitat and populations. While these are general objectives that address the range of management actions for all covered species, they also include establishing and maintaining appropriate buffers between giant garter snake habitat and incompatible land uses.

Restore and maintain connectivity between populations and protected lands. The following objectives address habitat connectivity.

- Objectives TANC 1.1, FMNC 1.1, and GGSN2.1 will promote connectivity between the Caldoni Marsh/White Slough subpopulation and the Badger Creek subpopulation; and
- ALNC1.2 and GGSN2.2 will protect cultivated habitats in Zones 2 and 4 for Swainson's hawk and greater sandhill crane, which will provide opportunities for enhancing north-south movement corridors for the Yolo/Willow Slough subpopulation within the Yolo Bypass and for Caldoni Marsh/White Slough subpopulation between Stone Lakes National Wildlife Refuge and the Caldoni Marsh/White Slough area.

Development management plans and guidelines for conservation lands. Developing site-specific management plans for BDCP lands is an essential element of all goals and objectives. The following objectives specifically target the need for the development of management plans.

- Objectives FMNC2.1, NWNC2.1, NANC2.1, and ALNC1.8 will require the development of site-specific management plans for all BDCP lands, which will protect, enhance, and manage essential habitat elements for all covered species including giant garter snake.

Restore connectivity to the Northern Sacramento Valley Recovery Unit. The following objectives address connectivity throughout the Northern Sacramento Valley Recovery Unit.

- ALNC1.5 and 1.6, NWNC1.1, and GGSN1.1 and 1.2 will increase connectivity outside of the Plan Area by protecting and enhancing habitat around the Yolo/Willow Slough and Caldoni Marsh/White Slough subpopulations.;
- TANC1.1 and FMNC1.1 will create substantial additional habitat for giant garter snake and promote connectivity between the Plan Area and habitats outside the Plan Area; and
- ALNC1.2 will protect substantial cultivated habitats that will promote connectivity between the Plan Area and habitats outside the Plan Area.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM4 Tidal Habitat Restoration
- CM8 Grassland Communities Restoration
- CM9 Vernal Pool Complex Restoration
- CM10 Nontidal Marsh Restoration
- CM11 Natural Communities Enhancement and Management

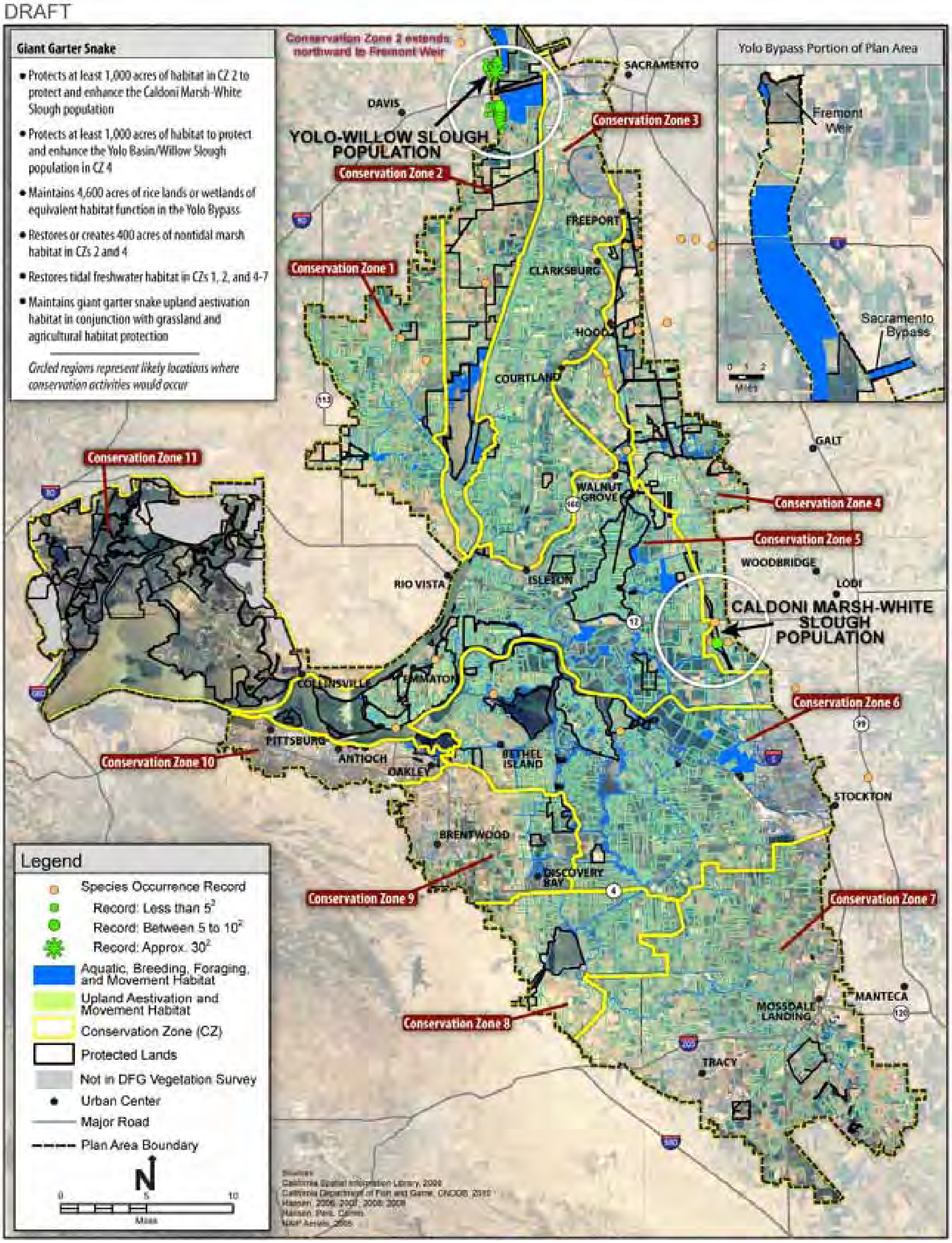

Figure 3-32. Giant Garter Snake Habitat Distribution and Conservation Strategy

3.3.2.4.20 Western Pond Turtle

The western pond turtle is a California Species of Special Concern and occurs in the Pacific states of North America from Baja California, north through Washington, and possibly into southernmost British Columbia, Canada (Bury and Germano 2008). The California Natural Diversity Database (CNDDB) reports several occurrences spread throughout the Plan Area in Sacramento, San Joaquin, and Contra Costa counties (CNDDB 2009); however, it is likely that this species is underreported and underrepresented in CNDDB. While primarily found in natural aquatic habitats, it also inhabits impoundments, irrigation ditches, and other artificial and natural water bodies (Ernst et al. 1994). The species is usually found in stagnant or slow-moving freshwater habitats, but brackish habitats are also utilized (Ernst et al. 1994). An upland habitat component is also used for movement, dispersal, and overwintering. Bury (1972) found adult males had the largest home ranges in his study (0.98 ha [2.42 ac]), followed by juveniles (0.36 ha [0.89 ac]) and adult females (0.25 ha [0.62 ac]) (Yolo Natural Heritage Program 2009). Most populations throughout the range have exhibited some declines. In California, Jennings and Hayes (1994) consider the western pond turtle as endangered from the Mokelumne River south and threatened elsewhere within the state. Loss of habitat is the most significant factor in western pond turtle declines. Over 90 percent of the historical wetlands in California have been drained, filled, or diked to support agricultural and urban development (Frayer et al. 1989).

Applicable Natural Community Goals and Objectives

Goal TANC1: The expected outcome is tidal perennial aquatic natural community that supports habitats for covered and other native species and that supports aquatic food web processes.

> **Objective TANC1.1**: Restore or create 10,000 to 20,000 acres of tidal perennial aquatic in BDCP Restoration Opportunity Areas (Conservation Zones 1, 2, 4, 5, 7, and 11) that supports aquatic food production and habitat for covered and other native species.

Goal BMNC1: The expected outcome is restored large expanses and interconnected patches of tidal brackish emergent wetland natural community.

> **Objective BMNC1.1:** Restore or create 3,600 to 4,800 acres of tidal brackish emergent wetland in the Suisun Marsh ROA (Conservation Zone 11).

Goal FMNC1: The expected outcome is restored large, interconnected patches of tidal freshwater emergent wetland natural community.

> **Objective FMNC1.1:** Restore or create 13,900 to 21,600 acres of tidal freshwater emergent wetland in the Cache Slough, West Delta, Cosumnes-Mokelumne, and South Delta ROAs (Conservation Zones 1, 2, 4, 5, 6, and 7).

Goal FMNC2: The expected outcome is biologically diverse tidal freshwater emergent wetland that is enhanced for native species and sustained by natural ecological processes.

Objective FMNC2.1: Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal freshwater emergent wetlands for covered and other native species over the term of the BDCP.

Goal NWNC1: The expected outcome is nontidal freshwater perennial emergent wetland natural community that supports habitat for covered and other native species.

Objective NWNC1.1: Create 400 acres of nontidal freshwater marsh (including components of nontidal perennial aquatic and perennial emergent wetland communities) that functions as habitat for the giant garter snake, tricolored blackbird, and western pond turtle within or adjacent to habitat occupied by the Caldoni Marsh/White Slough giant garter snake subpopulation in Conservation Zone 4 and the Yolo/Willow Slough giant garter snake subpopulation in Conservation Zone 2.

Goal NWNC2: The expected outcome is biologically diverse nontidal freshwater perennial emergent wetland communities that are enhanced for native species and sustained by ecological processes.

Objective NWNC2.1: Maintain and enhance the habitat functions of protected and created nontidal freshwater perennial emergent wetlands for covered and other native species over the term of the BDCP.

Goal NANC2: The expected outcome is biologically diverse nontidal perennial aquatic communities that are enhanced for native species and sustained by ecological processes.

Objective NANC2.1: Maintain and enhance the habitat functions of protected and created nontidal open water habitats for covered and other native species over the term of the BDCP.

Goal VRNC1: The expected outcome is restored large expanses and interconnected corridors of valley/foothill riparian natural community.

Objective VRNC1.1: Restore or create 5,000 acres of valley/foothill riparian in Conservation Zones 1, 2, 4, 5, 6, 7, and/or 11.

Goal VRNC2: The expected outcome is biologically diverse valley/foothill riparian natural community that supports native species and is sustained by natural ecological processes.

Objective VRNC2.1: Maintain and enhance the habitat and ecosystem functions of BDCP restored valley/foothill riparian and patches of riparian forest and scrub present on BDCP preserved lands over the term of the BDCP.

Objective VRNC2.3: Restore connectivity of valley/foothill riparian corridors along linear watercourses to enhance habitat for covered species and facilitate wildlife movement.

Goal ALNC1: The expected outcome is increased habitat functions for covered and other native species that are supported by agricultural land cover types and management practices.

> **Objective ALNC1.1**: Maintain and protect the functions of 4,600 acres of rice lands as habitat for giant garter snake, western pond turtle, tricolored blackbird, white-tailed kite, waterfowl, and migrant shorebirds in Conservation Zone 2. This objective may be partially or fully achieved by maintaining an equivalent extent of natural or managed lands that support habitat functions similar to rice lands for associated covered and other native wildlife species.

> **Objective ALNC1.8**: Maintain and protect the small patches of important wildlife habitats associated with agricultural lands that occur within BDCP conserved agricultural lands, including isolated valley oak trees, trees and shrubs along field borders and roadsides, remnant groves, riparian corridors, water conveyance channels, grasslands, and wetlands.

Rationale and Conservation Approach

Because the primary stressor on the western pond turtle is loss of its aquatic and upland habitat due to urban and agricultural expansion, the preservation, enhancement, and restoration of these habitat types is considered to be the most effective approach to its conservation. Conservation of western pond turtle will be provided through the preservation and enhancement of 4,000 acres of its dispersal habitat, over 5,000 acres of its upland nesting and overwintering habitat, and restoration of 5,000 acres of overwintering and nesting habitat and between 27,900 and 46,800 acres of its aquatic habitat (Figure 3-33). The preservation and restoration of such large habitat areas is expected to significantly advance the conservation of western pond turtle in the region. Western pond turtle aquatic, dispersal, and upland nesting and overwintering occurs throughout the Plan Area.

Western pond turtle utilize a wide variety of aquatic habitats. Although primarily found in natural aquatic habitats, it also inhabits impoundments, irrigation ditches, and other artificial and natural water bodies. Western pond turtle is usually found in stagnant or slow-moving freshwater habitats, but brackish habitats are also utilized. Conservation of aquatic habitat will be provided through the restoration of tidal marsh plain and adjacent shallow subtidal habitats within Restoration Opportunity Areas (ROAs) that are expected to support extensive patches of western pond turtle habitat and _ acres of nontidal wetland that will be located in occupied giant garter snake habitat areas.

Western pond turtle upland nesting and overwintering habitat includes riparian areas and grassland. Nesting sites are typically placed about 100 m from aquatic habitat. Conservation of western pond turtle upland nesting and overwintering habitat will be provided mainly through a combination of grassland protection and riparian habitat restoration within ROAs, with grassland restoration and vernal pool complex restoration having the potential to also benefit the species. Vernal pools in particular have been shown to be used during dispersal between nesting and overwintering sites (Reese and Welsh 1997) and vernal pool complex restoration may increase the ability of western pond turtles to disperse across the BDCP landscape. A substantial amount of restored riparian habitat is expected to be adjacent to restored tidal wetland and subtidal aquatic habitat, thus ensuring proximity of nesting and overwintering habitat to aquatic habitat. Dispersal habitat consists of agricultural land and is ubiquitous within the Plan Area (see Appendix A, *Covered Species Accounts*). Protection of cultivated habitats to achieve habitat conservation targets for other covered species (e.g., protection of Swainson's hawk foraging habitat) will also preserve western pond turtle dispersal habitat.

Following BDCP implementation, restoration of pond turtle aquatic habitat is expected to increase the extent of this habitat type in the Plan Area by up to 68 percent relative to current conditions. The proposed habitat conservation actions are expected to maintain sufficient habitat area to sustain or increase the existing Plan Area population of western pond turtle and to maintain connectivity with populations adjacent to the Plan Area that are covered under adjacent and overlapping HCP/NCCPs.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM4 Tidal Habitat Restoration
- CM8 Grassland Communities Restoration
- CM9 Vernal Pool Complex Restoration
- CM10 Nontidal Marsh Restoration
- CM11 Natural Communities Enhancement and Management

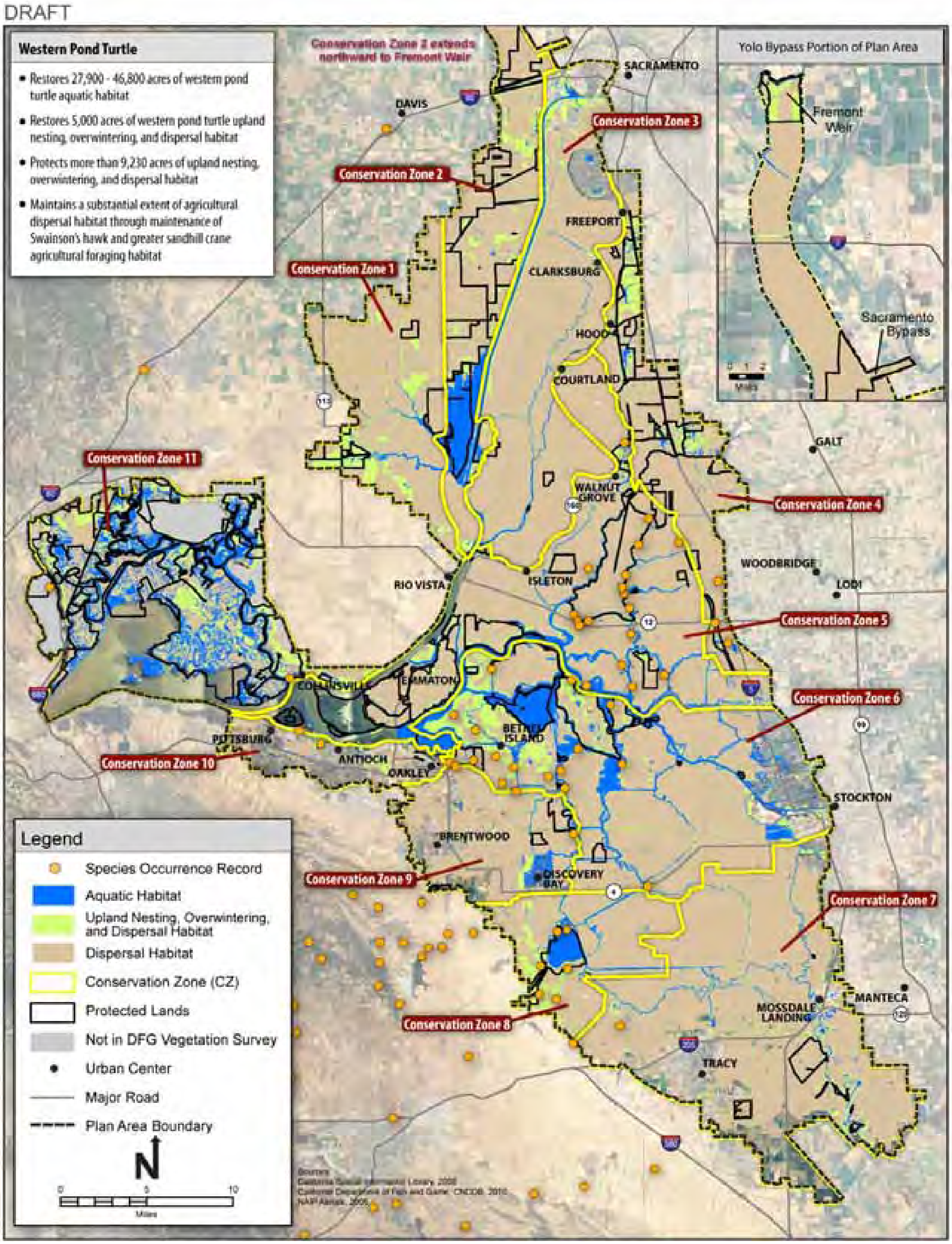

Figure 3-33. Western Pond Turtle Habitat Distribution and Conservation Strategy

3.3.2.4.21 California Red-Legged Frog

The historical range of the California red-legged frog is generally characterized as extending south along the coast from the vicinity of Point Reyes National Seashore and inland from the vicinity of Redding, southward along the interior Coast Ranges and Sierra Nevada foothills to northwestern Baja California (USFWS 2007b). Habitat typically consists of deep water ponds and pools, streams, and other aquatic habitat along with grasslands that provide movement corridors and aestivation sites. The USFWS (2002) estimates that the species has lost approximately 70 percent of its former range, with severe declines occurring primarily in the Central Valley and Southern California (Jennings and Hayes 1994). The principal factors contributing to the decline of the California red-legged frog are the loss of habitat due to urban development, the conversion of native habitats to agricultural lands, the introduction of nonnative predators, and pesticide use (Fisher and Shaffer 1996, Hobbs and Mooney 1998, Davidson et al. 2002).

Within the Plan Area, this species is restricted to the grassland natural community and associated aquatic habitats (stock ponds and small streams) in Conservation Zone 8 along the southwest periphery of the Plan Area.

Applicable Natural Community Goals and Objectives

Goal GRNC1: The expected outcome is grassland comprised of large interconnected patches or contiguous expanses.

> **Objective GRNC1.1**: Protect a minimum of 8,000 acres of grassland in Conservation Zones 1, 8, and 11. At least 1,000 acres will be protected in Conservation Zone 8, with the remainder distributed throughout these three Conservation Zones.

Goal GRNC2: The expected outcome is biologically diverse grassland managed to enhance native species and sustained by natural ecological processes.

> **Objective GRNC2.1**: Restore and sustain a mosaic of grassland vegetation alliances, reflecting local water availability, soil chemistry, soil texture, topography, and disturbance regimes, with consideration of historical states.

> **Objective GRNC2.2**: Increase the relative cover of native grasses and forbs in native grassland vegetation alliances.

> **Objective GRNC2.3**: Increase opportunities for wildlife movement through grassland habitat.

> **Objective GRNC2.4**: Increase burrow availability for burrow-dependent species.

Species-Specific Goals and Objectives

Goal CRLF1: The expected outcome is enhanced breeding California red-legged frog populations in the Plan Area.

> **ObjectiveCRLF1.1**: Enhance stock ponds in grassland in Conservation Zone 8 through partial livestock exclusion and predator control.

Rationale and Conservation Approach

Because a primary stressor on the California red-legged frog is the loss of its aquatic and upland habitat due to urban and agricultural expansion, the protection and enhancement of these habitat types are key elements of the U.S. Fish and Wildlife Service's Recovery Plan for the species and considered to be the most effective approach to its conservation. Conservation of California red-legged frog will be provided through the preservation of 1,000 acres of grassland natural community in Conservation Zone 8 (Figure 3-34). Habitat will be preserved and enhanced in the largest possible patch sizes adjacent to occupied habitat within and adjacent to the Plan Area and will be managed to enhance habitat functions for California red-legged frog. Conservation Zone 8 is the only location within the Plan Area where California red-legged frog is present or expected to occur. Conservation of California red-legged frog is focused on protecting its intact riparian and upland cover and dispersal habitat linking to its aquatic breeding habitat within the Plan Area and to occupied habitat areas adjacent to the Plan Area in Conservation Zone 8 south of Highway 4.

California red-legged frog upland habitat will be preserved in Conservation Zone 8. Upland habitats are comprised of grassland that supports aestivation and movement habitat to and from aquatic breeding habitats. Approximately 3,830 acres of upland cover and dispersal habitat is present in Conservation Zone 8 of which approximately 620 acres (16 percent) are currently protected. The proposed protection of grassland would be located such that it encompasses ponds and stream corridors that support breeding habitat. Protected habitat will be managed to increase the abundance of ground squirrel burrows to increase the availability of cover and aestivation sites and to increase the habitat function of any riparian habitat adjacent to preserved stream channels by providing dense stands of overhanging willows and a fringe of cattails between the willow roots and overhanging willow limbs. Stock ponds will also be enhanced by excluding livestock from a portion of the stock pond and allowing freshwater emergent vegetation to grow, facilitating red-legged frog occupancy.

California red-legged frog habitat within the Plan Area is located on the margin of its range and as such is not considered to support core habitat area for the species. Consequently, to increase the level of conservation benefits provided to California red-legged frog relative to benefits that would be provided by implementing the conservation actions within the Plan Area, the red-legged frog conservation actions may be implemented within core red-legged frog habitat areas that are located outside of the Plan Area consistent with conservation plans for those locations as described in Section 3.2.4, *Development of the Terrestrial Resources Component of the Conservation Strategy*.

Following BDCP implementation, approximately 33 percent of modeled California red-legged frog habitat in Conservation Zone 8 that links to occupied habitat outside the Plan Area would be preserved. The proposed habitat conservation actions are expected to preclude potential future fragmentation of the highest functioning frog habitat in the Plan Area and maintain sufficient habitat area to sustain or increase the existing Plan Area population of California red-legged frog and to maintain connectivity with occupied core populations adjacent to the Plan Area that are covered under adjacent and overlapping HCP/NCCPs.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM8 Grassland Communities Restoration
- CM11 Natural Communities Enhancement and Management

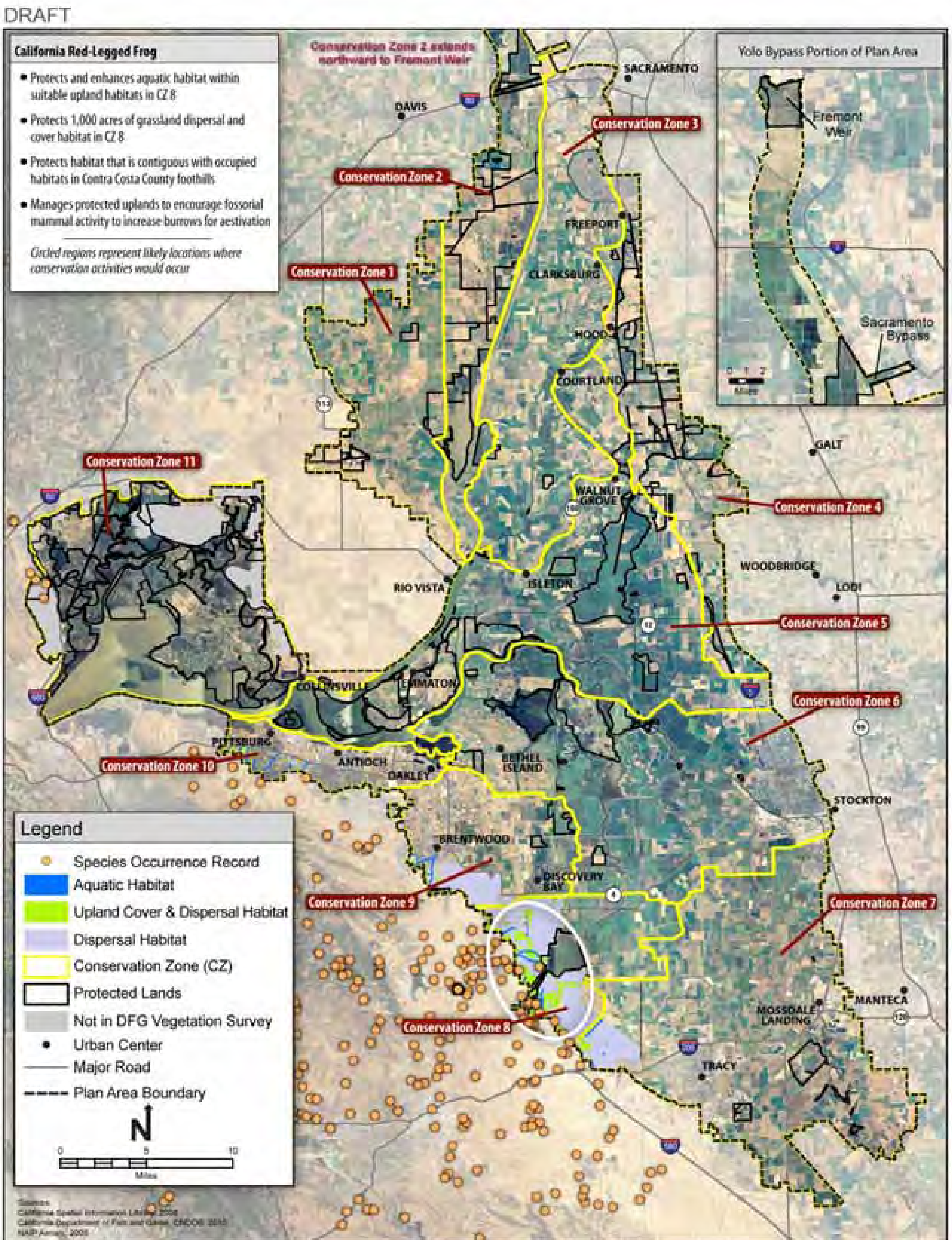

Figure 3-34. California Red-Legged Frog Habitat Distribution and Conservation Strategy

3.3.2.4.22 Western Spadefoot Toad

The western spadefoot toad is a state Species of Special Concern whose range includes portions of California, extending south to Mesa de San Carlos in Baja California, Mexico (Stebbins 1985, Jennings and Hayes 1994, California Academy of Sciences 2008, Museum of Vertebrate Zoology 2008). In California, the current range of the western spadefoot toad includes portions of the Central Valley and bordering foothills, and the Coast Ranges south of Monterey Bay (Stebbins 2003). The western spadefoot toad has been extirpated throughout most of the lowlands of southern California (Stebbins 1985) and from many historical locations within the Central Valley (Jennings and Hayes 1994, Fisher and Shaffer 1996). Fisher and Shaffer (1996) state that the western spadefoot toad populations have declined severely in the Sacramento Valley, and their density has been reduced in eastern San Joaquin Valley. Optimal habitat consists of vernal pool breeding habitat surrounded by grassland upland cover habitat. Western spadefoot toad also typically inhabits other lowland habitats such as washes, floodplains of rivers, alluvial fans, playas, and alkali flats (Stebbins 1985). Its range extends into the foothills and mountains to an elevation of 1,360 m (4,462 feet) (Jennings and Hayes 1994). The principal factors contributing to the decline of the western spadefoot are loss of habitat due to urban development, conversion of native habitats to agricultural lands, introduction of nonnative predators, and pesticide use (Fisher and Shaffer 1996, Hobbs and Mooney 1998, Davidson et al. 2002). The loss of vernal pool or other seasonal pool habitats due to land conversion is likely the greatest threat to the western spadefoot toad. More than 80 percent of occupied habitat in southern California and more than 30 percent in northern California have been lost to development or other incompatible land uses (Jennings and Hayes 1994).

Applicable Natural Community Goals and Objectives

Goal GRNC1: The expected outcome is grassland comprised of large interconnected patches or contiguous expanses.

> **Objective GRNC1.1**: Protect a minimum of 8,000 acres of grassland in Conservation Zones 1, 8, and 11. At least 1,000 acres will be protected in Conservation Zone 8, with the remainder distributed throughout these three Conservation Zones.

> **Objective GRNC1.2**: Restore 2,000 acres of grassland to connect fragmented patches of protected grassland.

Goal GRNC2: The expected outcome is biologically diverse grassland managed to enhance native species and sustained by natural ecological processes.

> **Objective GRNC2.1**: Restore and sustain a mosaic of grassland vegetation alliances, reflecting local water availability, soil chemistry, soil texture, topography, and disturbance regimes, with consideration of historical states.

> **Objective GRNC2.2**: Increase the relative cover of native grasses and forbs in native grassland vegetation alliances.

Objective GRNC2.3: Increase opportunities for wildlife movement through grassland habitat.

Objective GRNC2.4: Increase burrow availability for burrow-dependent species.

Goal VPNC1: The expected outcome is protected vernal pool complex natural community that represents a range of environmental conditions and is adjacent to other conserved lands.

Objective VPNC1.1: Protect 300 acres of vernal pool complex in Conservation Zones 1, 8, and 11.

Goal VPNC2: The expected outcome is restored biologically diverse vernal pool complex natural community with improved native biodiversity, habitat heterogeneity, and the ability to support populations of covered and other native species.

Objective VPNC2.1: Restore 200 acres of vernal pool complex natural community in Conservation Zones 1, 8, and/or 11 within patches of protected grassland that supports habitat for the western spadefoot toad, California tiger salamander, and the covered vernal pool shrimp and plant species.

Objective VPNC2.2: Maintain and, where habitat functions for covered species can be enhanced, increase the diversity and relative cover of native grasses and forbs.

Rationale and Conservation Approach

Because a primary stressor on the western spadefoot toad is the loss of its vernal pool breeding and upland habitat due to urban and agricultural expansion, the preservation, enhancement, and restoration of these habitat types is considered to be the most effective approach to its conservation. Conservation of western spadefoot toad will be provided mainly through the preservation and enhancement of 300 acres and restoration of 200 acres of its vernal pool complex breeding habitat and the preservation and enhancement of 8,400 acres of its grassland and associated alkali seasonal wetland cover habitat (Figure 3-35). Additionally, grassland restoration will be conducted in the Plan Area and has the potential to benefit the western spadefoot where vernal pools occur within dispersal distance. Although there are no records of western spadefoot toad occurring within the Plan Area (CNDDB 2009), potentially suitable habitat exists and the expected range extends through the Plan Area. Habitat will be preserved and restored in the largest possible patch sizes and management of preserved and restored vernal pool complex (e.g., livestock grazing) will be designed to enhance habitat functions for western spadefoot toad and other associated covered vernal pool-associated species. Western spadefoot toad breeding and upland habitat is present in Conservation Zones 1, 2, 4, 8, 9, and 11. Conservation of western spadefoot toad habitat is focused on preserving, enhancing, and restoring vernal pool complex and associated grassland habitats where opportunities for large scale conservation of western spadefoot toad habitat exist in Conservation Zones 1, 8, and 11. Breeding and associated grassland habitat in Conservation Zones 2 and 4 is almost entirely under protected status (99 percent) and vernal pool complex in Conservation Zone 9 (approximately

120 acres) is located in the vicinity of Discovery Bay and is largely fragmented by development and cultivated lands.

While western spadefoot toad lays its eggs in a variety of permanent and temporary wetlands, including rivers, creeks, pools in intermittent streams, vernal pools, temporary rain pools (CNDDB 2009) and stock ponds, optimal habitat consists of vernal pools and other temporary wetlands free of fish and other nonnative predators. Restored vernal pool complex will be designed to meet optimal habitat criteria and provide high breeding habitat function. Habitat will be restored at sites within Conservation Zones 1, 8, and 11 that historically supported fully functioning vernal pool habitats. Management of protected vernal pool complex (e.g., livestock grazing) will be designed to enhance western spadefoot toad breeding habitat functions. Habitat will preserved in conjunction with protected grassland and alkali seasonal wetlands in these same Conservation Zones.

Western spadefoot toad upland terrestrial cover and aestivation habitat will be preserved in Conservation Zones 1, 8, and 11. Upland habitat will be comprised of grassland and alkali seasonal wetland that encompasses protected aquatic breeding habitats and are within or connected to potentially occupied western spadefoot toad habitat. Connections to potentially occupied habitat will be of sufficient width to provide for the movement of western spadefoot toad to and from occupied habitat areas. Protected grassland will be managed to provide appropriate vegetative conditions to facilitate spadefoot movement and reduce predation exposure and to maintain or increase the abundance of ground squirrels and other fossorial mammal species to improve the availability of suitable aestivation sites.

Western spadefoot toad habitat within the Plan Area is located on the margin of its range and as such is not considered to support core habitat area for the species. Consequently, to maximize the level of conservation benefits provided to western spadefoot toad, conservation actions may be implemented within core western spadefoot toad habitat areas that are located outside of the Plan Area consistent with conservation plans for those locations as described in Section 3.2.4, Development of the Terrestrial Resources Component of the Conservation Strategy.

Following BDCP implementation, approximately 69 percent of modeled western spadefoot toad vernal pool complex breeding habitat and 99 percent of its modeled upland habitat will be preserved within the Plan Area. The proposed habitat conservation actions are expected to maintain sufficient habitat area to sustain or increase the potential Plan Area population of western spadefoot toad and to maintain connectivity with occupied core populations adjacent to the Plan Area and covered under adjacent and overlapping HCP/NCCPs.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM8 Grassland Communities Restoration
- CM9 Vernal Pool Complex Restoration
- CM11 Natural Communities Enhancement and Management

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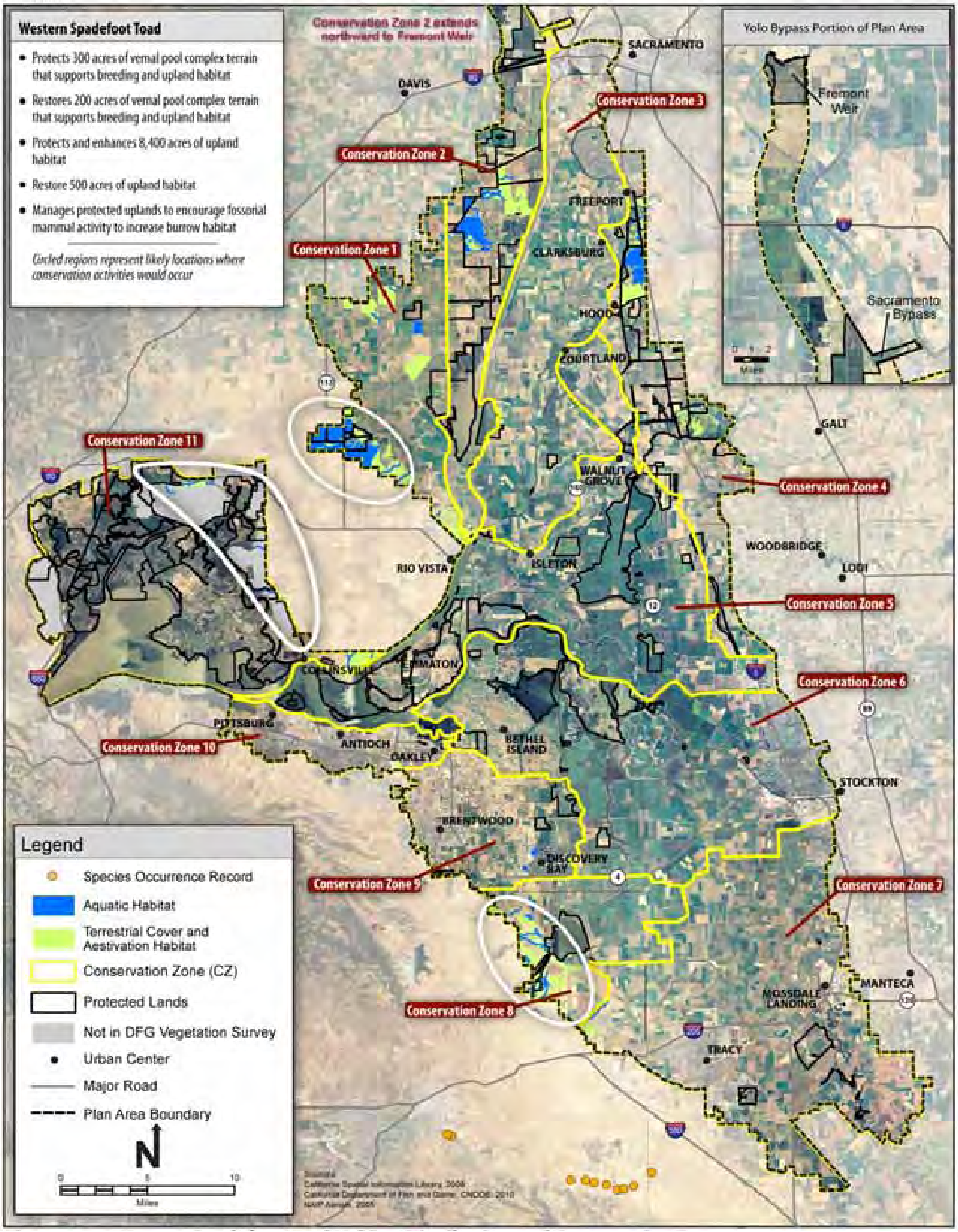

Figure 3-35. Western Spadefoot Toad Habitat Distribution and Conservation Strategy

3.3.2.4.23 California Tiger Salamander

The California tiger salamander is endemic to California, where its range is limited primarily by the availability of burrows and winter breeding habitat, primarily open grassland landscapes with vernal pools and playa pools and with burrowing squirrels and pocket gophers (Barry and Shaffer 1994). Extant populations of California tiger salamanders are believed to be declining as a result of habitat loss (Shaffer et al. 1993, Barry and Shaffer 1994, Holland 1998). In particular, an estimated 80 percent of the species' historical natural aquatic (i.e., vernal pool) habitat has been lost (Holland 1998) and the species has been eliminated from 55 to 58 percent of historical breeding sites (Barry and Shaffer 1994). There is no recovery plan for the species, but critical habitat has been designated for the species, and California tiger salamander conservation relies primarily on the preservation, enhancement, and restoration of its vernal pool complex breeding and grassland cover habitat (Appendix A, *Covered Species Accounts*). The focus on California tiger salamander habitat by BDCP not only addresses the species' primary need but also ties in with other regional conservation efforts such as the acquisition of land occupied by tiger salamander near the Bay Regional Parks District west of the Plan Area in Contra Costa and Alameda counties.

Applicable Natural Community Goals and Objectives

Goal GRNC1: The expected outcome is grassland comprised of large interconnected patches or contiguous expanses.

> **Objective GRNC1.1**: Protect a minimum of 8,000 acres of grassland in Conservation Zones 1, 8, and 11. At least 1,000 acres will be protected in Conservation Zone 8, with the remainder distributed throughout these three Conservation Zones.

> **Objective GRNC1.2**: Restore 2,000 acres of grassland to connect fragmented patches of protected grassland.

Goal GRNC2: The expected outcome is biologically diverse grassland managed to enhance native species and sustained by natural ecological processes.

> **Objective GRNC2.1**: Restore and sustain a mosaic of grassland vegetation alliances, reflecting local water availability, soil chemistry, soil texture, topography, and disturbance regimes, with consideration of historical states.

> **Objective GRNC2.2**: Increase the relative cover of native grasses and forbs in native grassland vegetation alliances.

> **Objective GRNC2.3**: Increase opportunities for wildlife movement through grassland habitat.

> **Objective GRNC2.4**: Increase burrow availability for burrow-dependent species.

Goal VPNC1: The expected outcome is protected vernal pool complex natural community that represents a range of environmental conditions and is adjacent to other conserved lands.

> **Objective VPNC1.1**: Protect 300 acres of vernal pool complex in Conservation Zones 1, 8, and 11.

Goal VPNC2: The expected outcome is restored biologically diverse vernal pool complex natural community with improved native biodiversity, habitat heterogeneity, and the ability to support populations of covered and other native species.

> **Objective VPNC2.1**: Restore 200 acres of vernal pool complex natural community in Conservation Zones 1, 8, and/or 11 within patches of protected grassland that supports habitat for the western spadefoot toad, California tiger salamander, and the covered vernal pool shrimp and plant species.

> **Objective VPNC2.2**: Maintain and, where habitat functions for covered species can be enhanced, increase the diversity and relative cover of native grasses and forbs.

Rationale and Conservation Approach

Conservation of California tiger salamander will be provided through the preservation and enhancement of 300 acres and the restoration of 200 acres of its vernal pool complex breeding habitat and the preservation, enhancement, and restoration of 8,400 acres of its grassland and associated alkali seasonal wetland cover habitat (Figure 3-36). Habitat will be protected and restored in the largest possible patch sizes and management of preserved and restored vernal pool complex (e.g., livestock grazing) will be designed to enhance habitat functions for California tiger salamander and other associated covered vernal pool-associated species. California tiger salamander breeding and upland habitat is present in Conservation Zones 1, 2, 4, 8, 9, and 11. Breeding and associated grassland habitat in Conservation Zones 2 and 4 is almost entirely under protected status (99 percent) and vernal pool complex in Conservation Zone 9 (approximately 120 acres) is located in the vicinity of Discovery Bay and is largely fragmented by development and cultivated lands. Preserved habitat will be acquired in locations that provide connectivity to existing protected and occupied habitat.

Optimal California tiger salamander breeding habitat consists of large vernal pools, playa pools, or ephemeral ponds that hold water until at least May. Pools and ponds with this long ponding duration prevent the establishment of nonnative predators, enable salamander larvae to metamorphose, and contain enough prey to allow for high breeding productivity (P. Trenham, pers. comm.). Restored vernal pool complex will be designed to meet all such California tiger salamander habitat criteria and provide high breeding habitat function. Additionally, it will be restored on sites within Conservation Zones 1, 8, and 11 that historically supported fully functioning vernal pool habitats. Management of preserved vernal pool complex (e.g., livestock grazing) will be designed to enhance tiger salamander breeding habitat functions. Habitat will be preserved in conjunction with preserved grassland and alkali seasonal wetland complex that will also be preserved in these Conservation Zones. Connections to occupied habitat will be of sufficient width to provide for the movement of salamanders to and from occupied areas.

California tiger salamander habitat within the Plan Area is located on the margin of the species' range and as such is not considered to support core habitat area for the species. Consequently, to maximize the level of conservation benefits provided to California tiger salamander, conservation actions may be implemented within core California tiger salamander habitat areas that are located outside of the Plan Area consistent with conservation plans for those locations as described in Section 3.2.4, *Development of the Terrestrial Resources Component of the Conservation Strategy*.

Following BDCP implementation, approximately 68 percent of modeled California tiger salamander vernal pool complex breeding habitat and 99 percent of its modeled upland habitat will be protected within the Plan Area. The proposed habitat conservation actions are expected to maintain sufficient habitat area to sustain or increase the existing Plan Area population of California tiger salamander and to maintain connectivity with occupied core populations adjacent to the Plan Area and covered under adjacent and overlapping HCP/NCCPs.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM8 Grassland Communities Restoration
- CM9 Vernal Pool Complex Restoration
- CM11 Natural Communities Enhancement and Management

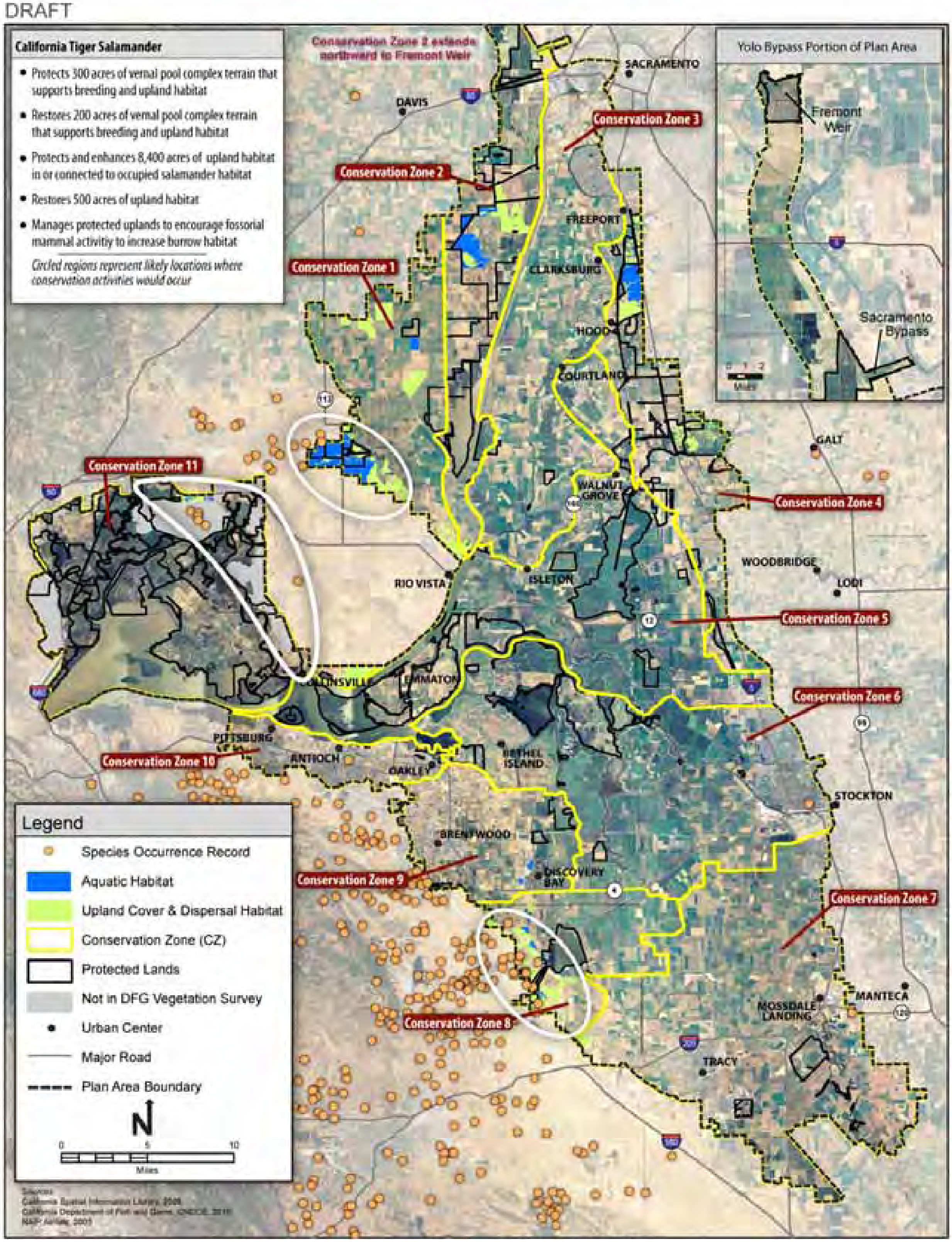

Figure 3-36. California Tiger Salamander Habitat Distribution and Conservation Strategy

3.3.2.4.24 Lange's Metalmark Butterfly

Lange's metalmark butterfly is endemic to areas of Oakley sand soil in east Contra Costa County that support nakedstem buckwheat which is its larval host plant and its adult nectar plant. It is entirely dependent on a particular white-flowered, sand-associated, ecotype of nakedstem buckwheat that grows only on the remnant of the Antioch Dune. Its dependence on the plant extends to the leaf litter that accumulates near the base of large plants growing in large clumps. The extent of the former dune has been reduced to 20 acres plus an unknown amount on two Pacific Gas & Electric (PG&E) parcels that total 12 acres. The 20-acre known extent is protected on the Antioch Dunes National Wildlife Refuge (ADNWR), while the PG&E parcels are being managed under an MOU with USFWS. All the existing habitat has been degraded by nonnative invasive plant species while some older dense stands of nakedstem buckwheat have been lost to wildfires.

The current USFWS management plan for the ADNWR provides for invasive nonnative plant species control efforts that include hand pulling of individual invasive plants through the efforts of volunteers, targeted herbicide application, the restoration of some dune-like topography, and planting of nursery-grown nakedstem buckwheat. Additionally, there is a captive breeding and reintroduction program for Lange's metalmark butterfly and a propagation and out-planting program for its host plant.

The known occurrences of Lange's metalmark butterfly within the Plan Area are located exclusively within the ADNWR and on the two adjacent PG&E properties and are fully protected by ownership and conservation MOUs. These protected lands are completely isolated from other terrestrial habitats by development to the west, south, and east, and by the San Joaquin River to the north. Consequently, to increase the level of conservation benefits provided to inland dune scrub species, inland dune scrub conservation will be implemented through funding support for appropriate management actions and studies.

<u>Applicable Natural Community Goals and Objectives</u>

Goal IDSC1: The expected outcome is support for funding of the USFWS management and enhancement of the inland dune scrub natural community on the Antioch Dunes National Wildlife Refuge.

> **Objective IDSC1.1:** The BDCP will support the funding of the USFWS program for management, enhancement, and monitoring of inland dune scrub natural community on the Antioch Dunes National Wildlife Refuge at an annual amount of $XX.XX for X years.

Species-Specific Goals and Objectives

Goal LMMB1: The expected outcome is funding support for the USFWS captive breeding and reintroduction program for Lange's metalmark butterfly.

Objective LMMB1.1: The BDCP will provide funding to support the USFWS program for the captive breeding and release of Lange's metalmark butterfly at an annual amount of $XX.XX for X years.

Rationale and Conservation Approach

Lange's metalmark butterfly is listed as endangered under the Federal Endangered Species Act but critical habitat has not been designated. The CALFED Bay-Delta Ecosystem Restoration Program Plan's Multi-Species Conservation Strategy designation for Lange's metalmark is "Recovery." After the recent 5-year review of the recovery plan by USFWS found that Lange's metalmark was declining significantly at the ADNWR and appeared to be headed towards extinction, a captive breeding and release program was begun in 2006. The current management plan is designed to meet the recovery needs for the species on the ADNWR, provides for invasive nonnative plant species control efforts, restores dune-like topography, and oversees the out-planting of nursery-grown nakedstem buckwheat.

Conservation of Lange's metalmark butterfly will be provided through the support of funding for the USFWS captive breeding program and its management of the ADNWR (Figure 3-37). The program will include the nursery propagation and out-planting of the white-flowered, sand-associated, ecotype of nakedstem buckwheat and the management of the nakedstem buckwheat to create dense patches of older plants with an extensive layer of leaf litter. The required sizes of self-sustainable Lange's metalmark butterfly populations have not yet been determined, but may be revealed as the controlled propagation studies proceed.

Applicable Conservation Measures

- CM11 Natural Communities Enhancement and Management

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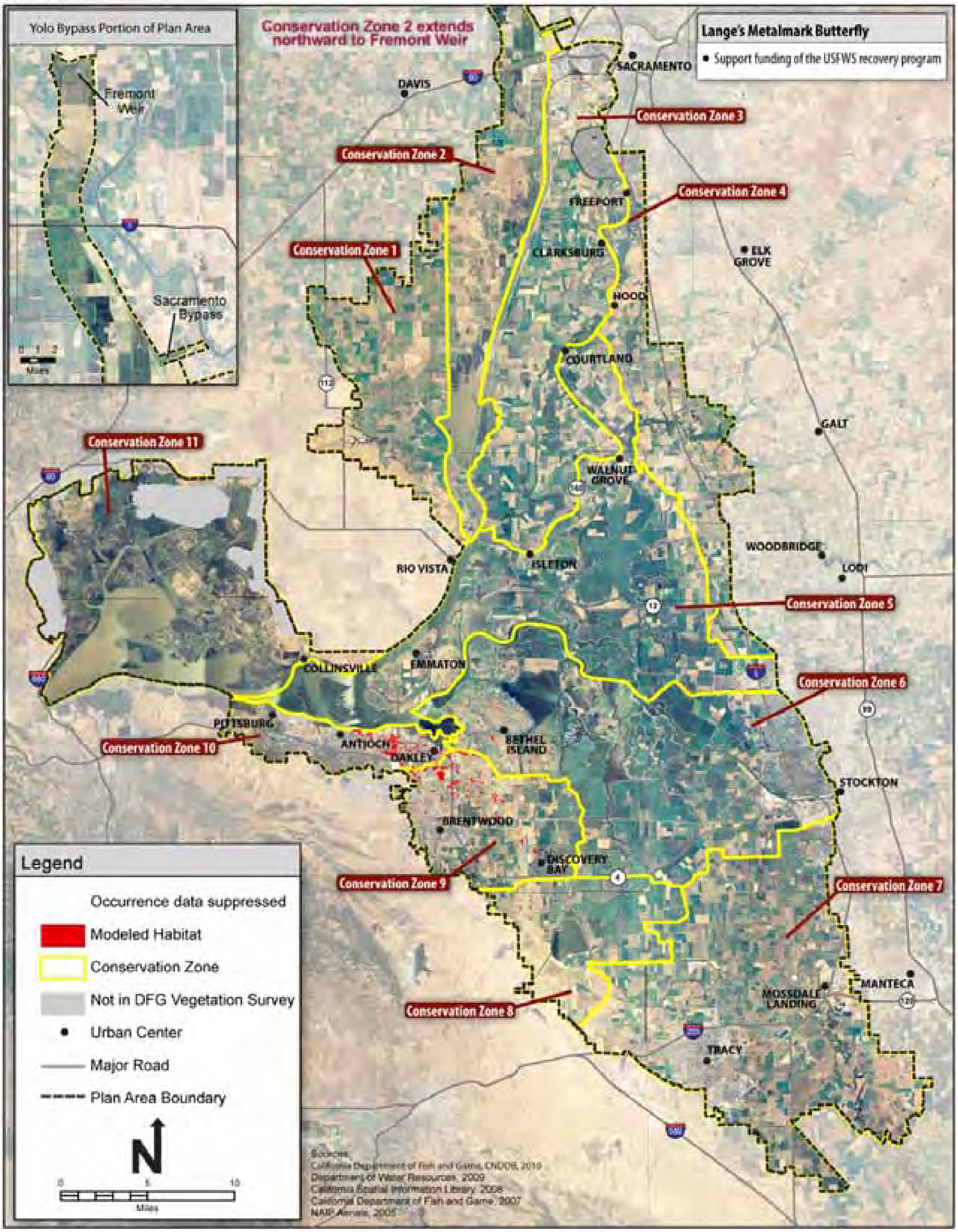

Figure 3-37. Lange's Metalmark Butterfly Habitat Distribution and Conservation Strategy

3.3.2.4.25 Valley Elderberry Longhorn Beetle

One of two subspecies of the longhorn beetle (*Desmocerus californicus*), the valley elderberry longhorn beetle is endemic to moist valley/foothill riparian corridors in the lower Sacramento and lower San Joaquin valleys (USFWS 1984c). Historically, valley elderberry longhorn beetle presumably occurred throughout the Central Valley of California. Little is known about the historical abundance of valley elderberry longhorn beetle, but the extensive destruction of its habitat suggests that the beetle's range has been largely reduced and fragmented (USFWS 1984c). Valley elderberry longhorn beetle is closely associated with a few species of elderberry (*Sambucus* spp.) that are obligate host plants for valley elderberry longhorn beetle larvae and are necessary for the completion of the beetle's life cycle (Linsley and Chemsak 1972, 1997, Eng 1984, Barr 1991, Collinge et al. 2001). The two main species of elderberry utilized by the valley elderberry longhorn beetle are the blue elderberry and red elderberry, two shrubs found in remnant riparian forests throughout the Central Valley.

Applicable Natural Community Goals and Objectives

Goal VRNC1: The expected outcome is restored large expanses and interconnected corridors of valley/foothill riparian natural community.

> **Objective VRNC1.1**: Restore or create 5,000 acres of valley/foothill riparian in Conservation Zones 1, 2, 4, 5, 6, 7, and/or 11.

Goal VRNC2: The expected outcome is biologically diverse valley/foothill riparian natural community that supports native species and is sustained by natural ecological processes.

> **Objective VRNC2.1**: Maintain and enhance the habitat and ecosystem functions of BDCP restored valley/foothill riparian and patches of riparian forest and scrub present on BDCP preserved lands over the term of the BDCP.

> **Objective VRNC2.3**: Restore connectivity of valley/foothill riparian corridors along linear watercourses to enhance habitat for covered species and facilitate wildlife movement.

Rationale and Conservation Approach

The valley elderberry longhorn beetle is listed as threatened under the federal Endangered Species Act (45 FR 52803). Critical habitat has been designated, but neither of the two sites with critical habitat is located within the boundaries of the Plan Area. Conservation guidelines for the valley elderberry longhorn beetle were established by the USFWS in 1999 to mitigate development-related impacts on valley elderberry longhorn beetle habitat (USFWS 1999b). Valley elderberry longhorn beetle conservation has also been addressed in several regional conservation plans. The valley elderberry longhorn beetle is a covered species under the approved San Joaquin County Multi-species Habitat Conservation and Open Space Plan and the Natomas Basin Habitat Conservation Plan. It is proposed for coverage under the South

Sacramento Habitat Conservation Plan, the Solano County Multispecies Habitat Conservation Plan, the Yolo County Natural Heritage Program Plan, and the Butte Regional Conservation Plan. Valley elderberry longhorn beetle conservation under BDCP will therefore tie in with conservation efforts under those other habitat conservation plans.

Conservation of valley elderberry longhorn beetle will be provided through the restoration of 5,000 acres of valley/foothill riparian distributed among Conservation Zones 1, 4, 6, 7, and/or 11 (Figure 3-38). Plantings of elderberry shrubs, including shrubs translocated as mitigation, will be incorporated into the design of restored habitat. Valley/foothill riparian will be provided in large patches that will be managed to control the establishment of undesirable nonnative vegetation that can affect the health of the beetle's host plants, mainly blue elderberry and red elderberry. Based on model projections, restoration of 5,000 acres of valley/foothill riparian, including elderberry shrubs, will increase the extent of the riparian habitat that will support the valley elderberry longhorn beetle's host plant by 29 percent relative to existing conditions (see detailed description of species habitat and model assumptions in Appendix A, *Covered Species Accounts*). This projected increase is expected to be sufficient to sustain beetle populations in the Plan Area while also allowing for any future increase in the distribution and abundance of the species. Numeric targets for preservation of existing habitat are not established; however, elderberry shrubs that are present within BDCP preserved habitat areas will be preserved and maintained.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM7 Riparian Habitat Restoration

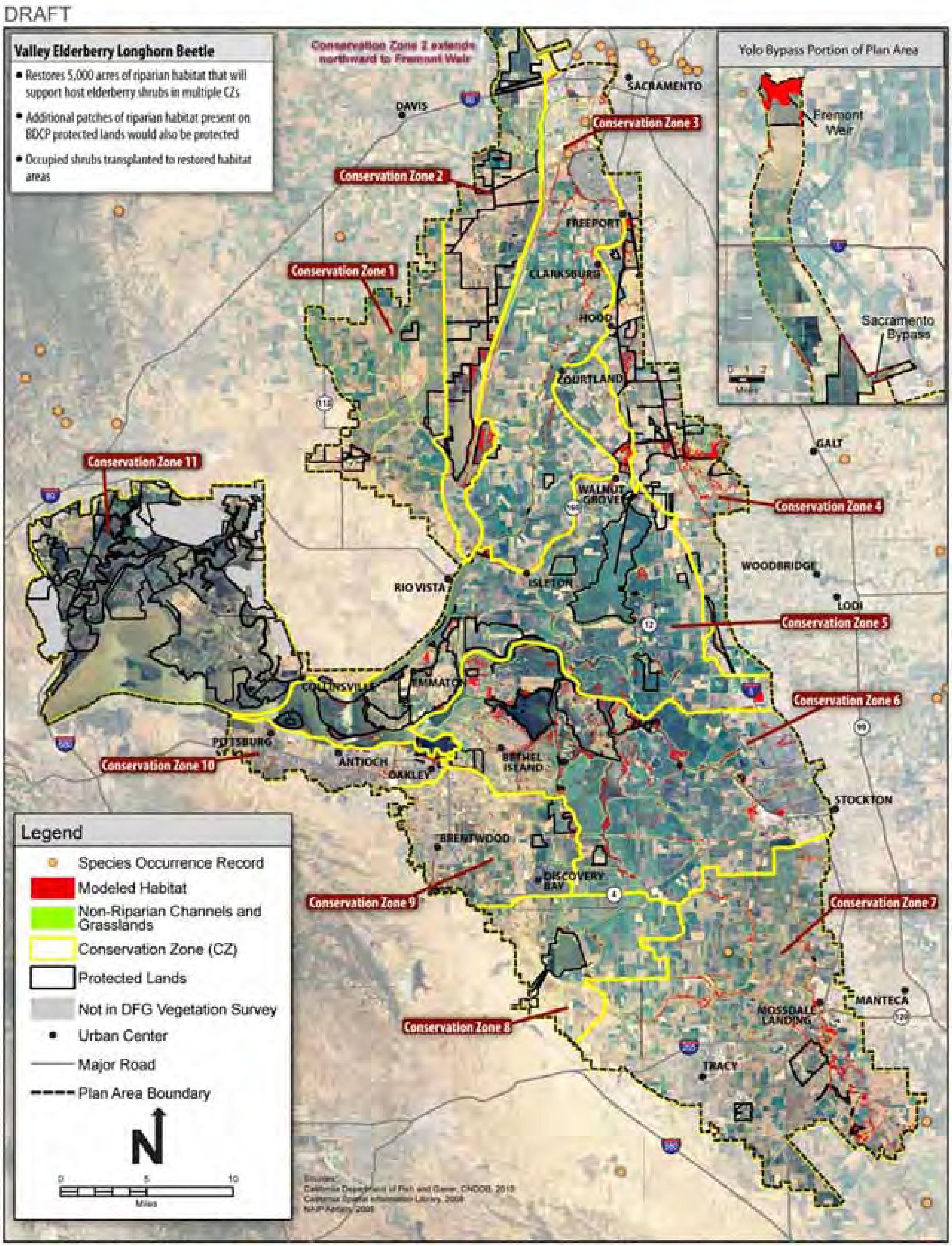

Figure 3-38. Valley Elderberry Longhorn Beetle Habitat Distribution and Conservation Strategy

3.3.2.4.26 Vernal Pool Shrimp Species (Vernal Pool Tadpole Shrimp, Conservancy Fairy Shrimp, Longhorn Fairy Shrimp, Vernal Pool Fairy Shrimp, Midvalley Fairy Shrimp, and California Linderiella)

Several vernal pool shrimp species (vernal pool tadpole shrimp, conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, midvalley fairy shrimp, and California linderiella) are found in the vernal pool complex natural community in California. While specific hydrological requirements, water chemistry, and water temperature requirements may vary somewhat between the species, within the Plan Area, all are closely associated with the vernal pool complex natural community. Development, conversion of the community to agriculture, and exotic plant species are considered to be the primary stressors on these species (Showers 1996, Witham 2003, EDAW 2004, ESA 2005, Dawson et al. 2007, CNDDB 2009, CNPS 2009).

Applicable Natural Community Goals and Objectives

Goal VPNC1: The expected outcome is protected vernal pool complex natural community that represents a range of environmental conditions and is adjacent to other conserved lands.

> **Objective VPNC1.1**: Protect 300 acres of vernal pool complex in Conservation Zones 1, 8, and 11.

Goal VPNC2: The expected outcome is restored biologically diverse vernal pool complex natural community with improved native biodiversity, habitat heterogeneity, and the ability to support populations of covered and other native species.

> **Objective VPNC2.1**: Restore 200 acres of vernal pool complex natural community in Conservation Zones 1, 8, and/or 11 within patches of protected grassland that supports habitat for the western spadefoot toad, California tiger salamander, and the covered vernal pool shrimp and plant species.

> **Objective VPNC2.2**: Maintain and, where habitat functions for covered species can be enhanced, increase the diversity and relative cover of native grasses and forbs.

Goal ONSW1: The expected outcome is increased habitat functions that support BDCP covered species in other natural seasonal wetland natural community within maintained and protected agricultural habitat areas.

> **Objective ONSW1.1**: Integrate management of other natural seasonal wetland natural community with management of BDCP maintained and protected agricultural lands to increase habitat functions for covered species.

Rationale and Conservation Approach

Vernal pool complex natural community supporting vernal pool shrimp habitat is present in Conservation Zones 1, 2, 4, 8, 9, and 11 along the margins of the Delta. Opportunities for large scale conservation of vernal pool shrimp species within the Plan Area, however, are located only in Conservation Zones 1, 8, and 11 (Figure 3-39). Vernal pool complex natural community in

Conservation Zones 2 and 4 is almost entirely under protected status (99 percent) and in Conservation Zone 9 (approximately 120 acres) is located in the vicinity of Discovery Bay and is largely fragmented by development and cultivated lands. Conservation of vernal pool fairy shrimp species habitat will be provided through the protection and restoration of vernal pool complex natural community that supports vernal pool shrimp species and will be protected and managed in conjunction with protected grassland and alkali seasonal wetland complex natural communities that will also be protected in these conservation zones. Habitat will be protected and restored in the largest possible patch sizes and management of protected and restored vernal pool complex natural community (e.g., invasive species control and livestock grazing) will be implemented to enhance habitat functions for vernal pool shrimp species and other associated covered vernal pool species.

It is important to conserve vernal pool complex natural community areas that encompass a range of environmental variation for the purpose of vernal pool shrimp reproduction. While Helm found no difference in the time to reproduce among fairy shrimp (Helm 1998), field data (Gallagher 1996, Alexander 2007) suggests that the average time to reproduce for California linderiella, conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp is approximately 8 weeks; while average time for midvalley fairy shrimp is approximately 2 weeks, and the minimum time to reproduce may be correlated with vernal pool hydrology. Field observations also suggest that the various shrimp species are seldom found inhabiting the same vernal pools.

The proposed protection and restoration of vernal pool complex natural community, in conjunction with existing protected natural communities and habitat, is expected to sustain vernal pool shrimp populations within the Plan Area and to increase the distribution and abundance of covered vernal pool shrimp species. Following completion of conservation actions, approximately 69 percent of vernal pool shrimp species vernal pool complex will be preserved. The conservation actions are consistent with and help to achieve the recovery objectives for Conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, midvalley fairy shrimp, and vernal pool tadpole shrimp as identified in the Vernal Pool Recovery Plan (USFWS 2005).

Vernal pool shrimp habitat within the Plan Area is located on the margin of the distribution of the Central Valley vernal pool complex natural community and as such is not considered to support core habitat area for these species. Consequently, to increase the level of conservation benefits provided to vernal pool shrimp species relative to benefits that would be provided by implementing the conservation actions within the Plan Area, the vernal pool shrimp species conservation actions may be implemented within core vernal pool shrimp species habitat areas that are located outside of the Plan Area consistent with conservation plans for those locations.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM9 Vernal Pool Complex Restoration
- CM11 Natural Communities Enhancement and Management

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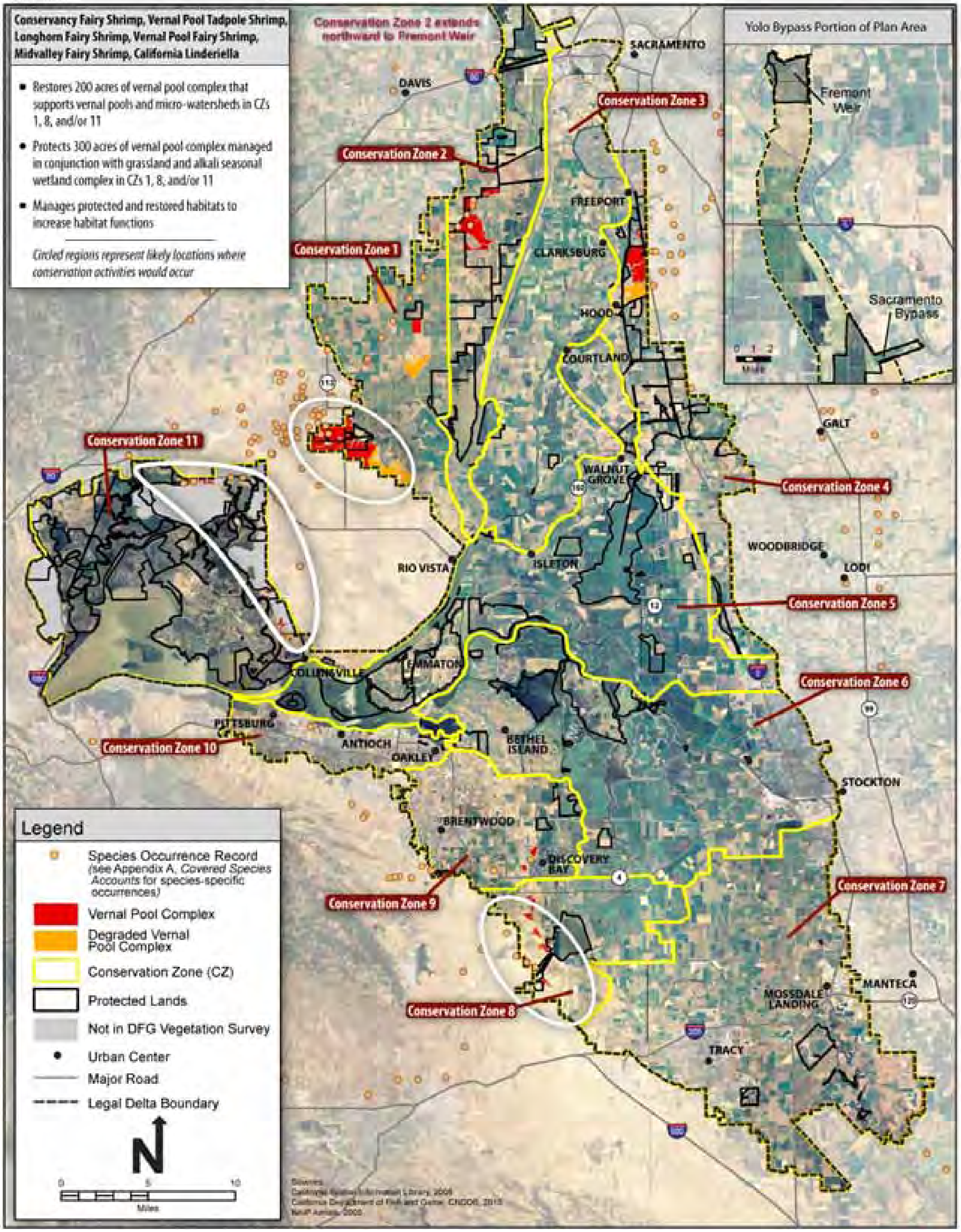

Figure 3-39. Vernal Pool Shrimp Species Habitat Distribution and Conservation Strategy

3.3.2.4.27 Vernal pool plant species (alkali milk-vetch, San Joaquin spearscale, dwarf downingia, Boggs Lake hedge-hyssop, legenere, and Heckard's peppergrass)

Several vernal pool plant species (alkali milk-vetch, San Joaquin spearscale, Boggs Lake hedge-hyssop, Heckard's peppergrass, and legenere) are endemic to California. While specific soil requirements and micro-habitat restrictions vary somewhat between species, within the Plan Area, all are closely associated with the vernal pool complex natural community. Development, agricultural conversion, and exotic plant species are considered to be the primary stressors on these species (Showers 1996, Witham 2003, EDAW 2004, ESA 2005, Dawson et al. 2007, CNDDB 2009, CNPS 2009).

Applicable Natural Community Goals and Objectives

Goal VPNC1: The expected outcome is protected vernal pool complex natural community that represents a range of environmental conditions and is adjacent to other conserved lands.

> **Objective VPNC1.1**: Protect 300 acres of vernal pool complex in Conservation Zones 1, 8, and 11.

Goal VPNC2: The expected outcome is restored biologically diverse vernal pool complex natural community with improved native biodiversity, habitat heterogeneity, and the ability to support populations of covered and other native species.

> **Objective VPNC2.1**: Restore 200 acres of vernal pool complex natural community in Conservation Zones 1, 8, and/or 11 within patches of protected grassland that supports habitat for the western spadefoot toad, California tiger salamander, and the covered vernal pool shrimp and plant species.

> **Objective VPNC2.2**: Maintain and, where habitat functions for covered species can be enhanced, increase the diversity and relative cover of native grasses and forbs.

Species-Specific Goals and Objectives

Goal ALMV1: The expected outcome is protected and enhanced alkali milk-vetch populations.

> **Objective ALMV1.1**: Protect at least 3 unprotected occurrences of alkali milk-vetch in Conservation Zones 1 and/or 11.

> **Objective ALMV1.2:** Maintain and enhance the habitat functions of preserved alkali milk-vetch habitat over the term of the BDCP.

Goal HEPE1: The expected outcome is protected and enhanced Heckard's peppergrass populations.

> **Objective HEPE 1.2**: Protect at least 2 unprotected occurrences of Heckard's peppergrass in Conservation Zones 1, 8, or 11.

> **Objective HEPE1.2:** Maintain and enhance the habitat functions of preserved Heckard's peppergrass habitat over the term of the BDCP.

Rationale and Conservation Approach

Because habitat loss and exotic species are the primary stressors on vernal pool plants, protecting, enhancing, and restoring vernal pool complex natural community is expected to help maintain and potentially increase the abundance and distribution of these species. Conservation of vernal pool plant species will be directed at preserving and enhancing 300 acres and restoring 200 acres of vernal pool complex natural community (Figure 3-40) to improve habitat conditions for these species. Additionally, at least 3 unprotected occurrences of alkali milk-vetch and 2 unprotected occurrences of Heckard's peppergrass will be preserved and enhanced. Protection of vernal pool complex natural community will be achieved through the preservation and restoration of clay alluvium vernal pools and playa pools, Montezuma Block vernal pools and playa pools, and alkaline sink/meadow vernal pools (see Section 2.3.4.9, *Vernal Pool Complex*) that support vernal pool plant species in Conservation Zones 1, 8, and 11 (Figure 3-40) and will be conducted in conjunction with the preservation, enhancement, and restoration of grassland and alkali seasonal wetland complex natural communities in those conservation zones. To the extent practicable, vernal pool complex natural community will be protected and restored in the largest possible patch sizes and management of protected and restored vernal pool complex natural community (e.g., control of nonnative invasive species, restoration of natural hydrological regime, spatial linkages between patches of vernal pool complex natural community, etc.) will be designed to enhance habitat functions for vernal pool plant species and other covered vernal pool associated species.

The proposed protection and restoration of vernal pool complex natural community, in conjunction with existing protected habitat, is expected to sustain vernal pool plant species populations within the Plan Area and increase the distribution and abundance of covered vernal pool plant species. While vernal pool complex natural community supporting vernal pool plant species habitat is present in Conservation Zones 1, 2, 4, 8, 9, and 11 along the margins of the Plan Area, opportunities for the large scale conservation of vernal pool plant species within the Plan Area are located only in Conservation Zones 1, 8, and 11. Vernal pool complex natural community in Conservation Zones 2 and 4 is almost entirely under preserved status (99 percent) and vernal pool complex natural community in Conservation Zone 9 (approximately 120 acres) is located in the vicinity of Discovery Bay and is largely fragmented by development and cultivated lands.

The areas of vernal pool complex natural community within the Plan Area are located in areas that are transitional between tidal wetland communities and uplands and generally contain fragmented and degraded vernal pool complex natural community compared to areas immediately outside of the Plan Area. Because of this transitional location and due to a history of relatively intensive agricultural land uses, those areas contain little of the community that is occupied by robust populations of vernal pool plant species. Consequently, to increase the level of conservation benefits provided to vernal pool plant species relative to benefits that would be provided by implementing the conservation actions within the Plan Area, the vernal pool plant species conservation actions may be implemented within vernal pool plant species habitat core areas that are located outside of the Plan Area when consistent with conservation plans for those locations.

Following full implementation of the BDCP, 69 percent of the modeled vernal pool complex natural community in the Plan Area will be preserved (Table 3-10).

The conservation actions are consistent with and help to achieve the recovery objectives for alkali milk-vetch, Boggs Lake hedge-hyssop, and legenere identified in the Vernal Pool Recovery Plan (USFWS 2005).

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM9 Vernal Pool Complex Restoration
- CM11 Natural Communities Enhancement and Management

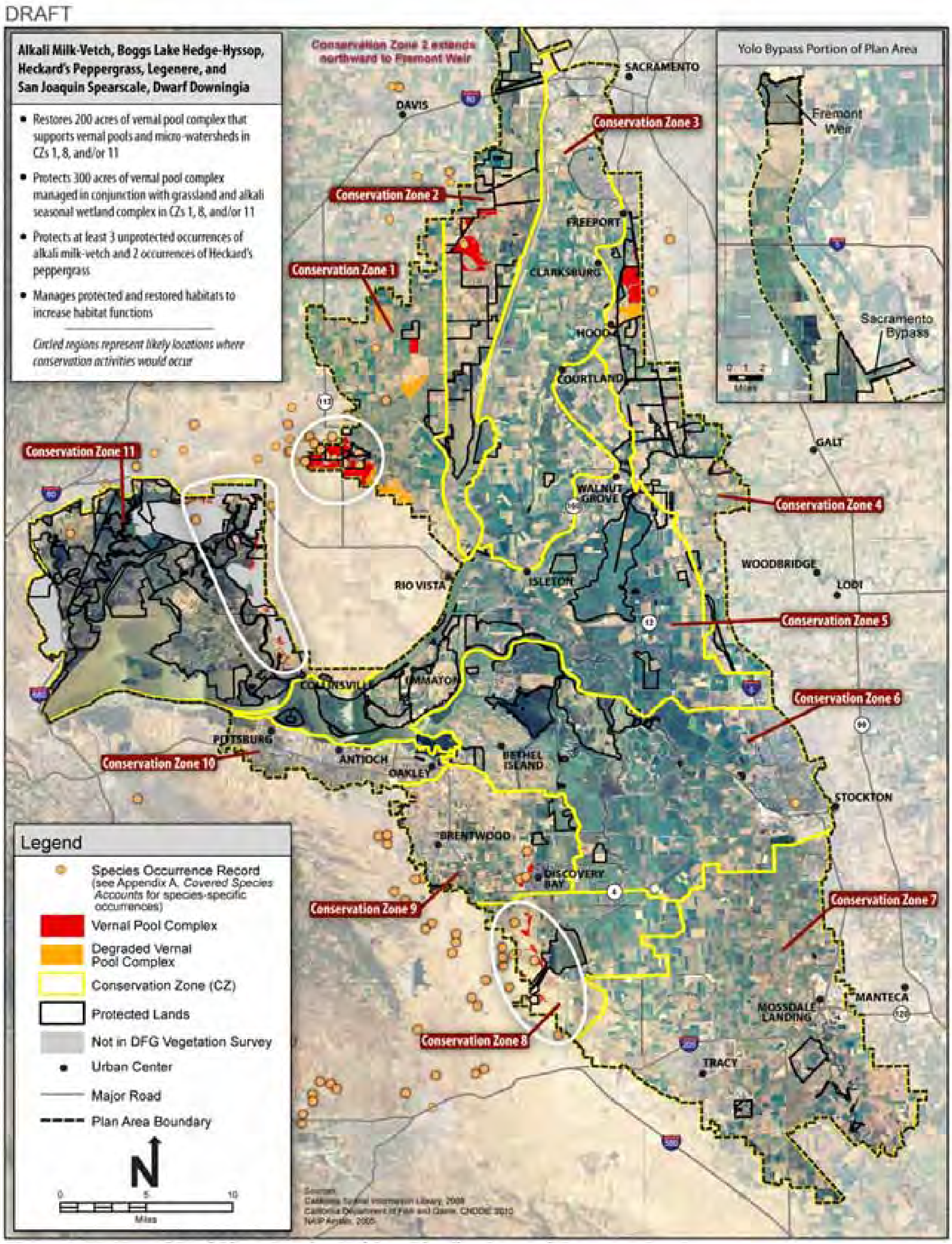

Figure 3-40. Vernal Pool Plant Species Habitat Distribution and Conservation Strategy

3.3.2.4.28 Heartscale and Brittlescale

Heartscale and brittlescale are found only in very limited habitat types in close proximity to hydrological features such as stream corridors and playa pools which are located on either alluvium associated with the Montezuma Block along the western boundary of the Plan Area or on alluvium associated with tertiary formations located along the southwest boundary of the Plan Area. The population sizes of the occurrences tend to be very small. Throughout its range it has been impacted by development, agricultural intensification, conversion of habitat to waterfowl habitat, and invasive species. BDCP tidal restoration activities could potentially affect some occurrences.

Applicable Natural Community Goals and Objectives

Goal GRNC1: The expected outcome is grassland comprised of large interconnected patches or contiguous expanses.

> **Objective GRNC1.1**: Protect a minimum of 8,000 acres of grassland in Conservation Zones 1, 8, and 11. At least 1,000 acres will be protected in Conservation Zone 8, with the remainder distributed throughout these three Conservation Zones.

> **Objective GRNC1.2**: Restore 2,000 acres of grassland to connect fragmented patches of protected grassland.

Goal GRNC2: The expected outcome is biologically diverse grassland managed to enhance native species and sustained by natural ecological processes.

> **Objective GRNC2.1**: Restore and sustain a mosaic of grassland vegetation alliances, reflecting local water availability, soil chemistry, soil texture, topography, and disturbance regimes, with consideration of historical states.

> **Objective GRNC2.2**: Increase the relative cover of native grasses and forbs in native grassland vegetation alliances.

Goal AWNC1: The expected outcome is protected alkali seasonal wetland complex natural community that represents a range of environmental conditions and is adjacent to other conserved lands.

> **Objective AWNC1.1**: Protect 400 acres of alkali seasonal wetland complex natural community in Conservation Zones 1, 8, and/or 11.

Goal AWNC2: The expected outcome is biologically diverse alkali seasonal wetland complex natural community with improved native biodiversity, habitat heterogeneity, and the ability to support populations of covered and other native species.

> **Objective AWNC2.1**: Maintain and, where habitat functions for covered species can be increased, increase the diversity and relative cover of native grasses and forbs.

Goal VPNC1: The expected outcome is protected vernal pool complex natural community that represents a range of environmental conditions and is adjacent to other conserved lands.

> **Objective VPNC1.1**: Protect 300 acres of vernal pool complex in Conservation Zones 1, 8, and 11.

Goal VPNC2: The expected outcome is restored biologically diverse vernal pool complex natural community with improved native biodiversity, habitat heterogeneity, and the ability to support populations of covered and other native species.

> **Objective VPNC2.1**: Restore 200 acres of vernal pool complex natural community in Conservation Zones 1, 8, and/or 11 within patches of protected grassland that supports habitat for the western spadefoot toad, California tiger salamander, and the covered vernal pool shrimp and plant species.

> **Objective VPNC2.2**: Maintain and, where habitat functions for covered species can be enhanced, increase the diversity and relative cover of native grasses and forbs.

Species-Specific Goals and Objectives

Goal HART/BRIT1: The expected outcome is protected and expanded alkali seasonal wetland complex natural community-associated covered species populations.

> **Objective HART/BRIT1.1:** Of the 400 acres of protected alkali seasonal wetland complex natural community, protect 150 acres that support heartscale and brittlescale habitat.

> **Objective HART/BRIT1.2**: Protect at least 3 unprotected occurrences of heartscale in Conservation Zones 1 and /or 11.

> **Objective HART/BRIT1.3**: Protect at least 3 unprotected occurrences of brittlescale in Conservation Zones 1, 8, or 11.

> **Objective HART/BRIT1.4**: Maintain and enhance the habitat functions of preserved heartscale and brittlescale habitat over the term of the BDCP.

Rationale and Conservation Approach

Heartscale and brittlescale are both endemic to California and within the Plan Area are found in meadows, seeps, and vernal pools with alkaline clay soils (CNPS 2009). The primary stressors to these species are agricultural intensification, development, nonnative plants, overgrazing, and trampling (CNDDB 2009, CNPS 2009). Because habitat loss and incompatible land management practices are the primary stressors on these species, preserving and enhancing heartscale and brittlescale habitat is expected to help maintain and potentially increase the abundance and distribution of these species.

Conservation of heartscale and brittlescale will be directed at known occurrences and protecting and enhancing currently unprotected heartscale and brittlescale habitat that supports the known elements (e.g., soils, hydrology) of their habitat. Priority will be given to protecting three unprotected occurrences and protecting habitat that supports species occurrences or is within the watersheds that support known occurrences. Conservation will be provided through protecting and enhancing 150 acres of stream corridors and appropriate buffers on alkaline soils in the same general locations as clay alluvium vernal pools and playa pools, Montezuma Block vernal pools and playa pools, and alkaline sink/meadow vernal pools and associated grassland and alkali seasonal wetland complex (see Section 2.3.4.9, *Vernal Pool Complex*) that support heartscale and brittlescale habitat in Conservation Zones 1, 8, and 11 (Figure 3-41).

Protection and enhancement of their habitat will be conducted in conjunction with the protection, enhancement, and restoration of grassland, alkali seasonal wetland complex, and vernal pool complex natural communities in those Conservation Zones. To the extent practicable, heartscale and brittlescale habitat will be protected in the largest possible linear corridor extents, and management of protected habitat (e.g., control of nonnative invasive species, restoration of natural hydrological regime, appropriate grazing intensity, etc.) will be designed to enhance habitat functions for heartscale, brittlescale and other covered associated species. Following full implementation of the BDCP, 277 acres (56 percent) of the modeled heartscale and brittlescale habitat in the Plan Area will be protected (Table 3-10).

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM8 Grassland Communities Restoration
- CM9 Vernal Pool Complex Restoration
- CM11 Natural Communities Enhancement and Management

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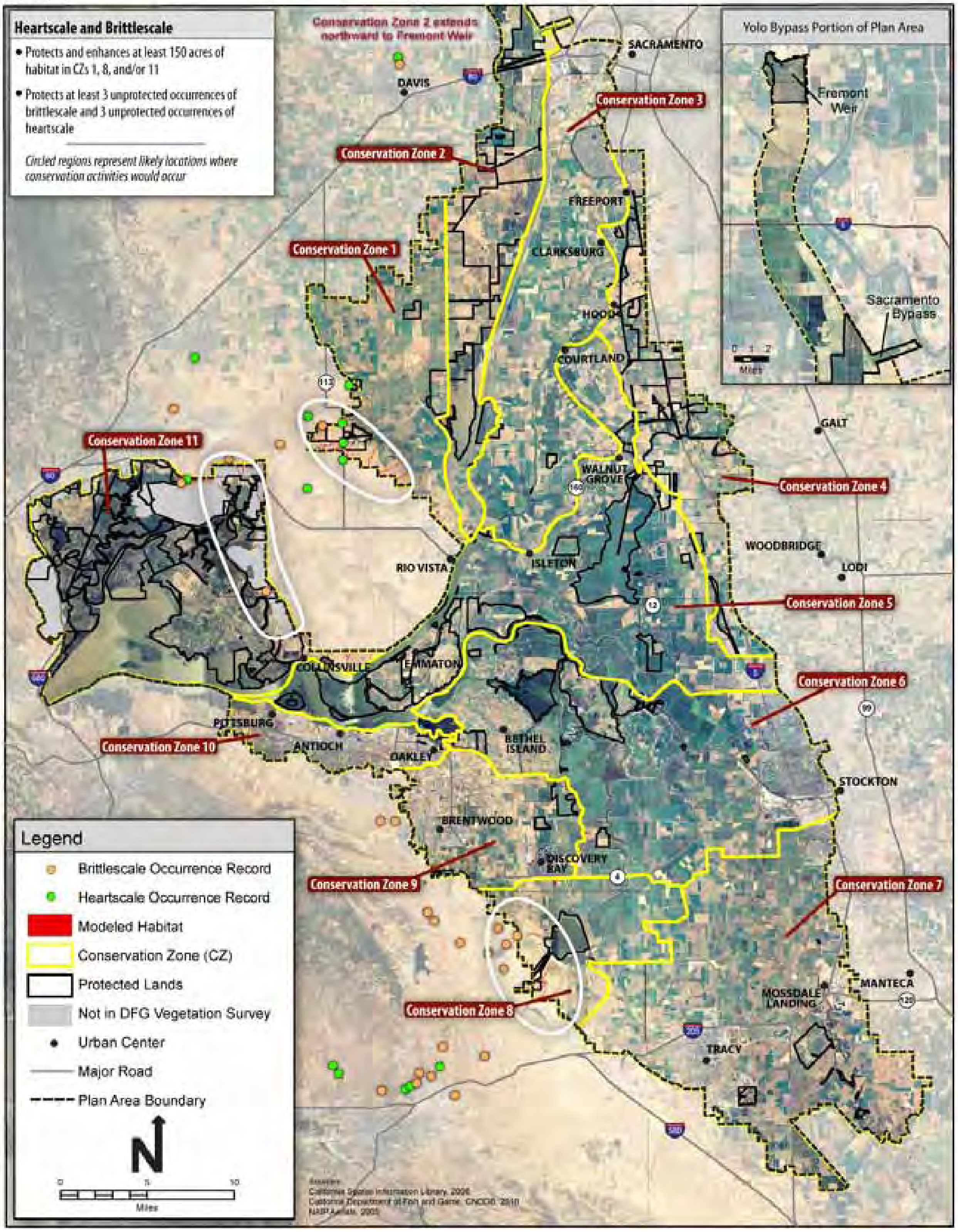

Figure 3-41. Heartscale and Brittlescale Habitat Distribution and Conservation Strategy

3.3.2.4.29 Slough Thistle

Slough thistle is endemic to the San Joaquin Valley and has been reported from San Joaquin County in the north and in Kings and Kern counties in the south (CNPS 2009). Slough thistle occurs in the southern end of the Plan Area in the San Joaquin River. There are seven records from near Lathrop and Vernalis; all but two of which have been extirpated by agriculture or urbanization (CNDDB 2009). The locations reported in the southern San Joaquin Valley are all along or adjacent to high flood flow areas (CNDDB 2009). Historically slough thistle was likely present in lesser flow channels as well. It is generally found within the portions of river channels that flood at high water and on the banks of flood water conveyance canals and drains (T. Griggs pers. comm. 2009, R. Hansen pers. comm. 2009). Historical and current records of this species indicate that its distribution within the Plan Area is limited to the floodplain of the San Joaquin River (Figure 3-42). Based on its distribution in the southern San Joaquin Valley, its habitat is likely to be areas along the river that have been disturbed by flood events and are being colonized by willow scrub vegetation.

Conversions of suitable habitat to agricultural land uses and competition from nonnative plants have been reported as the primary threats to slough thistle (CNPS 2009). In the southern San Joaquin Valley, other threats include removing vegetation from the banks of drains and canals, and weed control efforts (T. Griggs pers. comm. 2009, R. Hansen pers. comm. 2009).

Slough thistle has been reported from freshwater marshes and swamps, and in chenopod scrub and riparian scrub habitats (CNPS 2009). Under natural conditions, it almost always occurs in wetlands (Calflora 2009). The locations reported in the southern San Joaquin Valley are all along or adjacent to high flood flow areas (CNDDB 2009) such as the Hacienda Spillway where high flows from the Kern River broke through the Sand Ridge and flowed into Tulare Lake (R. Hansen pers. comm. 2009). Because these high flow areas have been preserved, albeit in a modified condition, for floodwater conveyance, some habitat has been preserved in what is now an area of intensive agricultural production. Historically slough thistle was likely present throughout the Tulare Basin in lesser flow channels as well. It is generally found within the portions of channels that flood at high water and on the banks of flood water conveyance canals and drains (T. Griggs pers. comm. 2009, R. Hansen pers. comm. 2009).

Applicable Natural Community Goals and Objectives

Goal VRNC1: The expected outcome is restored large expanses and interconnected corridors of valley/foothill riparian natural community.

> **Objective VRNC1.1**: Restore or create 5,000 acres of valley/foothill riparian in Conservation Zones 1, 2, 4, 5, 6, 7, and/or 11.

Goal VRNC2: The expected outcome is biologically diverse valley/foothill riparian natural community that supports native species and is sustained by natural ecological processes.

> **Objective VRNC2.1**: Maintain and enhance the habitat and ecosystem functions of BDCP restored valley/foothill riparian and patches of riparian forest and scrub present on BDCP preserved lands over the term of the BDCP.

> **Objective VRNC2.3**: Restore connectivity of valley/foothill riparian corridors along linear watercourses to enhance habitat for covered species and facilitate wildlife movement.

Rationale and Conservation Approach

Conservation of slough thistle will be directed at restoring floodplain habitat along the San Joaquin River that provides slough thistle habitat which consists of seasonally scoured areas within the floodplain and corresponding channel morphology (Figure 3-42). Reestablishing patterns of flood flows to floodplain that were historically occupied by this species is expected to sustain the species within the Plan Area and provide for increases in species distribution and abundance.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM5 Seasonally Inundated Floodplain Restoration
- CM7 Riparian Habitat Restoration
- CM11 Natural Communities Enhancement and Management

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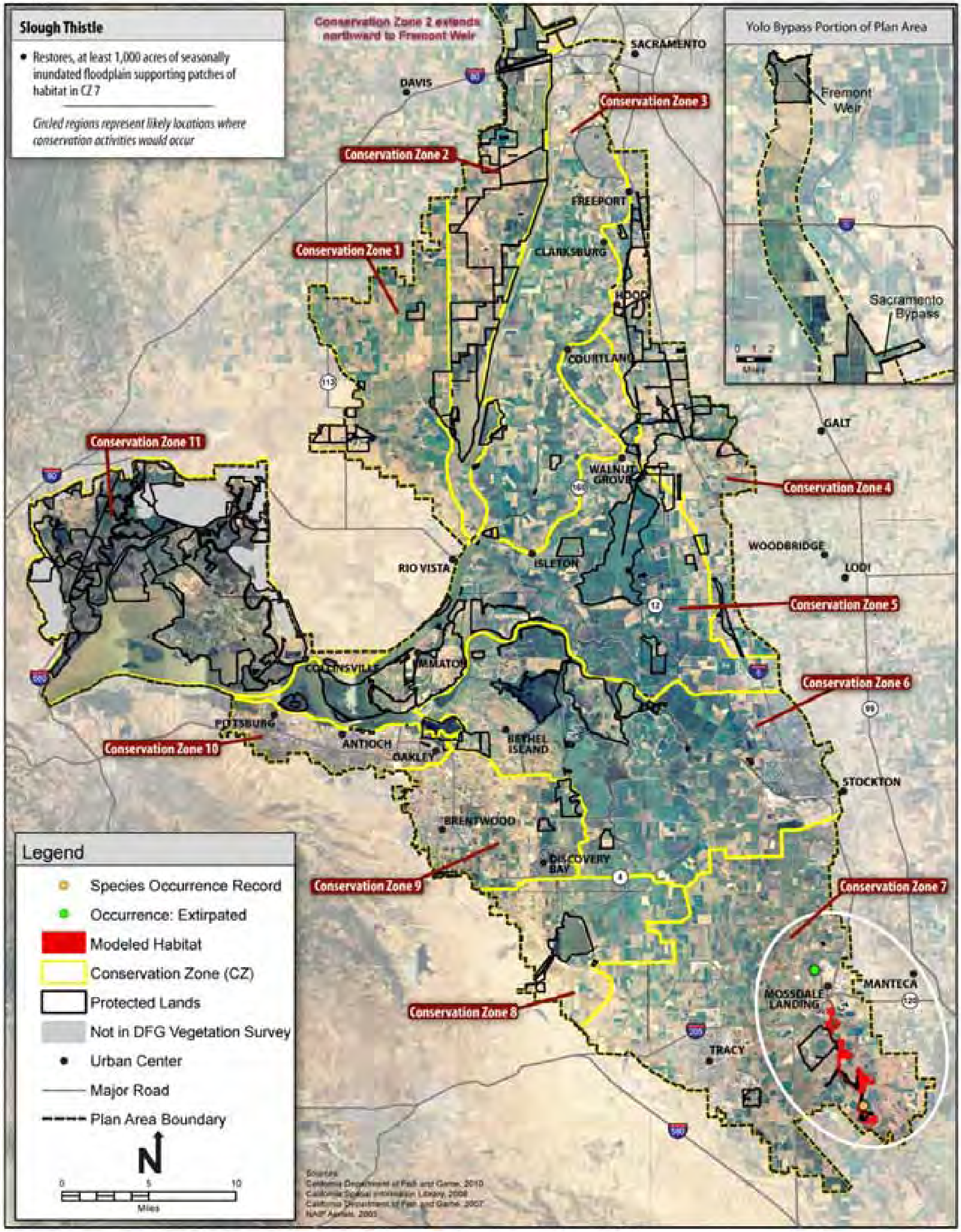

Figure 3-42. Slough Thistle Habitat Distribution and Conservation Strategy

3.3.2.4.30 Suisun Thistle and Soft Bird's-beak

Suisun thistle and soft bird's-beak co-occur in Suisun Marsh. Suisun thistle is found only in the tidal brackish marshes of Suisun Marsh (62 FR 61916, USFWS 2009a, b) and is almost always found adjacent to first-order channels or mosquito control ditches that link to first-order channels (Fiedler et al. 2007, USFWS 2009a, b). In 1975, Suisun thistle was presumed to be extinct because it had not been observed for 15 years (62 FR 61916, USFWS 2009a); however, extensive surveys conducted at Suisun Marsh in 1989 rediscovered this species at two locations. Historically, the range of soft bird's-beak extended from tidal marshes of Napa and Solano counties in the north, Contra Costa County in the south, Sonoma and Marin counties in the west, and Sacramento and San Joaquin counties in the east. It is now believed to be extirpated from Marin, San Joaquin, Sonoma, and Sacramento counties; and extant in Napa, Solano, and Contra Costa counties (CNDDB 2010).

The tidal brackish emergent wetland natural community that is suitable habitat for Suisun thistle and soft bird's-beak has been lost mostly through development, dredge disposal, waterfowl habitat creation, agricultural conversion, and diking of tidal marshes. Diked marshes generally lack rare tidal marsh species. It is believed that the conditions brought about by dikes favor robust generalist species that can better tolerate the long inundation periods in diked managed wetlands (Goals Project 2000). Current threats to Suisun thistle include: the nonnative and highly invasive perennial pepperweed, feral pigs, and fire during sensitive periods of the species' lifecycle (Fiedler et al. 2007, USFWS 2009a). Other potential but unquantified threats specific to Suisun thistle include hybridization with bull thistle and seed predation by the introduced biocontrol thistle weevil (Fiedler et al. 2007, USFWS 2009a). Threats specific to soft bird's-beak include overgrazing and trampling by livestock and the invasion of its habitat by nonnative annual plants that are inappropriate hosts, and invasion of its habitat by perennial pepperweed (Grewell et al. 2003, Grewell 2005, Fiedler et al 2007, CNDDB 2008, USFWS 2009b, USFWS 2010).

Applicable Natural Community Goals and Objectives

Goal BMNC1: The expected outcome is restored large expanses and interconnected patches of tidal brackish emergent wetland natural community.

> **Objective BMNC1.1**: Restore or create 3,600 to 4,800 acres of tidal brackish emergent wetland in the Suisun Marsh ROA (Conservation Zone 11).

Goal BMNC2: The expected outcome is biologically diverse tidal brackish emergent wetland that is enhanced for native species and sustained by natural ecological processes.

> **Objective BMNC2.1:** Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal brackish emergent wetland for covered and other native species over the term of the BDCP.

Species-Specific Goals and Objectives

Goal SUTH1: The expected outcome is protected and expanded Suisun thistle populations.

> **Objective SUTH1.1:** Protect 3 unprotected occurrences of Suisun thistle in Suisun Marsh in Conservation Zone 11.

> **Objective SUTH1.2**: Maintain and enhance the habitat functions of preserved Suisun thistle habitat over the term of the BDCP.

Goal SOBB1: The expected outcome is protected and expanded soft bird's-beak populations.

> **Objective SOBB1.1:** Protect 3 unprotected occurrences of soft bird's-beak in Suisun Marsh in Conservation Zone 11.

> **Objective SOBB1.2**: Maintain and enhance the habitat functions of preserved soft bird's-beak habitat over the term of the BDCP.

Rational and Conservation Approach

Conservation of Suisun thistle and soft bird's-beak will be directed at protecting 3 unprotected occurrences of each species and restoring 3,600-4,800 acres[29] of tidal brackish emergent wetland that supports the known elements (e.g., soils, hydrology, etc.) of their habitat (Figures 3-43 and 3-44). The conservation actions are consistent with and help to achieve the draft recovery objectives for Suisun thistle and soft bird's-beak identified in the Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California (USFWS 2010).

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM4 Tidal Habitat Restoration
- CM11 Natural Communities Enhancement and Management

[29] Restored tidal habitat acreage ranges are a component of the 65,000 acre target for restored tidal habitat. Acreage ranges are based on the results of hydrodynamic modeling of realistic hypothetical restoration designs. While these ranges are not the acreage targets for restored tidal habitats, but rather the results of modeling, the hypothetical designs provided verification of the practicability of achieving restoration targets.

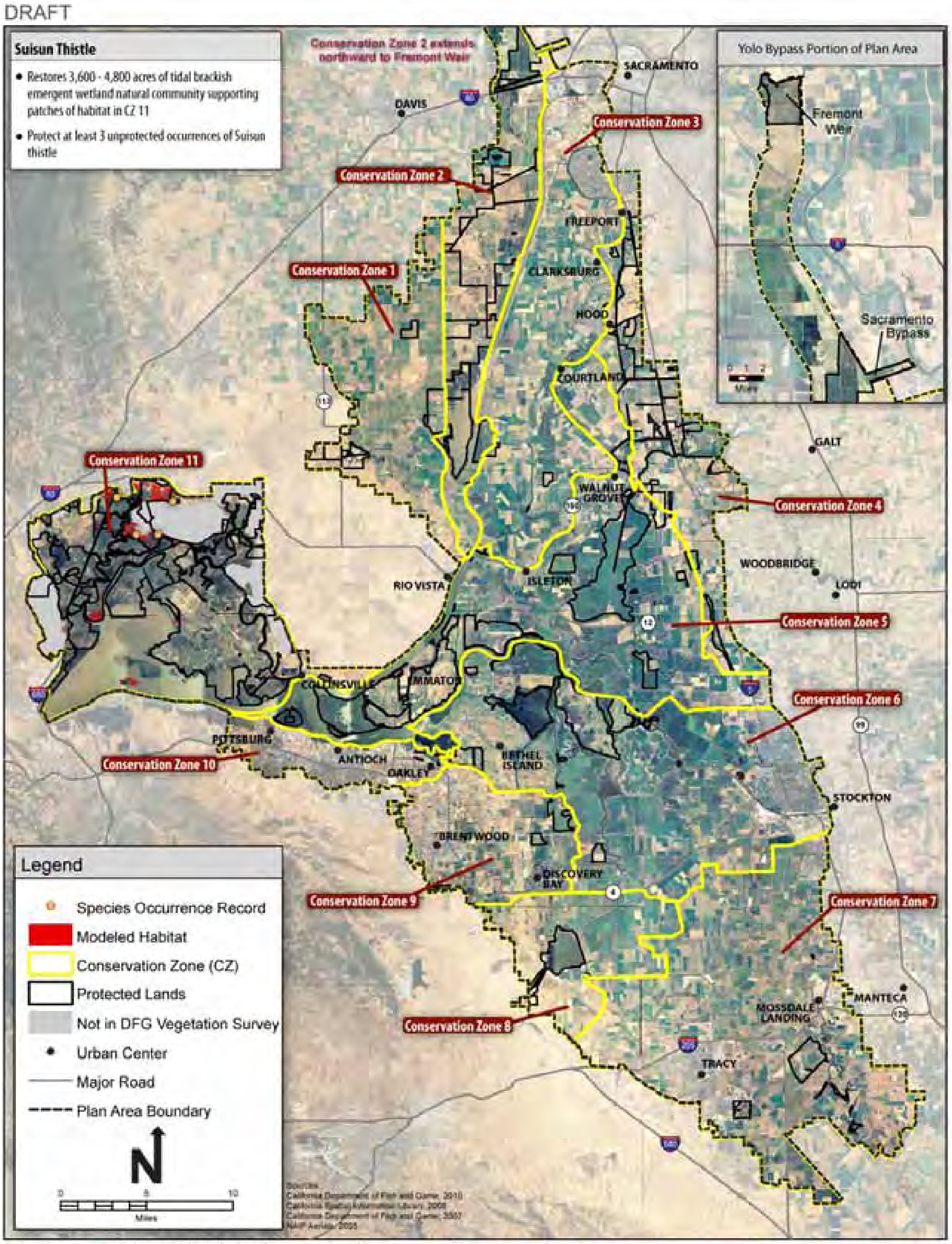

Figure 3-43. Suisun Thistle Habitat Distribution and Conservation Strategy

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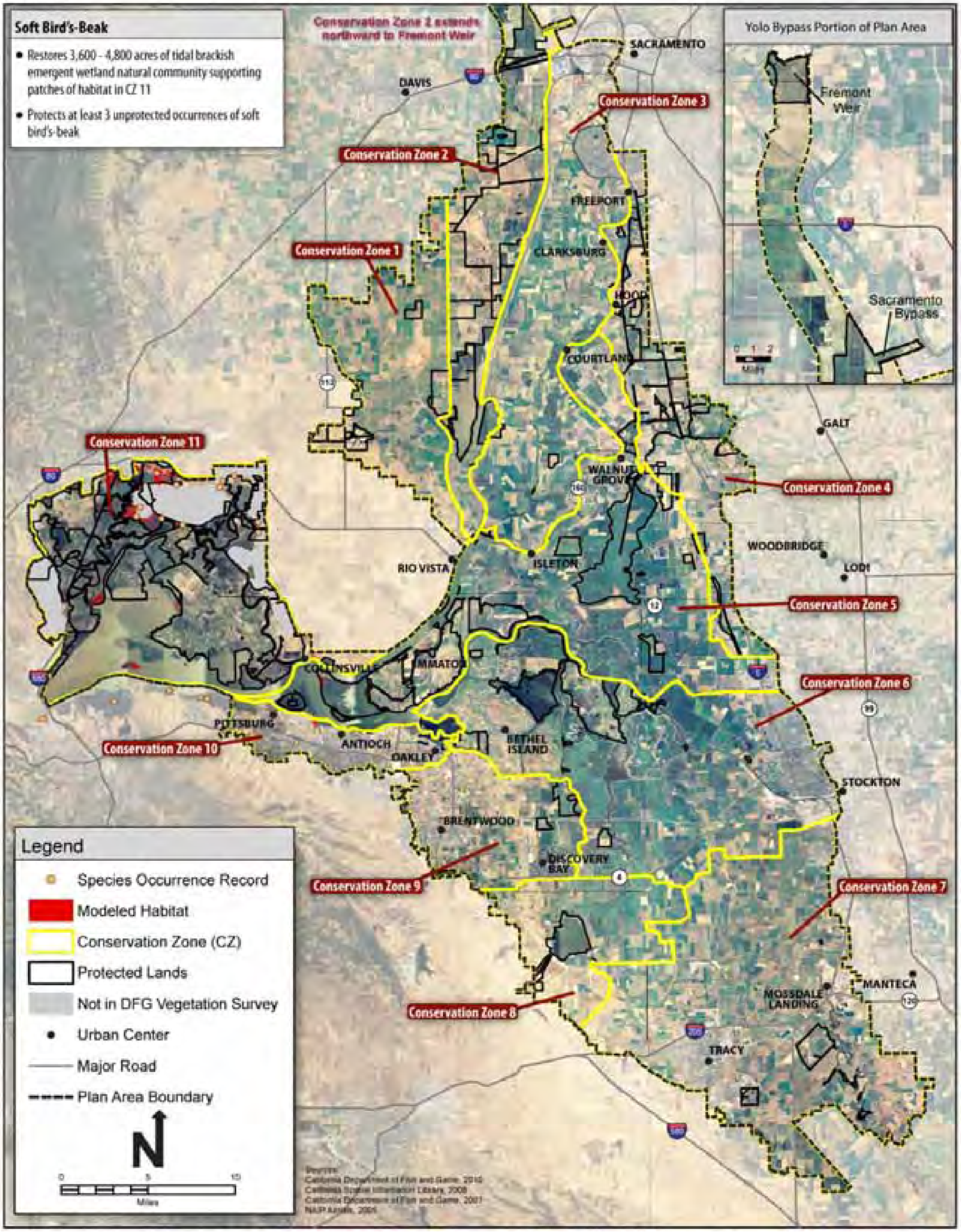

Figure 3-44. Soft Bird's-Beak Habitat Distribution and Conservation Strategy

3.3.2.4.31 Delta Button-celery

Delta button-celery is endemic to the San Joaquin Valley of California and is listed as endangered under the California Endangered Species Act (see Appendix A, *Covered Species Accounts*). It occurs in two habitat types: (1) seasonally scoured and inundated swales, depressions, and clay flats in the floodplain of the San Joaquin River (D. Woolington pers. comm.); (2) alkaline clay deltas of Coast Range tributaries that are deposited immediately above the flood basin of the San Joaquin River where plant cover is typical alkaline sink vegetation (NatureServe 2008). The primary threats to Delta button-celery include habitat loss through agricultural habitat conversion, channelization and channel maintenance activities and other impacts that include overgrazing, invasive nonnative plant species. Six of all 26 recorded occurrences have been extirpated by agricultural expansion and disturbance (NatureServe 2008). Thus, where the Delta button-celery still occurs – including both locations where it has been recorded in the Plan Area, land preservation is important to protect it from any further extirpation. BDCP implementation will tie in with habitat preservation on public lands such as Caswell Memorial State Park and the San Joaquin County Multi-species Habitat Conservation and Open Space Plan.

Applicable Natural Community Goals and Objectives

Goal VRNC1: The expected outcome is restored large expanses and interconnected corridors of valley/foothill riparian natural community.

> **Objective VRNC1.1**: Restore or create 5,000 acres of valley/foothill riparian in Conservation Zones 1, 2, 4, 5, 6, 7, and/or 11.

Goal VRNC2: The expected outcome is biologically diverse valley/foothill riparian natural community that supports native species and is sustained by natural ecological processes.

> **Objective VRNC2.1**: Maintain and enhance the habitat and ecosystem functions of BDCP restored valley/foothill riparian and patches of riparian forest and scrub present on BDCP preserved lands over the term of the BDCP.

> **Objective VRNC2.3**: Restore connectivity of valley/foothill riparian corridors along linear watercourses to enhance habitat for covered species and facilitate wildlife movement.

Goal AWNC1: The expected outcome is protected alkali seasonal wetland complex natural community that represents a range of environmental conditions and is adjacent to other conserved lands.

> **Objective AWNC1.1**: Protect 400 acres of alkali seasonal wetland complex natural community in Conservation Zones 1, 8, and/or 11.

Goal AWNC2: The expected outcome is biologically diverse alkali seasonal wetland complex natural community with improved native biodiversity, habitat heterogeneity, and the ability to support populations of covered and other native species.

Objective AWNC2.1: Maintain and, where habitat functions for covered species can be increased, increase the diversity and relative cover of native grasses and forbs.

Species-Specific Goals and Objectives

Goal DEBC1: The expected outcome is protected and expanded Delta button-celery populations.

Objective DEBC1.1: Of the 400 acres of protected alkali seasonal wetland complex natural community, protect at least 100 acres that support Delta button-celery habitat.

Objective DEBC1.2: Maintain and enhance the habitat functions of preserved Delta button-celery habitat over the term of the BDCP.

Rationale and Conservation Approach

Conservation of Delta button-celery will be directed at preserving at least 100 acres of currently unprotected alkali seasonal wetland complex that supports the known elements (e.g., soils, hydrology, etc.) of one of its habitat types and restoring at least 1,000 acres of floodplain habitat along the San Joaquin River that provide its other form of habitat which consists of seasonally scoured areas within the floodplain and channel (Figure 3-45). Protection of existing unprotected habitat will occur in Conservation Zone 8 and priority will be given to protecting habitat that supports occurrences or which will connect patches of occupied habitat. Restored floodplain habitat will be restored in Conservation Zone 7 and will be designed and managed to support patches of suitable habitat (e.g., soils, flood disturbance regime, etc.) (Figure 3-45). If appropriate, this species may be translocated to establish new occurrences within restored habitat. Protecting remaining occupied habitat areas and reestablishing patterns of flood flows to floodplain historically occupied by this species is expected to sustain the species within the Plan Area and provide for increases in the species distribution and abundance.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM5 Seasonally Inundated Floodplain Restoration
- CM7 Riparian Habitat Restoration
- CM11 Natural Communities Enhancement and Management

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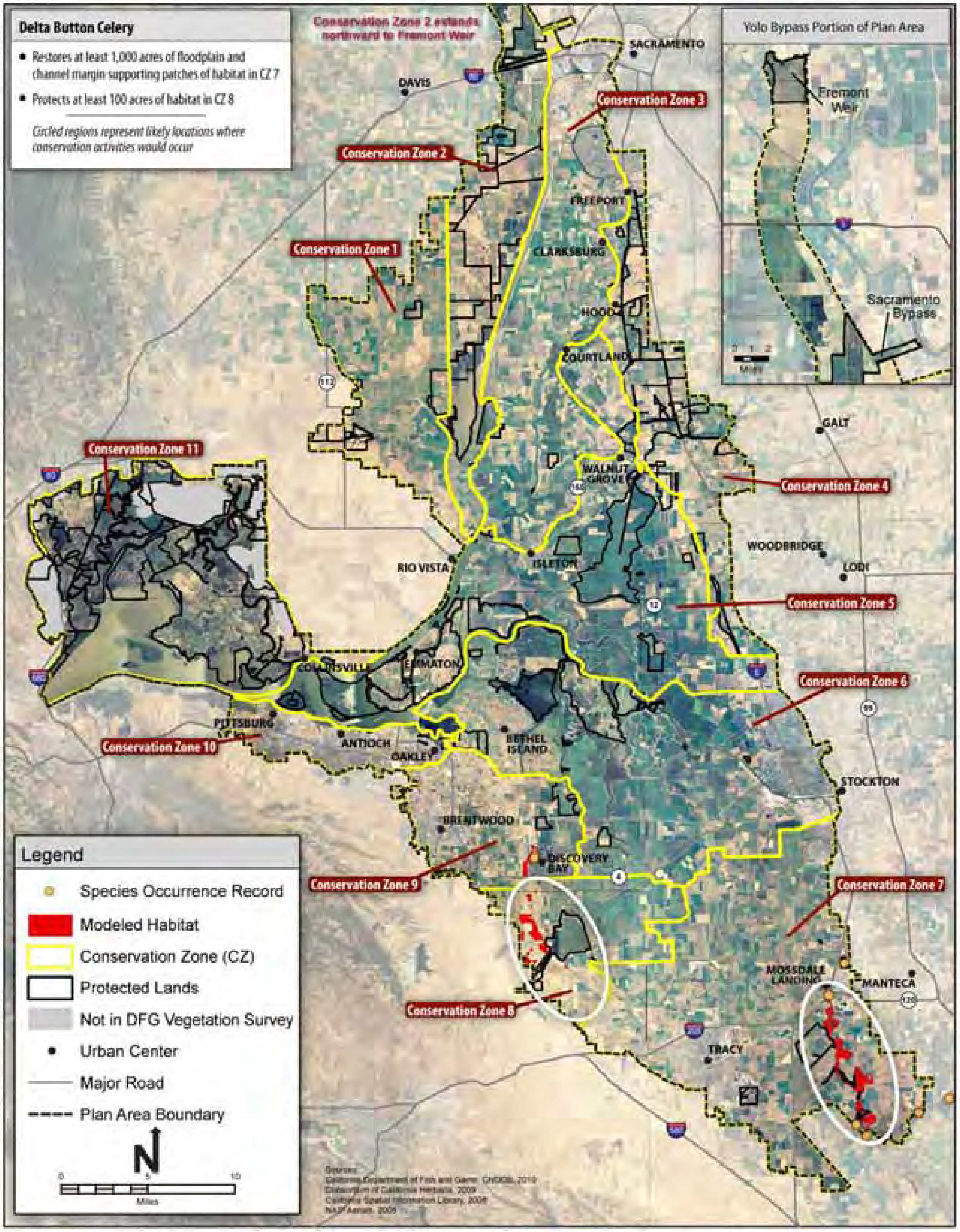

Figure 3- 45. Delta Button Celery Habitat Distribution and Conservation Strategy

3.3.2.4.32 Contra Costa Wallflower and Antioch Dunes Evening Primrose

Contra Costa wallflower and Antioch Dunes evening primrose are listed as endangered under both the federal Endangered Species Act and the California Endangered Species Act. They are endemic to the former Antioch Dune and persist on the small remnant of the dune. The extent of the former dune has been reduced to 20 acres plus an unknown amount on two Pacific Gas & Electric (PG&E) parcels that total 12 acres. The 20-acre known extent is protected on the Antioch Dunes National Wildlife Refuge (ADNWR) while the PG&E parcels are being managed under an MOU with USFWS. All existing habitat has been degraded by nonnative invasive plant species.

The current USFWS management plan for the ADNWR provides for invasive nonnative plant species control efforts that include hand pulling of individual invasive plants through the efforts of volunteers, targeted herbicide application, the restoration of some dune-like topography, and the planting of nursery grown stock and seed of Contra Costa wallflower and Antioch Dunes evening primrose.

The known natural occurrences of Contra Costa wallflower and Antioch Dunes evening primrose within the Plan Area are located exclusively within the ADNWR and on the two adjacent PG&E properties and are fully protected by ownership and conservation MOUs. These protected lands are completely isolated from other terrestrial habitats by development to the west, south, and east, and by the San Joaquin River to the north. Consequently, to increase the level of conservation benefits provided to inland dune scrub species, the inland dune scrub conservation will be implemented through the funding support of appropriate management actions and studies.

Applicable Natural Community Goals and Objectives

Goal IDSC1: The expected outcome is support for funding of the USFWS management and enhancement of the inland dune scrub natural community on the Antioch Dunes National Wildlife Refuge.

> **Objective IDSC1.1:** The BDCP will support the funding of the USFWS program for management, enhancement, and monitoring of inland dune scrub natural community on the Antioch Dunes National Wildlife Refuge at an annual amount of $XX.XX for X years.

Species-Specific Goals and Objectives

Goal CCWF/ADEP1: The expected outcome is funding support for the USFWS implementation of the propagation and out-planting program for Contra Costa wallflower and Antioch Dunes evening primrose.

> **Objective CCWF/ADEP1.1:** The BDCP will support the funding of the USFWS program for propagation and out-planting program for Contra Costa wallflower and Antioch Dunes evening primrose at an annual amount of $XX.XX for X years.

Rationale and Conservation Approach

After the recent 5-year review of the recovery plan by USFWS found that Contra Costa wallflower and Antioch Dunes evening primrose were declining significantly at the ADNWR and appeared to be headed towards extinction, USFWS began an out-planting of nursery grown stock and direct seeding into restored sandy habitat in 2005 and 2006 which appears to have stopped the decline. However, the populations are not yet considered to be self-sustaining because of invasive species problems (USFWS 2008). The current ADNWR management plan is designed to meet the recovery needs for the species of the ADNWR and provides for invasive nonnative plant species control efforts, restoration of dune-like topography, and the out-planting of nursery-grown stock and seed.

Conservation of Contra Costa wallflower and Antioch Dunes evening primrose will be provided through the support of funding for the USFWS planting and seeding program and its management of the ADNWR (Figure 3-46).

Applicable Conservation Measures

- CM11 Natural Communities Enhancement and Management

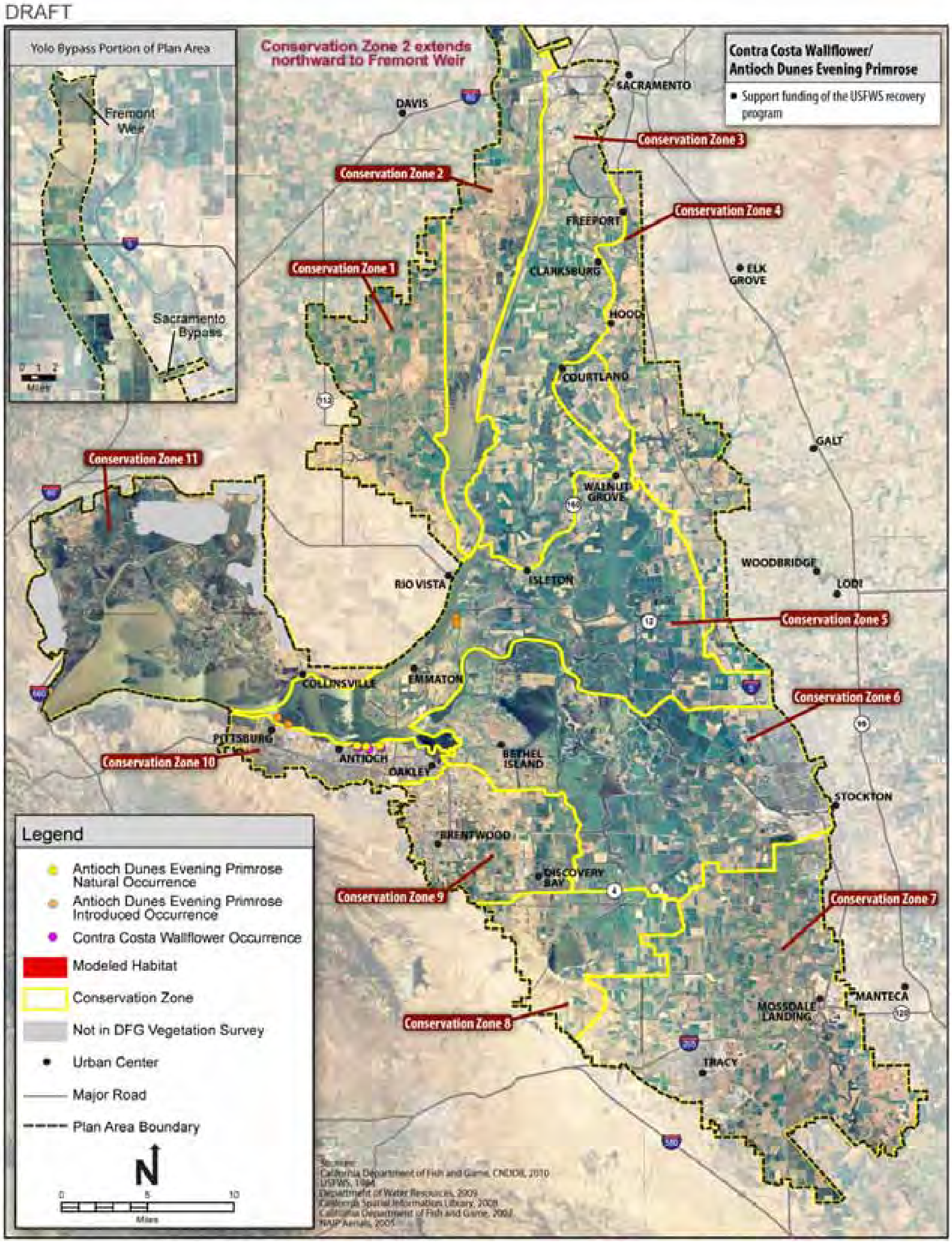

Figure 3- 46. Contra Costa Wallflower and Antioch Dunes Evening Primrose Habitat Distribution and Conservation Strategy

3.3.2.4.33 Carquinez Goldenbush

Carquinez goldenbush is known only from a very limited geographic range in Solano County, California (Nesom 1991, Hickman 1993, CNDDB 2009, CNPS 2009). It appears to be restricted to alluvial soils along ephemeral drainages associated with the Tehama geological formation and the Montezuma Block north and west of the Montezuma Hills in Solano County (Hickman 1993, Graymer et al. 2002, CNPS 2009, NRCS 2009). Carquinez goldenbush has been affected by agricultural land conversion, grazing, road widening, and development (CNPS 2009). Because Carquinez goldenbush is known only from 13 occurrences and its small populations are within the potential Impacts Area and in adjacent area immediately outside of the Plan and Impacts Areas, the emphasis of BDCP conservation measures will be on the protection of land with potential Carquinez goldenbush habitat.

Applicable Natural Community Goals and Objectives

Goal GRNC1: The expected outcome is grassland comprised of large interconnected patches or contiguous expanses.

> **Objective GRNC1.1**: Protect a minimum of 8,000 acres of grassland in Conservation Zones 1, 8, and 11. At least 1,000 acres will be protected in Conservation Zone 8, with the remainder distributed throughout these three Conservation Zones.

> **Objective GRNC1.2**: Restore 2,000 acres of grassland to connect fragmented patches of protected grassland.

Goal GRNC2: The expected outcome is biologically diverse grassland managed to enhance native species and sustained by natural ecological processes.

> **Objective GRNC2.1**: Restore and sustain a mosaic of grassland vegetation alliances, reflecting local water availability, soil chemistry, soil texture, topography, and disturbance regimes, with consideration of historical states.

> **Objective GRNC2.2**: Increase the relative cover of native grasses and forbs in native grassland vegetation alliances.

Goal AWNC1: The expected outcome is protected alkali seasonal wetland complex natural community that represents a range of environmental conditions and is adjacent to other conserved lands.

> **Objective AWNC1.1**: Protect 400 acres of alkali seasonal wetland complex natural community in Conservation Zones 1, 8, and/or 11.

Goal AWNC2: The expected outcome is biologically diverse alkali seasonal wetland complex natural community with improved native biodiversity, habitat heterogeneity, and the ability to support populations of covered and other native species.

> **Objective AWNC2.1**: Maintain and, where habitat functions for covered species can be increased, increase the diversity and relative cover of native grasses and forbs.

Species-Specific Goals and Objectives

Goal CAGB1: The expected outcome is protected and expanded Carquinez goldenbush populations.

> **Objective CAGB1.1:** Protect at least 3 unprotected occurrences of Carquinez goldenbush in Conservation Zones 1 and/or 11.

> **Objective CAGB1.2**: Maintain and enhance the habitat functions of preserved Carquinez goldenbush habitat over the term of the BDCP.

Rationale and Conservation Approach

Conservation of Carquinez goldenbush will be directed at preserving 300 acres of currently unprotected habitat that supports the known elements (e.g., soils, hydrology, etc.) of its habitat and 3 unprotected occurrences (Figure 3-47). Priority will be given to protecting habitat that supports occurrences or are connected to occupied habitat in Conservation Zones 1 and 11 (Figure 3-47). Protection of Carquinez goldenbush habitat will be achieved through the preservation and enhancement of its habitat in stream corridors with appropriate buffers and in localized patches along the margin of Suisun Marsh in the same general locations as Montezuma Block vernal pools and playa pools and associated grassland and alkali seasonal wetland complex natural communities (see Section 2.3.4.9, *Vernal Pool Complex*) in Conservation Zones 1 and 11 (Figure 3-47).

Protection and enhancement of Carquinez goldenbush habitat will be conducted in conjunction with the protection, enhancement, and restoration of grassland and alkali seasonal wetland complex natural communities in that conservation zone. To the extent practicable, Carquinez goldenbush habitat will be protected in the largest possible linear corridor extents and management of protected habitat (e.g., control of nonnative invasive species, restoration of natural hydrological regime, appropriate grazing intensity, etc.) will be designed to enhance habitat functions for Carquinez goldenbush and other covered associated species.

Protected habitat will be incorporated within larger patches of protected grassland and vernal pool complex habitats that will complement their wetland habitat functions and will be managed to improve habitat conditions for these species (e.g., control of invasive nonnative plant species). If desirable and consistent with adjacent conservation plans, unpreserved occupied habitat may be protected adjacent to the Plan Area.

The protection of Carquinez goldenbush habitat is expected to help maintain and provide the basis for potentially increasing the distribution and abundance Carquinez goldenbush in the Plan Area. Following implementation of BDCP actions, approximately 67 percent of the species' habitat will be preserved in the Plan Area.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM8 Grassland Communities Restoration
- CM9 Vernal Pool Complex Restoration
- CM11 Natural Communities Enhancement and Management

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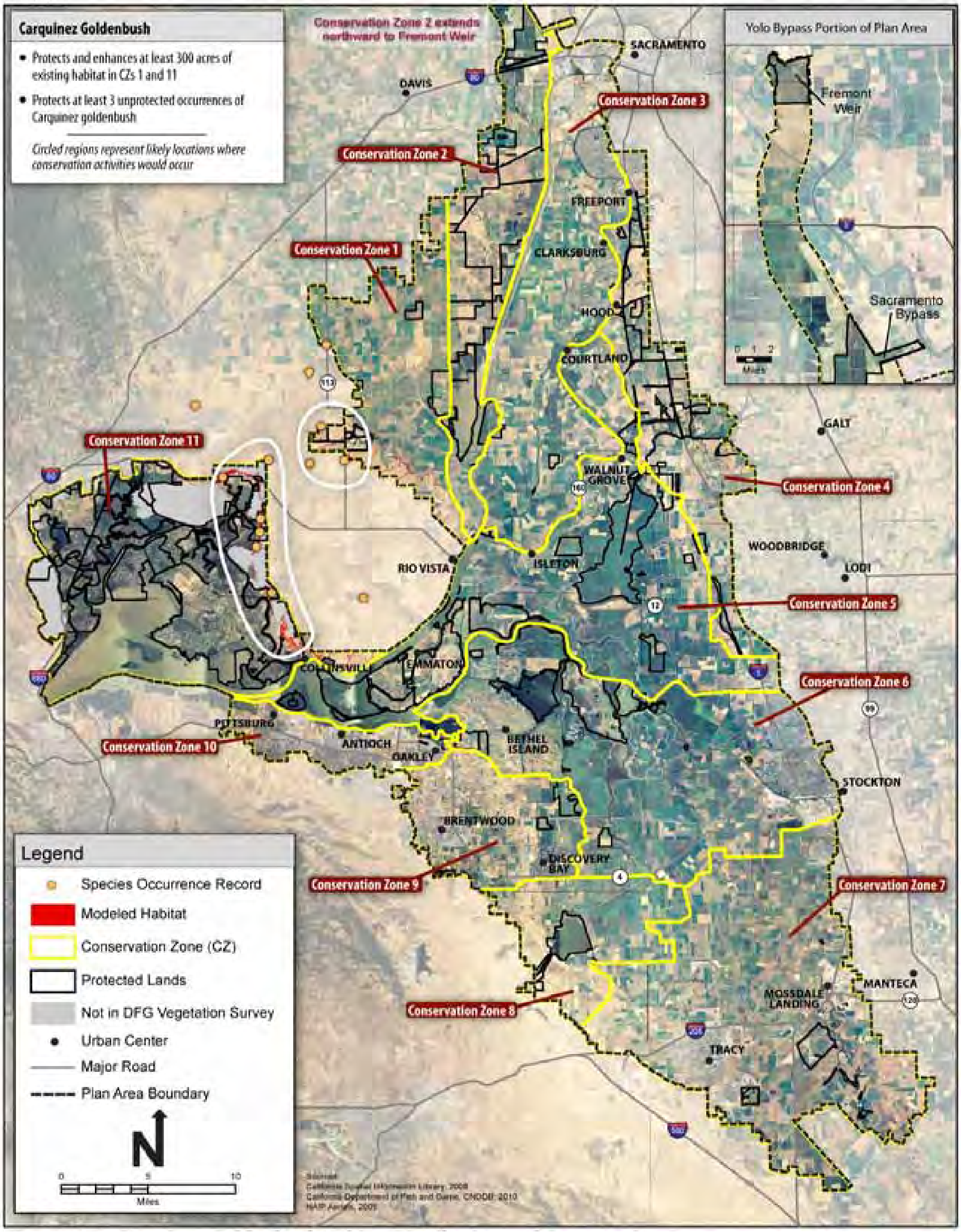

Figure 3- 47. Carquinez Goldenbush Habitat Distribution and Conservation Strategy

3.3.2.4.34 Delta Tule Pea and Suisun Marsh Aster

Delta tule pea and Suisun Marsh aster occur from Sacramento and Solano counties in the north, Napa and Sonoma counties in the west, and Contra Costa and San Joaquin counties in the south. Historically, Suisun Marsh aster was also known from marshes in the East Bay portion of San Francisco Bay (California State Coastal Conservancy 2003). Within the Plan Area, these species occur in tidal areas throughout Suisun Marsh and the west and central Delta with scattered occurrences in the north and south Delta (Figure 3-48). Typically they occur on the upper margins of tidal brackish and tidal freshwater marshes, river channels, creek channels, and sloughs in the ecotone with terrestrial habitats (Goals Project 2000). The tidal marsh habitat and channel margin habitat suitable for Delta tule pea and Suisun marsh aster has been lost mostly through development, dredge disposal, waterfowl habitat creation, agricultural conversion, and levee and dike building.

Applicable Natural Community Goals and Objectives

Goal MFNC1: The expected outcome is areas of tidal mudflat that provide foraging habitat for shorebirds and wading birds, and substrates suitable for the natural establishment of BDCP covered plant species.

> **Objective MFNC1.1:** Restore or create 20 linear miles of edge areas within other natural communities that serve as tidal mudflat substrate and which will support habitat for tidal mudflat-associated species as a component of BDCP restored tidal brackish emergent wetland and tidal freshwater emergent wetland natural communities and channel margin enhancement.

> **Objective MFNC1.2:** Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal mudflat as a component of BDCP restored brackish and freshwater tidal habitat and channel margin enhancement for covered and other native species over the term of the BDCP.

Goal BMNC1: The expected outcome is restored large expanses and interconnected patches of tidal brackish emergent wetland natural community.

> **Objective BMNC1.1:** Restore or create 3,600 to 4,800 acres of tidal brackish emergent wetland in the Suisun Marsh ROA (Conservation Zone 11).

Goal BMNC2: The expected outcome is biologically diverse tidal brackish emergent wetland that is enhanced for native species and sustained by natural ecological processes.

> **Objective BMNC2.1:** Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal brackish emergent wetland for covered and other native species over the term of the BDCP.

Goal FMNC1: The expected outcome is restored large, interconnected patches of tidal freshwater emergent wetland natural community.

> **Objective FMNC1.1:** Restore or create 13,900 to 21,600 acres of tidal freshwater emergent wetland in the Cache Slough, West Delta, Cosumnes-Mokelumne, and South Delta ROAs (Conservation Zones 1, 2, 4, 5, 6, and 7).

Goal FMNC2: The expected outcome is biologically diverse tidal freshwater emergent wetland that is enhanced for native species and sustained by natural ecological processes.

> **Objective FMNC2.1:** Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal freshwater emergent wetlands for covered and other native species over the term of the BDCP.

Goal VRNC1: The expected outcome is restored large expanses and interconnected corridors of valley/foothill riparian natural community.

> **Objective VRNC1.1**: Restore or create 5,000 acres of valley/foothill riparian in Conservation Zones 1, 2, 4, 5, 6, 7, and/or 11.

Goal VRNC2: The expected outcome is biologically diverse valley/foothill riparian natural community that supports native species and is sustained by natural ecological processes.

> **Objective VRNC2.1**: Maintain and enhance the habitat and ecosystem functions of BDCP restored valley/foothill riparian and patches of riparian forest and scrub present on BDCP preserved lands over the term of the BDCP.

Rationale and Conservation Approach

Because habitat loss and exotic species are the primary stressors on Delta tule pea and Suisun Marsh aster, protecting, enhancing, and restoring tidal natural communities is expected to help maintain and potentially increase the abundance and distribution of these species. Conservation of Delta tule pea and Suisun Marsh aster will be directed at restoring a total of between 16,970 and 26,470 acres of tidal freshwater emergent wetland, floodplain, and valley/foothill riparian habitat in Conservation Zones 1, 2, 5, 6, 7, and 11 (Figure 3-48). The conservation actions are consistent with and help to achieve the draft recovery objectives for Delta tule pea identified in the Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California (USFWS 2010).

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM4 Tidal Habitat Restoration
- CM6 Channel Margin Habitat Enhancement
- CM7 Riparian Habitat Restoration
- CM11 Natural Communities Enhancement and Management

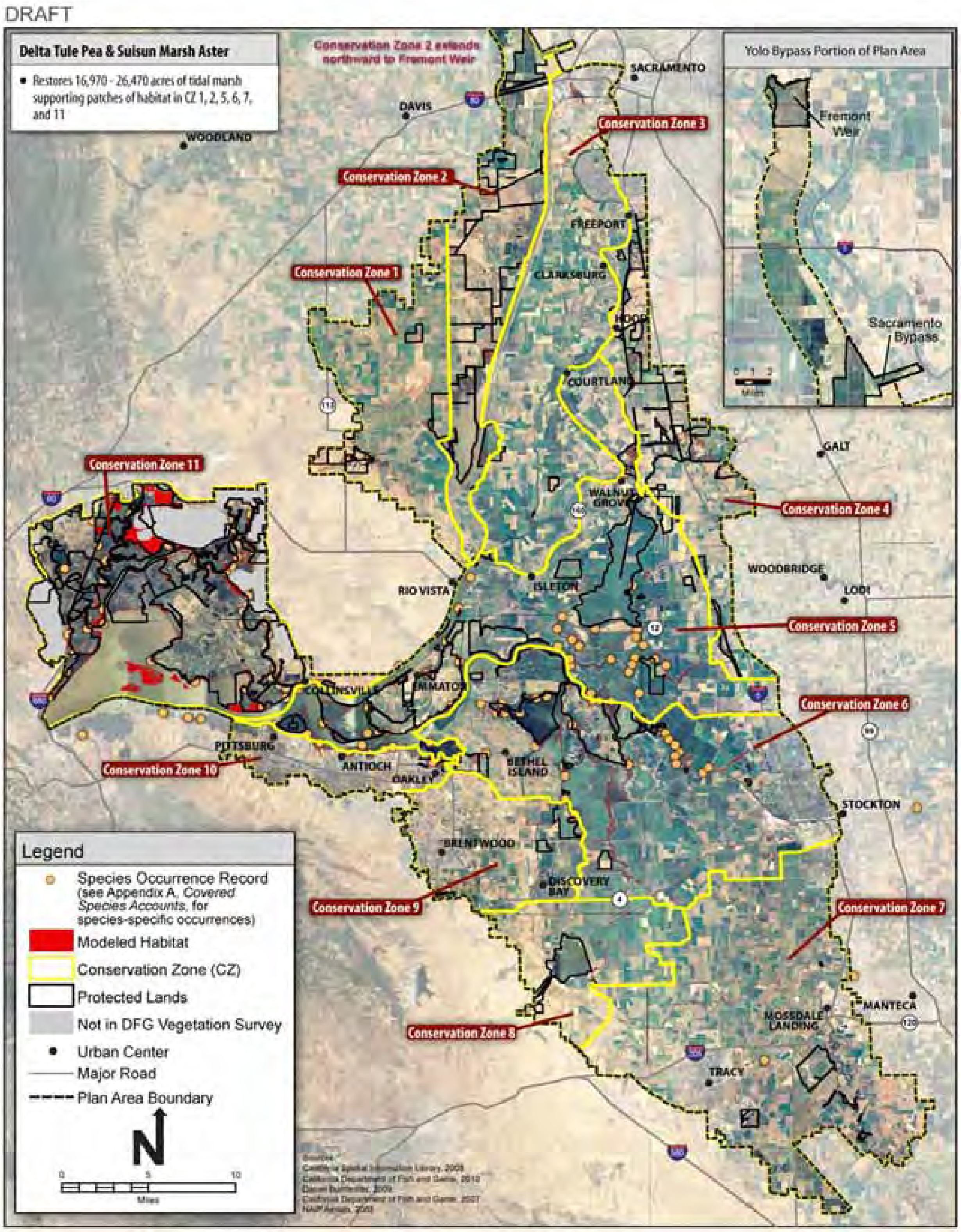

Figure 3-48. Delta Tule Pea and Suisun Marsh Aster Habitat Distribution and Conservation Strategy

3.3.2.4.35 Mason's Lilaeopsis and Delta Mudwort

Mason's lilaeopsis is endemic to California (Calflora 2007) while Delta mudwort can be found outside of California in British Columbia, on the east coast of North America, and in Europe (Hickman 1993). The range of Mason's lilaeopsis extends from Napa and Solano counties in the north, to Contra Costa and Alameda counties in the south, to Marin County in the west, and Sacramento and San Joaquin counties in the east while Delta mudwort only extends as far west as Suisun Marsh (CNDDB 2008).

Both species are found in relatively unvegetated areas within tidal brackish or tidal freshwater habitats that are inundated by waves or tides such as estuarine wetlands and immediately below the banks of tidal sloughs, rivers, and creeks (Golden and Fiedler 1991, Fiedler and Zebell 1993, DFG 2000, CNPS 2008). They are colonizing species that establish on newly deposited or exposed sediments (CNPS 2008) and prefer low tidal mudflats on clayey or silty soils (Witham and Kareofelas 1994).

The tidal marsh and tidal channel margin habitats suitable for Mason's lilaeopsis and Delta mudwort has been lost mostly through development, dredge disposal, waterfowl habitat creation, agricultural conversion, and levee and dike building.

Applicable Natural Community Goals and Objectives

Goal MFNC1: The expected outcome is areas of tidal mudflat that provide foraging habitat for shorebirds and wading birds, and substrates suitable for the natural establishment of BDCP covered plant species.

> **Objective MFNC1.1:** Restore or create 20 linear miles of edge areas within other natural communities that serve as tidal mudflat substrate and which will support habitat for tidal mudflat-associated species as a component of BDCP restored tidal brackish emergent wetland and tidal freshwater emergent wetland natural communities and channel margin enhancement.

> **Objective MFNC1.2:** Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal mudflat as a component of BDCP restored brackish and freshwater tidal habitat and channel margin enhancement for covered and other native species over the term of the BDCP.

Goal BMNC1: The expected outcome is restored large expanses and interconnected patches of tidal brackish emergent wetland natural community.

> **Objective BMNC1.1:** Restore or create 3,600 to 4,800 acres of tidal brackish emergent wetland in the Suisun Marsh ROA (Conservation Zone 11).

Goal BMNC2: The expected outcome is biologically diverse tidal brackish emergent wetland that is enhanced for native species and sustained by natural ecological processes.

> **Objective BMNC2.1:** Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal brackish emergent wetland for covered and other native species over the term of the BDCP.

Goal FMNC1: The expected outcome is restored large, interconnected patches of tidal freshwater emergent wetland natural community.

> **Objective FMNC1.1:** Restore or create 13,900 to 21,600 acres of tidal freshwater emergent wetland in the Cache Slough, West Delta, Cosumnes-Mokelumne, and South Delta ROAs (Conservation Zones 1, 2, 4, 5, 6, and 7).

Goal FMNC2: The expected outcome is biologically diverse tidal freshwater emergent wetland that is enhanced for native species and sustained by natural ecological processes.

> **Objective FMNC2.1:** Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal freshwater emergent wetlands for covered and other native species over the term of the BDCP.

Rationale and Conservation Approach

Because habitat loss and exotic species are the primary stressors on Mason's lilaopsis and Delta mudwort, protecting, enhancing, and restoring tidal natural communities is expected to help maintain and potentially increase the abundance and distribution of these species. Conservation of Mason's lilaopsis and Delta mudwort will be directed at restoring between 16,980 and 26,560 acres of tidal marsh, floodplain, and riparian habitat in Conservation Zones 1, 2, 4, 5, 6, 7, and 11 (Figure 3-49).

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM4 Tidal Habitat Restoration
- CM11 Natural Communities Enhancement and Management

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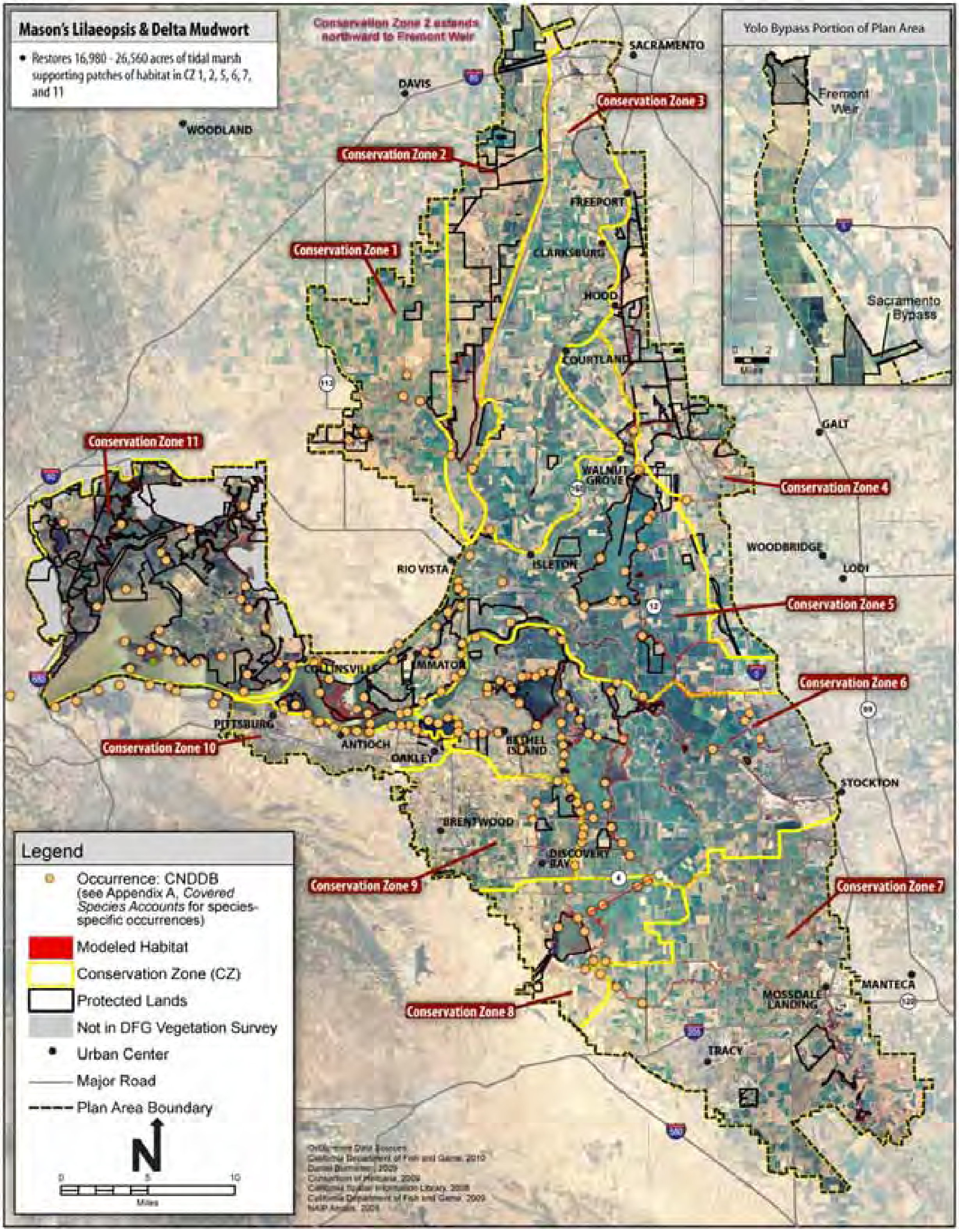

Figure 3- 49. Mason's Lileaopsis and Delta Mudwort Habitat Distribution and Conservation Strategy

3.3.2.4.36 Side-flowering Skullcap

Side-flowering skullcap is known only from a very limited geographic range in California, all of which are in the Delta around Bouldin Island in San Joaquin County, Delta Meadows State Park area, and Sycamore Slough (CNDDB 2010). The Bouldin Island location was recorded in 1892, and the exact location of the collection is unknown. The Delta Meadows State Park occurrence was recorded in 1993. During botanical surveys of the Plan Area conducted by DWR/DHCCP in the summer of 2009, side-flowering skullcap was found growing on rotting pilings and stumps in and along the channels of Snodgrass Slough, Lost Slough, and the Mokelumne River. In the Pacific Northwest it is found on similar coarse woody debris substrates.

Applicable Natural Community Goals and Objectives

Goal FMNC1: The expected outcome is restored large, interconnected patches of tidal freshwater emergent wetland natural community.

> **Objective FMNC1.1:** Restore or create 13,900 to 21,600 acres of tidal freshwater emergent wetland in the Cache Slough, West Delta, Cosumnes-Mokelumne, and South Delta ROAs (Conservation Zones 1, 2, 4, 5, 6, and 7).

Goal FMNC2: The expected outcome is biologically diverse tidal freshwater emergent wetland that is enhanced for native species and sustained by natural ecological processes.

> **Objective FMNC2.1:** Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal freshwater emergent wetlands for covered and other native species over the term of the BDCP.

Goal VRNC1: The expected outcome is restored large expanses and interconnected corridors of valley/foothill riparian natural community.

> **Objective VRNC1.1**: Restore or create 5,000 acres of valley/foothill riparian in Conservation Zones 1, 2, 4, 5, 6, 7, and/or 11.

Goal VRNC2: The expected outcome is biologically diverse valley/foothill riparian natural community that supports native species and is sustained by natural ecological processes.

> **Objective VRNC2.1**: Maintain and enhance the habitat and ecosystem functions of BDCP restored valley/foothill riparian and patches of riparian forest and scrub present on BDCP preserved lands over the term of the BDCP.

Rationale and Conservation Approach

Most side-flowering skullcap plants found in the Plan Area are located within or directly adjacent to Delta Meadows State Park, a California State Park that was established to preserve and protect one of the last remaining areas of the northern Sacramento-San Joaquin River Delta that possesses large stands of fairly mature valley/foothill riparian vegetation (California State Parks 2010). Historically, it may have existed on decaying fallen trees and stumps along riparian channels and sloughs at the lower margin of valley/foothill riparian and the upper margin of tidal freshwater emergent wetland natural communities.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for side-flowering skullcap is "Maintain" (CALFED Bay-Delta Program 2000). This designation indicates that the ERP will undertake actions to maintain the species by avoiding, minimizing, and compensating for any adverse effects to the species created by ERP restoration actions. It also means that the species' population and habitat are unlikely to be affected by ERP actions.

As part of valley/foothill riparian restoration and channel margin enhancement, coarse woody debris substrate will be made available for side-flowering skullcap establishment. Where side-flowering skullcap is found to already be present on stumps or other substrate, the movement and transplantation of the substrate and plants to appropriate sites in the immediate vicinity will be used to minimize impacts (Figure 3-50).

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM4 Tidal Habitat Restoration
- CM6 Channel Margin Habitat Enhancement
- CM7 Riparian Habitat Restoration
- CM11 Natural Communities Enhancement and Management

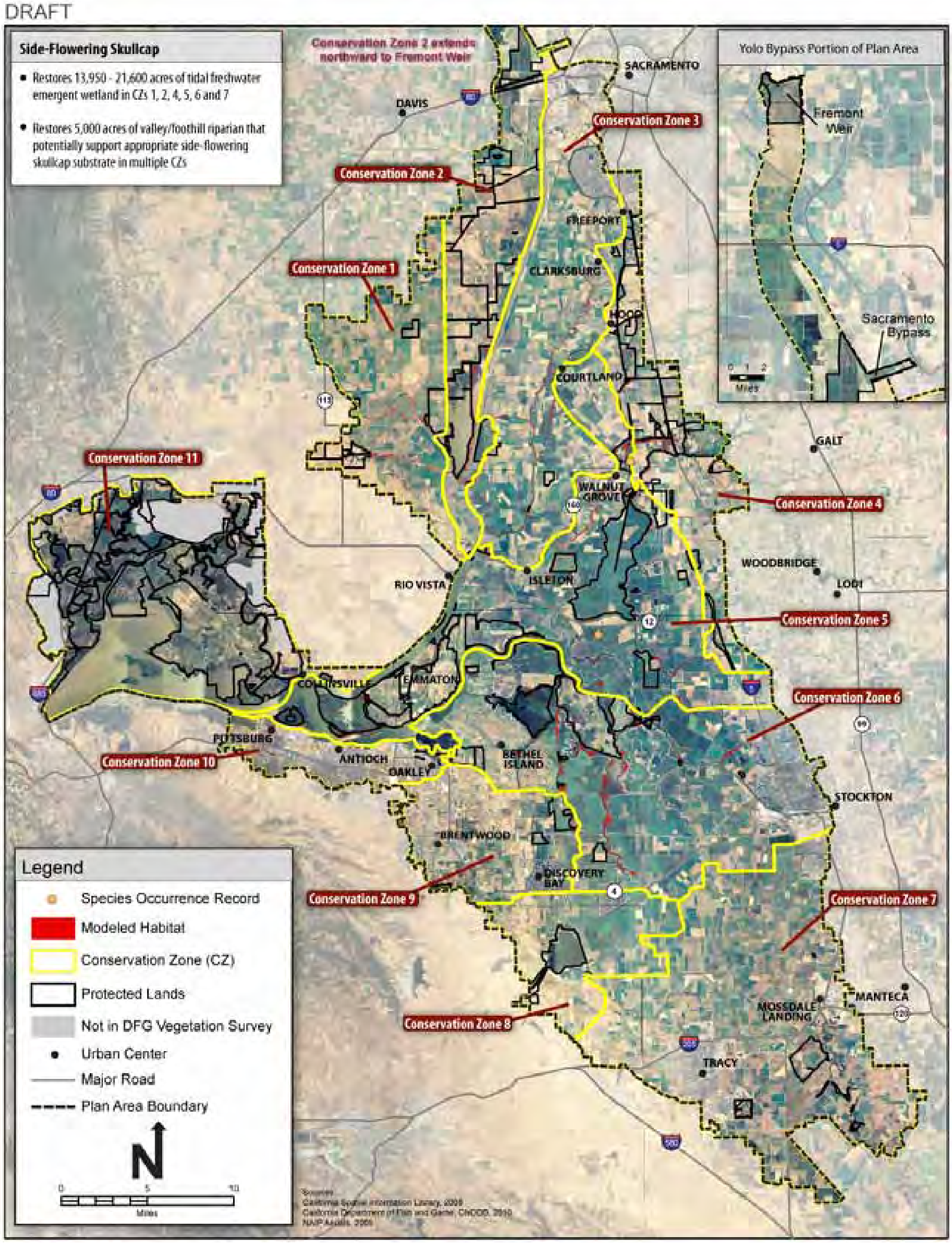

Figure 3-50. Side-Flowering Skullcap Habitat Distribution and Conservation Strategy

3.3.2.4.37 Caper-Fruited Tropidocarpum

Caper-fruited tropidocarpum is endemic to California, where its distribution is extremely limited (Appendix A, *Covered Species Accounts*). With only 19 observations of this plant and most known occurrences facing threats, caper-fruited tropidocarpum is considered by the California Native Plant Society to be seriously endangered (CNPS 2009). The reasons for its limited abundance and distribution are not known, but based on its historical distribution in the Plan Area, most impacts appear to have occurred through intensive agriculture and urbanization or other development activities. Caper-fruited tropidocarpum occurs on valley and foothill grassland habitats on moderately alkaline soils (CNPS 2009) or in foothill oak woodland on slightly alkaline clay soils (CNDDB 2009).

The protection of caper-fruited tropidocarpum habitat in the Plan Area is expected to provide the basis for potentially increasing the species' distribution and abundance. Caper-fruited tropidocarpum was historically distributed along the southwestern boundary of the Plan Area, but today may only reside as seeds in a long-lived soil seed bank. It is sporadically distributed in the inner southern Coast Range. Its potential habitat in the Plan Area ranges from pastures to abandoned dry-farmed grainlands to areas that were not farmed, but which have been invaded by nonnative annual grasses. Based on its historical distribution in the Plan Area, most impacts have occurred through intensive agriculture and urbanization or other development activities. The protection of caper-fruited tropidocarpum habitat in the Plan Area is expected to provide the basis for potentially increasing the species' distribution and abundance.

Applicable Natural Community Goals and Objectives

Goal GRNC1: The expected outcome is grassland comprised of large interconnected patches or contiguous expanses.

> **Objective GRNC1.1**: Protect a minimum of 8,000 acres of grassland in Conservation Zones 1, 8, and 11. At least 1,000 acres will be protected in Conservation Zone 8, with the remainder distributed throughout these three Conservation Zones.

> **Objective GRNC1.2**: Restore 2,000 acres of grassland to connect fragmented patches of protected grassland.

Goal GRNC2: The expected outcome is biologically diverse grassland managed to enhance native species and sustained by natural ecological processes.

> **Objective GRNC2.1**: Restore and sustain a mosaic of grassland vegetation alliances, reflecting local water availability, soil chemistry, soil texture, topography, and disturbance regimes, with consideration of historical states.

> **Objective GRNC2.2**: Increase the relative cover of native grasses and forbs in native grassland vegetation alliances.

Species-Specific Goals and Objectives

Goal CFTR1: The expected outcome is protection and expansion of caper-fruited tropidocarpum populations.

Objective CFTR1.1: Protect occurrences of caper-fruited tropidocarpum that reestablish on BDCP conservation lands.

Objective CFTR1.2: Maintain and enhance the habitat functions of protected caper-fruited tropidocarpum occurrences over the term of the BDCP.

Objective CFTR1.3: Protect and maintain 100 acres of unprotected caper-fruited tropidocarpum grassland habitat in Conservation Zone 8.

Rationale and Conservation Approach

Conservation of caper-fruited tropidocarpum will include protecting and maintaining 100 acres of its remaining unprotected grassland habitats in Conservation Zone 8 (Figure 3-51). All caper-fruited tropidocarpum occurrences have apparently been extirpated in the Plan Area although the species may be present as a persistent seed bank. Protected habitat will be contiguous with and managed in conjunction with other protected habitats in Conservation Zone 8. Protected habitat will be monitored to determine if plants germinate in future years and any located occurrences will be protected and managed to encourage the expansion of such occurrences. Based on the level of BDCP habitat effects, the proposed preservation of caper-fruited tropidocarpum habitat is expected to provide for the conservation of caper-fruited tropidocarpum.

Applicable Conservation Measures

- CM3 Natural Communities Protection
- CM8 Grassland Communities Restoration
- CM11 Natural Communities Enhancement and Management

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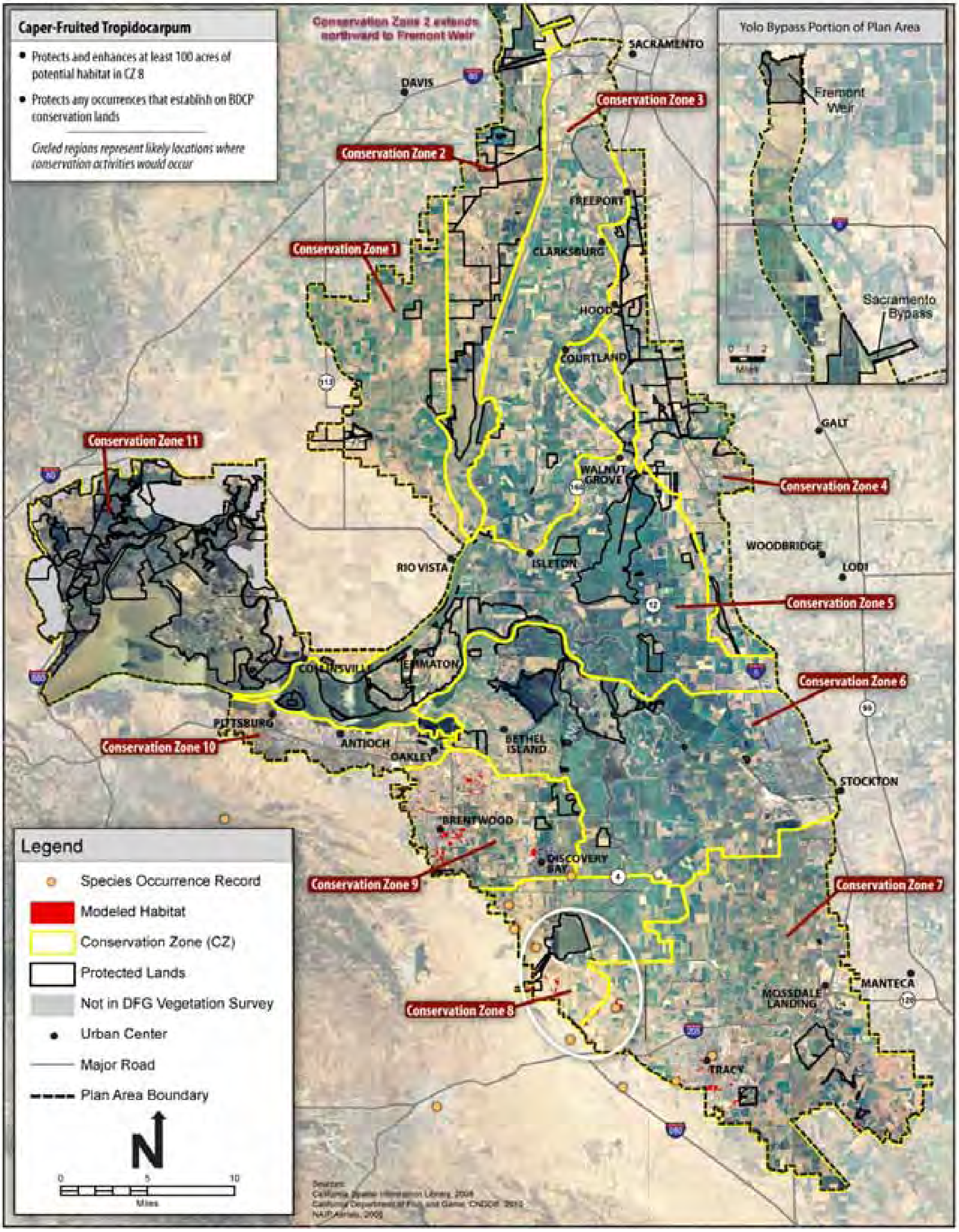

Figure 3-51. Caper-Fruited Tropidocarpum Habitat Distribution and Conservation Strategy

3.4 CONSERVATION MEASURES

This section presents the BDCP conservation measures that will be implemented by the BDCP Implementation Office to protect and improve the ecological function of natural communities; avoid, minimize, and compensate for impacts on covered species associated with implementation of covered activities; and provide for the conservation of covered species. Collectively the conservation measures are expected to achieve the BDCP biological goals and objectives. As described in Section 3.3, *Biological Goals and Objectives*, conservation measures address conveyance and water operations; protection, enhancement, and restoration of physical habitats that support covered species; and reductions in the effect of other stressors on covered species. Conservation measures were developed to address stressors at three ecological scales: ecosystem, natural community, and species-specific. Ecosystem-level conservation measures are presented in Section 3.4.2, natural community-level and species-specific conservation measures are presented in Sections 3.4.3 and 3.4.4, and avoidance and minimization measures for covered wildlife and plant species are presented in Section 3.4.5.

A summary list of BDCP conservation measures and the biological goals and objectives they serve is provided in Table 3-12. As is demonstrated in Table 3-12, many of the conservation measures address multiple goals and objectives. The following information is provided with each conservation measure, as appropriate, in Sections 3.4.2-3.4.4.

- **Problem Statement.** This section describes the ecological problems that are intended to be addressed by the conservation measure.
- **Hypothesized Benefits.** This section describes the hypotheses that justify the approach reflected in the conservation measure. Uncertainties and risks that could be associated with DRERIP-evaluated conservation measures are described in Appendix F, *DRERIP Evaluation Results*.

Table 3-12. Conservation Measures that Meet BDCP Conservation Strategy Goals and Objectives

Goals and Objectives	*Applicable Conservation Measures*
Ecosystem-Level Goals and Objectives	
Goal ECSY1: Protect and restore large landscapes representing a range of physical and biological attributes (e.g., hydrology, soil, and plant associations) necessary to sustain viable populations of covered species, and to preserve native species biodiversity.	
Objective ECSY1.1: Protect 25,000-41,000 acres of existing natural communities that support covered species.	CM3 Natural Communities Protection CM6 Channel Margin Habitat Enhancement
Objective ECSY1.2: Protect a range of environmental gradients (e.g., hydrology, elevation, and soils) across a diversity of natural communities.	CM3 Natural Communities Protection
Objective ECSY1.3: Restore or create up to 65,000 acres of tidally influenced habitat consisting of subtidal, mudflat, tidal marsh, and transitional upland habitat for sea level rise accommodation that supports a gradient of natural communities and habitat for covered species.	CM4 Tidal Habitat Restoration
Objective ECSY1.4: Restore or create up to 10,000 acres of seasonally inundated floodplain and 20 miles of channel margin habitat.	CM5 Seasonally Inundated Floodplain Restoration CM6 Channel Margin Habitat Enhancement
Objective ECSY1.5: Manage protected and restored or created habitats to enhance habitat functions for associated covered and other native species over the term of the BDCP.	CM11 Natural Communities Enhancement and Management
Goal ECSY2: Provide hydrodynamic conditions within Delta waterways that are more reflective of natural patterns of flow within the BDCP Plan Area and Suisun Marsh.	
Objective ECSY2.1: Support the movement of larval and juvenile life stages of native fish species to downstream rearing habitats.	CM1 Water Facilities and Operation CM2 Yolo Bypass Fisheries Enhancements CM16 Non-Physical Fish Barriers
Objective ECSY2.2: Support the movement of adult life stages of native fish species to natal spawning habitats.	CM1 Water Facilities and Operation CM2 Yolo Bypass Fisheries Enhancements
Objective ECSY 2.3: Promote water quality conditions within the Delta that help restore native fish habitat.	CM12 Methylmercury Management CM14 Stockton Deep Water Ship Channel Dissolved Oxygen Levels
Objective ECSY2.4: Maintain or increase life history diversity of native fishes and a diversity of rearing conditions for native fishes over time.	CM1 Water Facilities and Operation CM2 Yolo Bypass Fisheries Enhancements CM4 Tidal Habitat Restoration CM5 Seasonally Inundated Floodplain Restoration CM6 Channel Margin Habitat Enhancement CM7 Riparian Habitat Restoration
Objective ECSY 2.5: Promote greater connectivity between low salinity zone habitats and upstream freshwater habitats, and availability of spawning habitats for native pelagic species.	CM1 Water Facilities and Operation CM4 Tidal Habitat Restoration

Table 3-12. Terrestrial Conservation Measures that Meet BDCP Conservation Strategy Goals and Objectives (continued)

Goals and Objectives	*Applicable Conservation Measures*
Ecosystem-Level Goals and Objectives	
Goal ECSY3: Provide for connectivity among protected lands to provide for the movement of native organisms among habitat areas and to facilitate genetic exchange among populations.	
Objective ECSY3.1: Protect corridors of habitat that provide linkages among protected habitat areas within and adjacent to the Plan Area.	CM3 Natural Communities Protection
Objective ECSY3.2: Improve habitat corridors that allow covered and other native species to move into protected habitats from adjacent areas and to move among habitat areas within protected lands.	CM3 Natural Communities Protection CM4 Tidal Habitat Restoration CM5 Seasonally Inundated Floodplain Restoration CM6 Channel Margin Habitat Enhancement CM7 Riparian Habitat Restoration CM8 Grassland Communities Restoration CM11 Natural Communities Enhancement and Management
Goal ECSY4: Promote ecosystem processes that support natural communities, covered species, other native species, and the habitats of those species.	
Objective ECSY4.1: Maintain and improve disturbance regimes and other processes that support functioning natural communities.	CM4 Tidal Habitat Restoration CM5 Seasonally Inundated Floodplain Restoration CM11 Natural Communities Enhancement and Management
Goal ECSY5: Increase aquatic primary and secondary production in the Delta, Yolo Bypass and Suisun Marsh to increase the abundance and availability of food for native aquatic organisms.	
Objective ECSY5.1: Over the term of the BDCP, increase the abundance and productivity of zooplankton that provide food and support food production for covered fish species in Delta waterways.	CM2 Yolo Bypass Fisheries Enhancements CM4 Tidal Habitat Restoration CM5 Seasonally Inundated Floodplain Restoration CM6 Channel Margin Habitat Enhancement
Objective ECSY5.2: Over the term of the BDCP, increase the abundance and productivity of aquatic invertebrate species that provide food and support food production for covered fish species in Delta waterways.	CM2 Yolo Bypass Fisheries Enhancements CM4 Tidal Habitat Restoration CM5 Seasonally Inundated Floodplain Restoration CM6 Channel Margin Habitat Enhancement
Goal ECSY6: Reduce the adverse predation effects of non-native species on covered fish species.	
Objective ECSY6.1: Manage the distribution and abundance of established non-native predators in the Delta to reduce predation on native covered fishes.	CM13 Nonnative Aquatic Vegetation Control CM15 Predator Control
Objective ECSY6.2: Manage the distribution of covered fish species to minimize movements into high predation risk areas of the Delta.	CM1 Water Facilities and Operation CM2 Yolo Bypass Fisheries Enhancements CM16 Non-Physical Fish Barriers
Goal ECSY7: Protect lands with a sufficient range of habitat conditions to accommodate anticipated shifts in the distributions of covered species and natural communities in response to climate change.	
Objective ECSY7.1: Protect sufficient upland transitional habitat area adjacent to restored brackish and freshwater tidal emergent wetland to permit the future upslope natural establishment of tidal emergent wetland communities with sea level rise.	CM3 Natural Communities Protection CM4 Tidal Habitat Restoration

Table 3-12. Terrestrial Conservation Measures that Meet BDCP Conservation Strategy Goals and Objectives (continued)

Goals and Objectives	*Applicable Conservation Measures*
Natural Community Goals and Objectives	
Tidal Perennial Aquatic	
Goal TANC1: The expected outcome is tidal perennial aquatic natural community that supports habitats for covered and other native species and that supports aquatic food web processes.	
Objective TANC1.1: Restore or create 10,000 to 20,000 acres of tidal perennial aquatic in the BDCP Restoration Opportunity Areas (Conservation Zones 1, 2, 4, 5, 7, and 11) that supports aquatic food production and habitat for covered and other native species.	CM4 Tidal Habitat Restoration
Goal TANC2: The expected outcome is biologically diverse tidal perennial aquatic natural community that is enhanced for native species and sustained by natural ecological processes.	
Objective TANC2.1: Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal perennial aquatic community for covered and other native species over the term of the BDCP.	CM4 Tidal Habitat Restoration
Tidal Mudflat	
Goal MFNC1: The expected outcome is areas of tidal mudflat that provide foraging habitat for shorebirds and wading birds, and substrates suitable for the natural establishment of BDCP covered plant species.	
Objective MFNC1.1: Restore or create 20 linear miles of edge areas within other natural communities that serve as tidal mudflat substrate and which will support habitat for tidal mudflat-associated species as a component of BDCP restored tidal brackish emergent wetland and tidal freshwater emergent wetland natural communities and channel margin enhancement.	CM4 Tidal Habitat Restoration CM6 Channel Margin Habitat Enhancement
Objective MFNC1.2: Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal mudflat as a component of BDCP restored brackish and freshwater tidal habitat and channel margin enhancement for covered and other native species over the term of the BDCP.	CM1 Water Facilities and Operation CM11 Natural Communities Enhancement and Management
Tidal Brackish Emergent Wetland	
Goal BMNC1: The expected outcome is restored large expanses and interconnected patches of tidal brackish emergent wetland natural community.	
Objective BMNC1.1: Restore or create 3,600 to 4,800 acres of tidal brackish emergent wetland in the Suisun Marsh ROA (Conservation Zone 11).	CM4 Tidal Habitat Restoration
Goal BMNC2: The expected outcome is biologically diverse tidal brackish emergent wetland that is enhanced for native species and sustained by natural ecological processes.	
Objective BMNC2.1: Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal brackish emergent wetland for covered and other native species over the term of the BDCP.	CM11 Natural Communities Enhancement and Management

Table 3-12. Terrestrial Conservation Measures that Meet BDCP Conservation Strategy Goals and Objectives (continued)

Goals and Objectives	*Applicable Conservation Measures*
Natural Community Goals and Objectives	
Tidal Freshwater Emergent Wetland	
Goal FMNC1: The expected outcome is restored large, interconnected patches of tidal freshwater emergent wetland natural community.	
Objective FMNC1.1: Restore or create 13,900 to 21,600 acres of tidal freshwater emergent wetland in the Cache Slough, West Delta, Cosumnes-Mokelumne, and South Delta ROAs (Conservation Zones 1, 2, 4, 5, 6, and 7).	CM4 Tidal Habitat Restoration
Goal FMNC2: The expected outcome is biologically diverse tidal freshwater emergent wetland that is enhanced for native species and sustained by natural ecological processes.	
Objective FMNC2.1: Maintain and enhance the habitat and ecosystem functions of BDCP restored tidal freshwater emergent wetlands for covered and other native species over the term of the BDCP.	CM11 Natural Communities Enhancement and Management
Nontidal Freshwater Perennial Emergent Wetland	
Goal NWNC1: The expected outcome is nontidal freshwater perennial emergent wetland natural community that supports habitat for covered and other native species.	
Objective NWNC1.1: Create 400 acres of nontidal freshwater marsh (including components of nontidal perennial aquatic and perennial emergent wetland communities) that functions as habitat for the giant garter snake, tricolored blackbird, and western pond turtle within or adjacent to habitat occupied by the Caldoni Marsh/White Slough giant garter snake subpopulation in Conservation Zone 4 and the Yolo/Willow Slough giant garter snake subpopulation in Conservation Zone 2.	CM10 Nontidal Marsh Restoration
Goal NWNC2: The expected outcome is biologically diverse nontidal freshwater emergent wetland communities that are enhanced for native species and sustained by ecological processes.	
Objective NWNC2.1: Maintain and enhance the habitat functions of protected and created nontidal freshwater emergent wetlands for covered and other native species over the term of the BDCP.	CM11 Natural Communities Enhancement and Management
Nontidal Perennial Aquatic	
Goal NANC1: The expected outcome is nontidal perennial aquatic communities that support habitat for covered and other native species. ***Note:*** *The objective for nontidal perennial aquatic community Goal NANC1 is the same as that described under nontidal freshwater emergent wetland Goal NWNC1*.	
Objective NANC1.1: Restore 400 acres of nontidal marsh as per Objective NWNC1.1.	CM10 Nontidal Marsh Restoration
Goal NANC2: The expected outcome is biologically diverse nontidal perennial aquatic communities that are enhanced for native species and sustained by ecological processes.	
Objective NANC2.1: Maintain and enhance the habitat functions of protected and created nontidal open water habitats for covered and other native species over the term of the BDCP.	CM11 Natural Communities Enhancement and Management

Table 3-12. Terrestrial Conservation Measures that Meet BDCP Conservation Strategy Goals and Objectives (continued)

Goals and Objectives	*Applicable Conservation Measures*
Natural Community Goals and Objectives	
Valley/Foothill Riparian	
Goal VRNC1: The expected outcome is restored large expanses and interconnected corridors of valley/foothill riparian natural community.	
Objective VRNC1.1: Restore or create 5,000 acres of valley/foothill riparian in Conservation Zones 1, 2, 4, 5, 6, 7, and/or 11.	CM7 Riparian Habitat Restoration
Goal VRNC2: The expected outcome is biologically diverse valley/foothill riparian natural community that supports native species and is sustained by natural ecological processes.	
Objective VRNC2.1: Maintain and enhance the habitat and ecosystem functions of BDCP restored valley/foothill riparian and patches of riparian forest and scrub present on BDCP preserved lands over the term of the BDCP.	CM11 Natural Communities Enhancement and Management
Objective VRNC2.2: Establish seasonal buffers around riparian habitats occupied by covered species to minimize disturbance during the breeding season.	CM7 Riparian Habitat Restoration
Objective VRNC2.3: Restore connectivity of valley/foothill riparian corridors along linear watercourses to enhance habitat for covered species and facilitate wildlife movement.	CM7 Riparian Habitat Restoration
Grassland	
Goal GRNC1: The expected outcome is grassland comprised of large interconnected patches or contiguous expanses.	
Objective GRNC1.1: Protect a minimum of 8,000 acres of grassland in Conservation Zones 1, 8, and 11. At least 1,000 acres will be protected in Conservation Zone 8, with the remainder distributed throughout these three Conservation Zones.	CM3 Natural Communities Protection
Objective GRNC1.2: Restore 2,000 acres of grassland to connect fragmented patches of protected grassland.	CM8 Grassland Communities Restoration
Goal GRNC2: The expected outcome is biologically diverse grassland managed to enhance native species and sustained by natural ecological processes.	
Objective GRNC2.1: Restore and sustain a mosaic of grassland vegetation alliances, reflecting local water availability, soil chemistry, soil texture, topography, and disturbance regimes, with consideration of historical states.	CM8 Grassland Communities Restoration
Objective GRNC2.2: Increase the relative cover of native grasses and forbs in native grassland vegetation alliances.	CM8 Grassland Communities Restoration
Objective GRNC2.3: Increase opportunities for wildlife movement through grassland habitat.	CM8 Grassland Communities Restoration
Objective GRNC2.4: Increase burrow availability for burrow-dependent species.	CM8 Grassland Communities Restoration
Objective GRNC2.5: Increase prey, especially small mammals and insects, for grassland-foraging species.	CM8 Grassland Communities Restoration

Table 3-12. Terrestrial Conservation Measures that Meet BDCP Conservation Strategy Goals and Objectives (continued)

Goals and Objectives	***Applicable Conservation Measures***
Natural Community Goals and Objectives	
Alkali Seasonal Wetland Complex	
Goal AWNC1: The expected outcome is protected alkali seasonal wetland complex natural community that represents a range of environmental conditions and is adjacent to other conserved lands.	
Objective AWNC1.1: Protect 400 acres of alkali seasonal wetland complex natural community in Conservation Zones 1, 8, and/or 11.	CM3 Natural Communities Protection
Goal AWNC2: The expected outcome is biologically diverse alkali seasonal wetland complex natural community with improved native biodiversity, habitat heterogeneity, and the ability to support populations of covered and other native species.	
Objective AWNC2.1: Maintain and, where habitat functions for covered species can be increased, increase the diversity and relative cover of native grasses and forbs.	CM11 Natural Communities Enhancement and Management
Vernal Pool Complex	
Goal VPNC1: The expected outcome is protected vernal pool complex natural community that represents a range of environmental conditions and is adjacent to other conserved lands.	
Objective VPNC1.1: Protect 300 acres of vernal pool complex in Conservation Zones 1, 8, and 11.	CM3 Natural Communities Protection
Goal VPNC2: The expected outcome is restored biologically diverse vernal pool complex natural community with improved native biodiversity, habitat heterogeneity, and the ability to support populations of covered and other native species.	
Objective VPNC2.1: Restore 200 acres of vernal pool complex natural community in Conservation Zones 1, 8, and/or 11 within patches of protected grassland that supports habitat for the western spadefoot toad, California tiger salamander, and the covered vernal pool shrimp and plant species.	CM9 Vernal Pool Complex Restoration
Objective VPNC2.2: Maintain and, where habitat functions for covered species can be enhanced, increase the diversity and relative cover of native grasses and forbs.	CM8 Grassland Communities Restoration CM9 Vernal Pool Complex Restoration
Inland Dune Scrub	
Goal IDSC1: The expected outcome is support for funding of the USFWS management and enhancement of the inland dune scrub natural community on the Antioch Dunes National Wildlife Refuge.	
Objective IDSC1.1: The BDCP will support the funding of the USFWS program for management, enhancement, and monitoring of inland dune scrub natural community on the Antioch Dunes National Wildlife Refuge at an annual amount of $XX.XX for X years.	CM11 Natural Communities Enhancement and Management

Table 3-12. Terrestrial Conservation Measures that Meet BDCP Conservation Strategy Goals and Objectives (continued)

Goals and Objectives	*Applicable Conservation Measures*
Agricultural Habitats	
Goal ALNC1: The expected outcome is increased habitat functions for covered and other native species that are supported by agricultural land cover types and management practices.	
Objective ALNC1.1: Maintain and protect the functions of 4,600 acres of rice lands as habitat for giant garter snake, western pond turtle, tricolored blackbird, white-tailed kite, waterfowl, and migrant shorebirds in Conservation Zone 2. This objective may be partially or fully achieved by maintaining an equivalent extent of natural or managed lands that support habitat functions similar to rice lands for associated covered and other native wildlife species.	CM3 Natural Communities Protection
Objective ALNC1.2: Maintain and protect the functions of 12,020 to 28,040 acres of non-rice agricultural lands as foraging habitat for Swainson's hawk, white-tailed kite, and tricolored black bird that are located within 8 miles of occupied Swainson's hawk nesting habitat.	CM3 Natural Communities Protection
Objective ALNC1.3: Of the maintained 12,020 to 28,040 acres of non-rice agricultural lands, maintain at least 3,000 acres of pasture that supports moderate-value western burrowing owl foraging habitat. This objective may be partially or fully achieved through preservation of other land cover types that provide moderate-value or greater habitat function for the western burrowing owl.	CM3 Natural Communities Protection
Objective ALNC1.4: Of the maintained 12,020 to 28,040 acres of non-rice agricultural lands, maintain at least 4,800 acres that supports greater sandhill crane foraging habitat within its Winter Use Area and within 2 miles of known roosting sites in Conservation Zones 3, 4, 5 and/or 6.	CM3 Natural Communities Protection
Objective ALNC1.5: Of the maintained 12,020 to 28,040 acres of non-rice agricultural lands and 4,600 acres of rice lands, maintain and protect 1,000 acres within or adjacent to habitat occupied by the Yolo/Willow Slough giant garter snake subpopulation in Conservation Zone 2.	CM3 Natural Communities Protection
Objective ALNC1.6: Of the maintained 12,020 to 28,040 acres of non-rice agricultural lands, maintain and protect 1,000 acres within or adjacent to habitat occupied by the Caldoni Marsh/White Slough giant garter snake subpopulation in Conservation Zone 4.	CM3 Natural Communities Protection
Objective ALNC1.7: Target agricultural land conservation to provide connectivity between other protected lands.	
Objective ALNC1.8: Maintain and protect the small patches of important wildlife habitats associated with agricultural lands that occur within BDCP conserved agricultural lands, including isolated valley oak trees, trees and shrubs along field borders and roadsides, remnant groves, riparian corridors, water conveyance channels, grasslands, and wetlands.	CM3 Natural Communities Protection

Table 3-12. Terrestrial Conservation Measures that Meet BDCP Conservation Strategy Goals and Objectives (continued)

Goals and Objectives	***Applicable Conservation Measures***
Managed Wetland	
Goal MWNC1: The expected outcome is maintenance of the current level of habitat functions provided by existing managed wetlands in the Plan Area through enhancement and restoration of natural communities on BDCP conservation lands, such that those wildlife functions do not preclude achievement of the Central Valley Joint Venture (CVJV) Implementation Plan's waterfowl and shorebird conservation targets for the Delta and Yolo Basin.	
Objective MWNC1.1: Maintain the level of wintering and breeding waterfowl habitat functions currently supported by habitats in the Plan Area through protection, restoration, and management of habitat of equivalent function on BDCP conservation lands.	CM3 Natural Communities Protection CM4 Tidal Habitat Restoration CM8 Grassland Communities Restoration
Objective MWNC1.2: Maintain the current level of migrant shorebird habitat functions currently supported by habitats in the Plan Area through protection, restoration, and management of habitat of equivalent function on BDCP conservation lands.	CM3 Natural Communities Protection CM4 Tidal Habitat Restoration
Goal MWNC2: The expected outcome is biologically diverse managed wetlands that are enhanced for native species.	
Objective MWNC2.1: Maintain and enhance the habitat functions of BDCP managed wetlands present on BDCP preserved lands over the term of the BDCP.	CM11 Natural Communities Enhancement and Management
Other Natural Seasonal Wetland	
Goal ONSW1: The expected outcome is increased habitat functions that support BDCP covered species in other natural seasonal wetland natural community within maintained and protected agricultural habitat areas.	
Objective ONSW1.1: Integrate management of other natural seasonal wetland natural community with management of BDCP maintained and protected agricultural lands to increase habitat functions for covered species.	CM3 Natural Communities Protection
Species-Specific Goals and Objectives *[**Note to Reviewers:** This table will be revised to indlcude the covered fish species pending further development of the covered fish species goals and objectives.]*	
Riparian Woodrat	
Goal RIWR1: The expected outcome is restored and protected habitat for the riparian woodrat.	
Objective RIWR1.1: Of the 5,000 acres of restored valley/foothill riparian, restore and manage 300 acres to meet the ecological requirements of the riparian woodrat in Conservation Zone 7.	CM7 Riparian Habitat Restoration
Riparian Brush Rabbit	
Goal RIBR1: The expected outcome is restored and protected habitat for riparian brush rabbit.	
Objective RIBR1.1: Of the 5,000 acres of riparian restoration, restore and manage at least 300 acres to meet the ecological requirements of the riparian brush rabbit in Conservation Zones 7 or 8.	CM7 Riparian Habitat Restoration
California Least Tern	
Goal CALT1: The expected outcome is an expanded California least tern population in the Plan Area.	
Objective CALT1.1: Create two patches of California least tern nesting habitat during restoration of tidal marsh communities.	CM11 Natural Communities Enhancement and Management

Table 3-12. Terrestrial Conservation Measures that Meet BDCP Conservation Strategy Goals and Objectives (continued)

Goals and Objectives	*Applicable Conservation Measures*
Species-Specific Goals and Objectives	
Greater Sandhill Crane	
Goal GSHC1: The expected outcome is expansion and protection of greater sandhill crane winter range.	
Objective GSHC1.1: Create 320 acres of seasonally managed greater sandhill crane roosting habitat within Conservation Zones 3, 4, 5, or 6.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management
Giant Garter Snake	
Goal GGSN1: The expected outcome is high quality upland and aquatic habitat containing a mosaic of features provided for extant giant garter snake populations.	
Objective GGSN1.1: Create functional landscapes on giant garter snake preserves that include a mosaic of restored freshwater marsh intermixed with protected agricultural lands and interconnected water conveyance canals and natural drainages.	CM3 Natural Communities Protection CM4 Tidal Habitat Restoration CM10 Nontidal Marsh Restoration CM11 Natural Communities Enhancement and Management
Goal GGSN2: The expected outcome is protected giant garter snake corridors facilitating movement and linking populations.	
Objective GGSN2.1: Establish connectivity between giant garter snake preserve lands, restored tidal wetlands, and protected agricultural lands in Conservation Zone 4 to facilitate movement into unoccupied portions of the Delta and with the Badger Creek subpopulation.	CM3 Natural Communities Protection CM4 Tidal Habitat Restoration CM10 Nontidal Marsh Restoration CM11 Natural Communities Enhancement and Management
Objective GGNS2.2: Establish a giant garter snake north-south corridor that includes protected agricultural lands and restored tidal and nontidal wetlands between Coldani Marsh/White Slough and the Stone Lakes National Wildlife Refuge.	CM3 Natural Communities Protection CM4 Tidal Habitat Restoration CM10 Nontidal Marsh Restoration CM11 Natural Communities Enhancement and Management
California Red-Legged Frog	
Goal CRLF1: The expected outcome is enhanced breeding California red-legged frog populations in the Plan Area.	
ObjectiveCRLF1.1: Enhance stock ponds in grassland in Conservation Zone 8 through partial livestock exclusion and predator control.	CM11 Natural Communities Enhancement and Management
Lange's Metalmark Butterfly	
Goal LMMB1: The expected outcome is funding support for the USFWS captive breeding and reintroduction program for Lange's metalmark butterfly.	
Objective LMMB1.1: The BDCP will provide funding to support the USFWS program for the captive breeding and release of Lange's metalmark butterfly at an annual amount of $XX.XX for X years.	CM11 Natural Communities Enhancement and Management
Vernal Pool Plant Species **(**Alkali Milk-vetch, San Joaquin Spearscale, Dwarf Downingia, Boggs Lake Hedge-hyssop, Legenere, and Heckard's Peppergrass**)**	
Goal ALMV1: The expected outcome is protected and enhanced alkali milk-vetch populations.	
Objective ALMV1.1: Protect at least 3 unprotected occurrences of alkali milk-vetch in Conservation Zones 1 and/or 11.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management
Objective ALMV1.2: Maintain and enhance the habitat functions of preserved alkali milk-vetch habitat over the term of the BDCP.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management

Table 3-12. Terrestrial Conservation Measures that Meet BDCP Conservation Strategy Goals and Objectives (continued)

Goals and Objectives	*Applicable Conservation Measures*
Species-Specific Goals and Objectives	
Vernal Pool Plant Species **(**Alkali Milk-vetch, San Joaquin Spearscale, Dwarf Downingia, Boggs Lake Hedge-hyssop, Legenere, and Heckard's Peppergrass**)**	
Goal HEPE1: The expected outcome is protected and enhanced Heckard's peppergrass populations.	
Objective HEPE 1.2: Protect at least 2 unprotected occurrences of Heckard's peppergrass in Conservation Zones 1, 8, or 11.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management
Objective HEPE1.2: Maintain and enhance the habitat functions of preserved Heckard's peppergrass habitat over the term of the BDCP.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management
Heartscale and Brittlescale	
Goal HART/BRIT1: The expected outcome is protected and expanded alkali seasonal wetland complex natural community-associated covered species populations.	
Objective HART/BRIT1.1: Of the 400 acres of protected alkali seasonal wetland complex natural community, protect 150 acres that support heartscale and brittlescale habitat.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management
Objective HART/BRIT1.2: Protect at least 3 unprotected occurrences of heartscale in Conservation Zones 1 and /or 11.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management
Objective HART/BRIT1.3: Protect at least 3 unprotected occurrences of brittlescale in Conservation Zones 1, 8, or 11.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management
Objective HART/BRIT1.4: Maintain and enhance the habitat functions of preserved heartscale and brittlescale habitat over the term of the BDCP.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management
Suisun Thistle and Soft Bird's-Beak	
Goal SUTH1: The expected outcome is protected and expanded Suisun thistle populations.	
Objective SUTH1.1: Protect 3 unprotected occurrences of Suisun thistle in Suisun Marsh in Conservation Zone 11.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management
Objective SUTH1.2: Maintain and enhance the habitat functions of preserved Suisun thistle habitat over the term of the BDCP.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management
Goal SOBB1: The expected outcome is protected and expanded soft bird's-beak populations.	
Objective SOBB1.1: Protect 3 unprotected occurrences of soft bird's-beak in Suisun Marsh in Conservation Zone 11.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management
Objective SOBB1.2: Maintain and enhance the habitat functions of preserved soft bird's-beak habitat over the term of the BDCP.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management
Delta Button-Celery	
Goal DEBC1: The expected outcome is protected and expanded Delta button-celery populations.	
Objective DEBC1.1: Of the 400 acres of protected alkali seasonal wetland complex natural community, protect at least 100 acres that support Delta button-celery habitat.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management
Objective DEBC1.2: Maintain and enhance the habitat functions of preserved Delta button-celery habitat over the term of the BDCP.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management

Table 3-12. Terrestrial Conservation Measures that Meet BDCP Conservation Strategy Goals and Objectives (continued)

Goals and Objectives	***Applicable Conservation Measures***
Species-Specific Goals and Objectives	
Contra Costa Wallflower and Antioch Dunes Evening Primrose	
Goal CCWF/ADEP1: The expected outcome is funding support for the USFWS implementation of the propagation and out-planting program for Contra Costa wallflower and Antioch Dunes evening primrose.	
Objective CCWF/ADEP1.1: The BDCP will support the funding of the USFWS program for propagation and out-planting program for Contra Costa wallflower and Antioch Dunes evening primrose at an annual amount of $XX.XX for X years.	CM11 Natural Communities Enhancement and Management
Carquinez Goldenbush	
Goal CAGB1: The expected outcome is protected and expanded Carquinez goldenbush populations.	
Objective CAGB1.1: Protect at least 3 unprotected occurrences of Carquinez goldenbush in Conservation Zones 1 and/or 11.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management
Objective CAGB1.2: Maintain and enhance the habitat functions of preserved Carquinez goldenbush habitat over the term of the BDCP.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management
Caper-Fruited Tropidocarpum	
Goal CFTR1: The expected outcome is protection and expansion of caper-fruited tropidocarpum populations.	
Objective CFTR1.1: Protect occurrences of caper-fruited tropidocarpum that reestablish on BDCP conservation lands.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management
Objective CFTR1.2: Maintain and enhance the habitat functions of protected caper-fruited tropidocarpum occurrences over the term of the BDCP.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management
Objective CFTR1.3: Protect and maintain 100 acres of unprotected caper-fruited tropidocarpum grassland habitat in Conservation Zone 8.	CM3 Natural Communities Protection CM11 Natural Communities Enhancement and Management

3.4.1 Development Process

The BDCP conservation measures were developed on the basis of the best available scientific and commercial information, including input of a broad range of technical experts and an extensive body of scientific study and analysis compiled over the past several decades. The conservation measures further reflect the recommendations of independent scientists with extensive knowledge of Delta ecological issues. The conservation measure development process, including descriptions of technical evaluations, is described in Appendix D, *Background on the Process of Developing the BDCP Conservation Measures.* On several occasions, the Steering Committee convened these scientists to provide guidance and insight on a range of issues important to the development of a comprehensive conservation strategy for the BDCP, the recommendations of which are are reflected in many of the conservation measures set out in this section (see Appendix G, *Independent Science Advisors Reports*).

The BDCP conservation measures were initially developed to address the conservation needs of the covered fish species and the aquatic ecosystem by groups of technical experts convened by the Steering Committee. To guide initial development of potential conservation measures, these experts, based on review of the body of relevant scientific information and input from the Fishery Agencies and topical experts, identified important environmental stressors affecting the covered fish species and aquatic ecosystem. The groups then identified the range of potential conservation measures that could reduce or remove the effects of these stressors on the covered fish species. The conservation measure development process was informed through application of several tools and processes described in the following paragraphs. Following development of a range of potential conservation measures, the groups iteratively screened and refined the conservation measures based on evaluations of their likely biological effectiveness and implementability.

A large body of information on the Delta ecosystem and approaches to ecosystem and species conservation has been developed over many years that provided a starting point for the development of the BDCP conservation measures. Important sources of scientific information and conservation approach ideas included the CALFED Bay Delta Program, particularly the Science Program and Ecosystem Restoration Program; the Interagency Ecological Program; two reports on the Delta prepared by the California Public Policy Institute; the Delta Vision Program, various plan and technical documents; and the Delta Risk Management Strategy. Building on this knowledge base, the BDCP conservation measures to address aquatic resources were developed using additional investigations, state-of-the-art physical models, specially developed conceptual models, and expert input from a large number of scientists and resource managers.

At several stages in the development of the conservation measures, interim evaluations where conducted to assess the potential for measures under consideration to improve ecological conditions within the Delta for the covered fish species. Central to these assessments were the conceptual ecological models and detailed evaluation processes that were developed under the CALFED Ecosystem Restoration Program to gauge the likely effect of potential actions on Delta fish and ecosystem processes. This process, known as the Delta Regional Ecosystem Restoration

Implementation Plan (DRERIP) Scientific Evaluation Process, was used to evaluate draft BDCP conservation measures in December 2008-March 2009 (see Appendix F, *DRERIP Evaluation Results*). Under the DRERIP process, potential conservation measures were evaluated individually to assess their benefits and drawbacks without factoring in potential synergies with other actions. To account for interrelationships with other potential measures, the BDCP Synthesis Team was established to review the results of the DRERIP process and identify instances in which combinations of measures would likely provide benefits greater than the sum of the individual measures. The Synthesis Team assessed potential synergies and conflicts between various measures and suggested modifications to the draft conservation measures to improve the overall effectiveness of measures. Based on input from the DRERIP Evaluation and the Synthesis Team, the conservation measures were revised to improve their potential effectiveness.

Following development of draft conservation measures for the aquatic ecosystem and covered fish species, the Steering Committee assembled a team of technical experts to develop conservation measures to address the nontidal natural communities and covered wildlife and plant species. These experts reviewed and refined the draft habitat restoration measures intitially developed to address aquatic resources to ensure that the measures included elements that would also support high functioning habitat for the associated covered wildlife and plant species. Using the best available information, additional conservation measures to protect, enhance, restore, and manage nontidal habitats were developed based on assessments of each covered wildlife and plant species conservation needs. These assessments included consideration for each species distribution within the Plan Area, known species stressors, the extent and distribution of existing protected and unprotected habitat areas, effects of implementing the BDCP actions on each species and their habitats, opportunities to protect and improve habitat corridors, and opportunities to improve habitat connectivity among habitat areas within and adjacent to the Plan Area in accordance with the principles of conservation biology.

3.4.2 Ecosystem-Level Conservation Measures

Ecosystem-level conservation measures include water operations and the spatial distribution of landscape-scale protection and restoration of natural communites to improve the processes and ecological functions supported by the Plan Area's aquatic and terrestrial ecosystems. Water operations are designed to enhance aquatic foodweb processes to improve food abundance and availability and to improve the hydrodynamic and water quality conditions that support the habitat and movement of the covered fish and other native aquatic organisms. Large-scale protection and restoration of connected natural communities are designed to maintain and increase the extent of high functioning habitat areas for the covered and other native wildlife and plant species and that support the movements of covered and other native wildlife. Because these conservation measures will have a systemic effect on ecosystem condtions within the Plan Area, they are designed to complement and guide implementation of the natural community-level conservation measures described in Section 3.4.3, *Natural Community-Level Conservation Measures*.

3.4.2.1 CM1 Water Facilities and Operation

*[**Note to Reviewers:** On January 29, 2010 the BDCP Steering Committee approved, for the purposes of the detailed Effects Analysis, a set of BDCP initial long-term operating criteria. A table of these criteria can be found in the February 11 Steering Committee agenda packet on the BDCP web site. A companion document titled "Aquatic Conservation Measures Proposed for Effects Analysis under BDCP" can also be found in the February 11 agenda packet and describes the steps that were used to develop this set of criteria. These criteria reflected the thinking of the Steering Committee at that time for the purpose of a comprehensive Effects Analysis. The Steering Committee noted that these criteria might become the final criteria or they might be modified based on the results of the Effects Analysis, evaluation of alternatives under CEQA and NEPA, or efforts to optimize them and permit achievement of the ecosystem and water supply goals of the BDCP. The Steering Committee envisioned an iterative process to refine the conservation strategy, including the development of the final set of initial long-term operating criteria and the adaptive range for these criteria.*

An effects analysis has been underway by the SAIC team over the past 10 months and the Steering Committee has been given several presentations on the preliminary results of that analysis. The Effects Analysis continues to be reviewed by the technical staff of the Steering Committee representatives and will be revised as necessary. To date, several issues have been identified that necessitate analysis of potential changes to the initial long-term operating criteria by January 2011. These include:

- *North Delta intake configuration related to predation concerns (in-river vs on-bank)*
- *Spring-run salmon egg mortality on the Sacramento River in the fall*
- *Reduced Sacramento River flows downstream of the north Delta intakes*
- *Refinement of April-May south Delta operations*
- *Winter-spring X2 and outflow effects on longfin smelt*
- *Summer and fall X2 and delta smelt abiotic habitat*

A process has begun to evaluate how modifications to some of the conservation measures, including initial long-term operating criteria, might address some of these issues in a manner that provides a refined approach to fishery protection while being sensitive to the water supply goals. This will lead to an iteration process that will take place for the purpose of describing the final conservation strategy and the initial long-term operating criteria for complete evaluation in the effects analysis. Also, as part of this process, an adaptive range for the operational criteria will be developed.]

This conservation measure provides for significant proposes changes to water operations in the Delta under the BDCP. This conservation measure includes two major components: (1) construction of new water facilities, and (2) operations of new operational control facilities or changes to the operations of existing operational control facilities. The evaluation of proposed new conveyance facilities (or changes to existing facilities) addresses two core issues that are separate and distinct, but are also closely interrelated. The first is the design issue associated with the new facility; that is, whether the new facility itself may enable improvements in flows and hydrodynamics if operated properly, and how to design the facility to achieve those improvements. The second issue is the operational issue; that is, what types of operational parameters would be most appropriate for the new facility to contribute to BDCP goals and objectives. It is important to recognize that these two aspects of proposed new water conveyance facilities are separate and distinct yet also closely joined, and must be evaluated as such.

The proposed new north Delta diversion facility offers an instructive example of this distinction. The appropriateness of the north Delta facility as a major new conservation measure for the BDCP demonstrates how both issues must be addressed together. There is a relatively broad agreement within the fisheries conservation community that a properly operated new north Delta facility will provide substantial benefits for certain listed species over the existing system, for all of the reasons enumerated below. The far more energetic debate focuses on what constitutes the proper operating parameters for the new facility, and less on the design parameters of the north Delta facility itself – although both are essential components of the proposal. Determining the appropriateness of the north Delta facility, therefore, considers the operational parameters that will govern it as much as the reliability of the governance structures that will apply those parameters. Hence, clearly distinguishing the design features from the operational features is important for an accurate appraisal of the merits of the measure overall.

The lower Sacramento River, Delta, and Suisun Bay and Marsh provide habitat for a diverse and complex assemblage of resident and migratory fish and other aquatic organisms. Section 3.2.3 *Development of the Aquatic Resources Component of the Conservation Strategy*, describes the BDCP approach to conservation and outlines the basic principles governing the approach. Several of these principles apply directly to the design of the conservation measure proposed in this section and are, therefore, expanded upon here. Development of water operations conservation measure as part of the BDCP is based, in large part, on the balance of seasonal and interannual variation in hydrologic conditions occurring within the watershed, and seasonal variation in the habitat requirements and geographic distribution of each of the lifestages of the covered fish within the estuary and tributary rivers, as well as many other factors. These include the beneficial interactions between establishing new aquatic habitats and hydrodynamics, a variety of flow-based and other mechanisms affecting the habitat quality and availability for these species and their food supplies, growth, survival, reproduction, and overall population dynamics in response to implementation of conservation measures. In addition, the water operations conservation measure is designed to provide a reliable water supply in a manner that avoids and reduces adverse effects to covered species and their habitat.

The proposed water operations also reflect the fact that the covered fish and other aquatic species have evolved in the Central Valley rivers and Delta. Their life histories are keyed to seasonal changes that naturally occur in flows, water temperatures, and other environmental cues that affect processes such as the seasonal timing of juvenile emigration downstream through the Delta, seasonal timing of reproduction, seasonal patterns in phytoplankton and zooplankton production that are food for covered fish and other aquatic species, seasonal inundation of floodplain habitat, and other important biological mechanisms.

One factor considered in the development of the water operations conservation measure is unidirectional downstream sweeping flows across the new fish screens proposed for the lower Sacramento River as part of long-term dual facility operations. Another consideration is the downstream transport of planktonic fish eggs and larvae, organic material, phytoplankton, and zooplankton from the lower Sacramento River into the Delta and Suisun Bay. A third factor is the consideration of sufficient flows in the lower Sacramento River during the primary migration period for juvenile Chinook salmon, steelhead, and other species (December-June) to reduce the frequency of bidirectional tidal flows in areas like Sutter and Steamboat Sloughs that are thought to reduce migration rates and increase the risk of juvenile fish to mortality from sources such as predation. Another factor that is taken into account is the provision of operations to maintain and improve habitat quality and availability for aquatic species in areas such as the Cache Slough complex, the lower Sacramento River, Delta and the low salinity zone located in the western Delta and Suisun Bay. The long-term water operations described below were developed to meet these and other biological objectives, water supply objectives, and water quality objectives of the BDCP.

In addition to reducing direct entrainment loss as a result of BDCP covered activities, the new water facilities and operations are designed to reduce other sources of harm to listed species, both direct and indirect (e.g. stranding, loss of homing ability, and reduced predation). In addition, implementation will be adaptively managed to optimize benefits to covered species while maintaining water supply reliability (see Section 3.7, *Adaptive Management Program*). Uncertainties concerning these actions will be managed through ongoing monitoring and research under the BDCP monitoring and adaptive management programs.

Water operations in the Delta are an integrated collection of actions that affect flow and water quality. This water facilities and operational conservation measure is closely intertwined with other components of the conservation strategy, including measures that will restore habitat and address other stressors to covered species. For example, the ability of habitat restoration in the south Delta to increase the amount of biological productivity transported to the western Delta and Suisun Bay will be realized only after preferential operation of the north Delta diversion facility over south Delta facilities begins (i.e., long-term operations).

Where applicable, criteria (quantitative values) are identified here for each parameter for specific times of year and specific water year types.

Water Facilities

This section presents an introduction to and summary of the proposed new and existing water facilities operated by the SWP and CVP within and near the Plan Area (Figure 3-52). These facilities include physical control structures such as gates, intakes, and pumps that can modify flows and affect Delta hydrodynamics in the immediate vicinity of the structure and often across large portions of the surrounding Delta. The physical construction and modification of these facilities are described and evaluated separately from the operations of the facilities under the BDCP.

The following is a list of new and existing water facilities and brief description of their functions:

1. North Delta Diversion Facilities and Tunnel/Pipeline – The north Delta diversion facilities will include five new intakes along the Sacramento River between Freeport and Courtland (Figure 3-52). Intakes will be equipped with state-of-the-art positive barrier fish screens to reduce entrainment of fish and will connect to tunnel/pipeline to carry water to a new regulating forebay adjacent and connected to existing south Delta SWP and CVP export facilities. More detail on specific features of the tunnel/pipeline facility is provided in Chapter 4, *Covered Activities. [**Note to Reviewers**: The design and location of the new intakes and conveyance facilities to be included in the proposed BDCP have not been determined.]*
2. Fremont Weir Operable Gates – New operable gates on the Fremont Weir will allow for the control of the timing, duration, and frequency of inundation of the Yolo Bypass during periods when the Sacramento River would not currently spill over the Fremont Weir into the Yolo Bypass. Operations for Fremont Weir Operable Gates are described in Section 3.4.2.2. *CM2 Yolo Bypass Fishery Enhancement*.
3. Delta Cross Channel Gates – Delta Cross Channel Gates are existing radial gates that control the flow of Sacramento River water through the Delta Cross Channel into the interior Delta.
4. Montezuma Slough Salinity Control Gate – Existing gate at the eastern opening of Montezuma Slough that controls the flow of fresh and salt water into Montezuma Slough.
5. South Delta Diversions – Two existing diversion facilities, the CVP Jones Pumping Plant and the SWP Banks Pumping Plant, divert water from the south Delta to meet water supply demands outside the Delta.

   In addition to the above listed facilities, the existing Barker Slough Pumping Plant diverts water from Barker Slough into the North Bay Aqueduct (NBA) for delivery in Napa and Solano counties. New diversion from the Sacramento River proposed as the North Bay Aqueduct Alternative Intake would operate in conjunction with the existing North Bay Aqueduct intake at Barker Slough.

<u>*Near-Term Water Operations*</u>

*[**Note to Reviewers**: At this time, BDCP does not have proposed near-term operations.]*

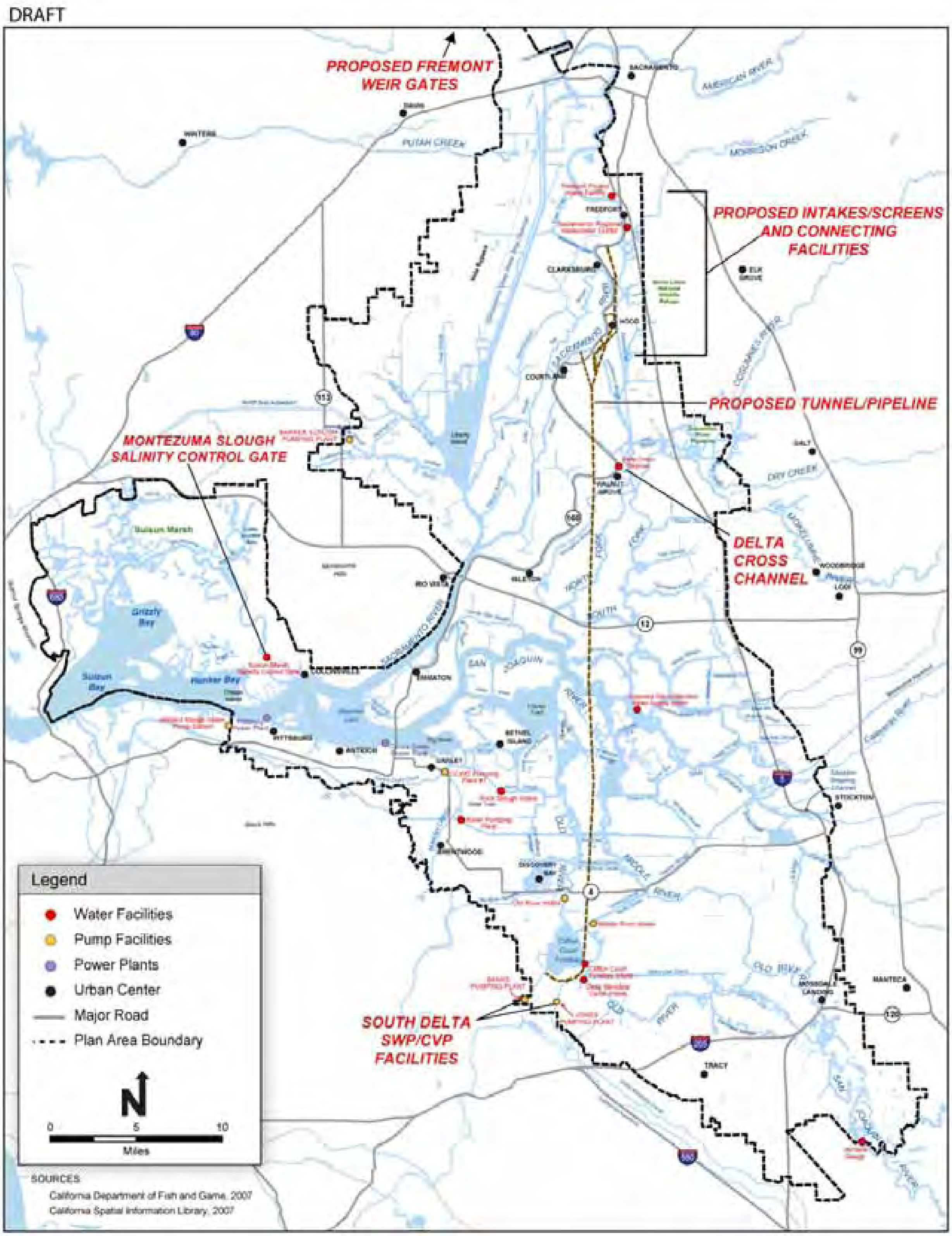

Figure 3-52. Water Operations Facilities in the Delta (Existing and Proposed)

Long-Term Water Operations

This section provides descriptions of the long-term water operations for multiple parameters across the Delta. Long-term operations are made possible by facilities constructed during the near-term implementation period (e.g., new north Delta diversions, tunnel/pipeline, and new gates at Fremont Weir). In the long-term implementation period, dual operations of the existing south Delta diversion facilities and the new north Delta diversion facilities will provide greater flexibility to benefit covered fish and water exports not possible during the near-term implementation period. Long-term operations under the dual facility will allow water to be diverted from the lower Sacramento River using state-of-the-art positive barrier fish screens that are expected to substantially reduce the risk of entrainment of covered fish and other aquatic organisms, but will also provide positive benefits resulting from a reduction in the rate of water diversions occurring from the south Delta when covered fish species are present. Long-term water operations described in this section will replace certain near-term water operations once the new north Delta diversions and the new tunnel/pipeline are completed and functional.

Construction and Preferential Operation of a New Water Diversion Facility in the North Delta.

Five new water diversion facilities with 3,000 cfs capacity each (combined 15,000 cfs capacity) will be constructed and operated on the Sacramento River in the north Delta to minimize impacts on fish at the SWP and CVP south Delta diversion facilities. A tunnel/pipeline facility with a 15,000 cfs capacity will be constructed to convey water from the new diversion facilities to the south Delta, where it will join existing SWP and CVP diversion facilities. The capacity of the new facilities will be 15,000 cfs, which is approximately the capacity of existing export pumps at SWP and CVP facilities in the southern Delta. The new tunnel/pipeline will follow a route through the Delta (Figure 3-52). Each new intake will be screened with state-of-the-art positive barrier fish screens and have a pump station, power lines, access roads, and other associated infrastructure.

Five locations for intakes have been identified in the north Delta (Figure 3-52). Selection of locations is based on multiple considerations including, but not limited to, maximizing function and effectiveness of screens; minimizing impacts to in-channel, on-bank, and terrestrial resources; applicable navigational and flood conveyance regulations; channel geometry and bathymetry; location relative to tidal influence and ranges of covered fish; future climate change and sea level rise; and proximity to other infrastructure (e.g., Sacramento Regional Wastewater outfall, existing developed land, and other intakes). Each intake will be engineered to allow variable rate pumping to handle variation in the location of covered fish and tidally-induced flows, as well as sea level rise from climate change. The influence of tides, which could produce reverse or stagnant flows in channels, attenuates upstream such that the most northern intakes are expected to be less influenced by tides than downstream intakes, particularly during higher river flow.

After the comprehensive evaluation of three types of intake/screens structures (on-bank, near-shore, and in-channel screens) for flood control, effects to covered fish species, and feasibility, it was concluded that on-bank structures would best meet these criteria for this reach of the river Fish screens will be designed to NMFS, DFG, and USFWS criteria to include specific screen mesh sizes (1.75 mm open area), a maximum approach velocity of 0.2 feet per second (ft/sec), sweeping velocity of at least two times the approach velocity (0.4 ft/sec), screen cleaning mechanisms, and monitoring systems. Three types of screening materials are currently being investigated: stainless steel, copper-nickel, and plastic. The advantages and disadvantages of each will be considered in the ultimate decision by the Implementation Office of which material to use. Further, with the high risk of invasion into the Delta by quagga and zebra mussels in the future, the use of anti-fouling material or alternative cleaning systems is also being considered.

The tunnel/pipeline will route water through the Delta to a new 600-acre forebay on Byron Tract (Figure 3-52). Water will be conveyed from the five intakes via pipelines to either an intake tunnel or a 750-acre Intermediate Forebay. A 33.5-mile tunnel will convey water from the Intermediate Forebay to the Byron Tract Forebay, where it will tie into existing SWP and CVP facilities.

Although construction of the new north Delta facility and associated infrastructure will be initiated as early as practicable following BDCP authorization, operation of the new facility will not start until and defines the beginning of the long-term implementation period (estimated at implementation year 10). The north Delta diversion facility will be operated in conjunction with, but preferentially to (except during summer months and at other times where necessary to meet the goals of fish conservation and water supply), existing south Delta SWP and CVP diversion facilities to minimize adverse effects on fish in the Delta while maintaining water supply reliability as described in Chapter 4, *Covered Activities*. The quantity and timing of diversions will be affected by specific parameters described in this chapter.

The new intake facilities will be operated to maintain flows in the Sacramento River to meet five primary objectives for flows at and downstream of the new north Delta facilities:

1. Maintain fish screen sweeping velocities,
2. Minimize undesirable upstream transport of water and aquatic resources from downstream channels,
3. Support fish transport to regions of suitable habitat,
4. Minimize predation effects downstream, and
5. Maintain or improve rearing habitat in the north Delta.

These north Delta facilities “bypass flows” represent the rate of flow at which the Sacramento River must pass downstream of the new diversion points. Bypass flows are intended to serve as an operational parameters to limit or otherwise manage water diversions from the new north Delta diversion facilities to minimize and reduce the effects of those diversions on downstream hydrodynamics (e.g., reduce Sacramento River flow downstream of the point of diversion) needed to support functions within and downstream of the river. Bypass flows for the Sacramento River act as an operational criteria in which water diversions will only occur when flows are maintained above the minimum criteria. The minimum bypass flow rates act as restrictions on water diversions during those years and seasons when flow in the Sacramento River is low. To meet water supply goals (see Chapter 4, *Description of Covered Activities*), constraints on the amount of water diverted from north Delta facilities may require commensurate increases in diversions from the south Delta SWP and CVP facilities. To maintain water quality in the south and central Delta during low flow periods on the San Joaquin River in summer months (July-September), existing south Delta pumps will be preferentially operated up to 3000 cfs (see *Delta water quality maintenance* below).

In addition to establishing the minimum bypass flow rates as one set of operating criteria, two additional operating criteria will be implemented in response to low river flow conditions. The first operational condition is preferential operation of the new diversion facilities located the farthest upstream to reduce the effects of low Sacramento River flow on tidal reversal in the vicinity of the diversion (maintain positive downstream flows across the intake structures and reduce the likelihood that larval and juvenile fish will move upstream into the area of potential entrainment/impingement at the diversion). Results of hydrodynamic modeling indicate that a higher level of Sacramento River flow needs to be maintained to avoid tidal flow reversal downstream (e.g., near Walnut Grove) when compared to the flow needed to maintain downstream river flows at more upstream sites. A second operational response to low Sacramento River flow conditions is to implement preferential diversion operations in response to tidal conditions (e.g., divert water during ebb tide stage to maintain sweeping velocity and avoid tidal flow reversal) and then reduce or curtail diversion during the flood tide stage.

Factors considered in developing north Delta diversion bypass flows included:

- Seasonal timing of various life stages of covered fish inhabiting the Sacramento River in the vicinity of the proposed water diversion locations;
- Changes in the biological processes and relationship in response to river flow that occur seasonally (e.g., differences in the biological processes of phytoplankton and zooplankton production between winter-spring and summer-fall);
- The relationship between bypass flows and hydrologic synchrony of flows and environmental cues within the Sacramento River watershed;
- The relationship between river bypass flow rate and constraints on water diversions and water supplies;
- The relationship between downstream transport rate of planktonic particles (simulating larval delta and longfin smelt transport between the upstream spawning areas, such as Cache Slough, and the downstream estuarine habitat where first feeding and juvenile rearing occur) and river flow rate;

- The relationship between river flow and downstream transport of phytoplankton, zooplankton, and organic material;
- The relationship between fall river flows and attraction and migration flows in the mainstem river for adult upstream migration by fall-run and late fall-run Chinook salmon, steelhead, delta and longfin smelt, splittail, and other upstream migrating adults;
- Relationships between river flow rate and juvenile transit time through the lower river (a factor thought to affect vulnerability to predation mortality), juvenile survival rates, and river flow;
- Relationships between river flow and habitat conditions for predatory fish (e.g., largemouth bass, smallmouth bass, pikeminnow, and striped bass) in the river and sloughs;
- The relationship between river flow rate and tidal dynamics (e.g., changes in water velocity and direction in response to flood and ebb tide conditions) and the river flows at various potential diversion locations that maintain a net unidirectional downstream flow over all tidal conditions;
- The relationship between mainstem river flows and seasonal flows into a floodplain habitat such as the Yolo Bypass and the resultant effects on hydrodynamic conditions in the river at the points of diversion;
- The relationship between existing and expanded tidal marsh habitat within the Cache Slough complex and tidal hydrodynamics within the river at various potential points of diversion;
- The relationships between seasonal timing of juvenile winter-run Chinook salmon downstream migration and pulse flows down the lower Sacramento River (del Rosario and Redler 2010); and
- The relationship between river flow, channel geometry, and resulting sweeping velocities across a positive barrier fish screen at each potential diversion location. Sweeping velocity is intended to transport fish downstream in a timely manner to reduce their exposure to entrainment and impingement at the diversion and to help remove accumulated debris from the fish screen surface to maintain approach velocities.

Analysis of seasonal timing of juvenile winter-run Chinook salmon migration (del Rosario and Redler 2010) suggests that pulse flows provide an environmental cue that stimulates the downstream migration of juvenile winter-run Chinook salmon into the Delta and subsequently their migration into coastal marine waters. Pulse flows provide a change in river flow over a short time period and are also typically associated with increases in turbidity and suspended sediments within the water column. Increased turbidity has been identified as an important environmental condition affecting pre-spawning adult delta smelt geographic distribution within the Delta and lower reaches of the Sacramento River. Therefore, bypass operations include provisions for operations in response to seasonal pulse flow events.

Operational Criteria and Adaptive Limits. The north Delta facilities operations and bypass flow requirements will apply in the BDCP long-term implementation period following completion of facilities construction. Specifics on the operational criteria and adaptive range of north Delta facilities bypass flows are provided in Table 3.13. The bypass operations will be based on three parameters “Constant Low Flow Pumping,” “Initial Pulse Protection,” and “Post-Pulse Operations.” Table 3.14 provides post-pulse flows criteria.

To allow for flexible and responsive implementation of the BDCP, several conservation measures include a defined “adaptive range” that establishes the parameters within which a conservation measure may be adjusted to improve its effectiveness or respond to changing biological conditions. Adaptive Ranges are specifically established upper and lower boundaries and limits that govern the scope of changes that can be made to water operations criteria for specific operational parameters under this conservation measure pursuant to the adaptive management program. These adaptive ranges are expected to be included within the bounds of BDCP regulatory authorizations and provide for both flexibility to change operation criteria to improve conservation or water supply performance and limitations to clearly define the confines of the Plan. Adjustments to the water operations criteria set out in the BDCP and reflected in its associated authorizations, and within the adaptive range for water operations described Tables 3-13 and 3-14, may only be conducted through the process identified in Section 3.7.3.2, *Decision Process for Adjusting Water Operations within the Adaptive Range*.

[***Note to Reviewers:*** *Adaptive range limits have not been determined at this time. Tables 3-13 and 3-14 provide “analytical ranges” used in the BDCP Effects Analysis as a step in the process of development of adaptive ranges.]*

Problem Statement: For decades, water has been diverted directly from the south Delta through SWP and CVP facilities to meet agricultural and urban water demands south and west of the Delta. These diversions both require and create an artificial north-to-south flow of water through the Delta (as opposed to the natural general east-to-west flow pattern) and have resulted in the development of reverse flows in major Delta channels that result in entrainment of fish, invertebrates, nutrients, and other organic material. Existing diversion facilities are equipped with louvers that guide juvenile and larger fish into salvage facilities. Salvaged fish are subsequently transported to release locations on the lower Sacramento and San Joaquin Rivers where they are subject to high predation pressure (Miranda et al. 2010). Planktonic eggs, larvae, and small juveniles are not effectively salvaged and do not survive when carried into conveyance facilities. Smelt and juvenile salmonids that are drawn into Clifton Court Forebay are subject to predation from the large populations of predatory fish that are present there as well as other sources of mortality (Gingras 1997, Clark et al. 2009, Castillo et al. 2009).

Table 3-13. Proposed Long-Term Operational Criteria and Adaptive Range Limits

*[**Note to Reviewers:** Table 3-13 and table 3-14 provide the proposed BDCP long term water operations for evaluation in the BDCP Effects Analysis. The criteria in these tables do not represent criteria agreed to by the Steering Committee; its purpose is for use in the Effects Analysis. These two tables are the same as the tables provided to the Steering Committee in February 2010. The operational criteria identified in these tables are the criteria agreed to by the BDCP Steering Committee on January 29, 2010 as documented in the handout titled: "SAIC Consultant Team Recommendations for Long Term Operations (January 29, 2010 draft D) – revised version based on SC input.]*

North Delta Diversion Bypass Flows		
Objectives include flows of the functional equivalent thereof to (1) maintain fish screen sweeping velocities, (2) reduce upstream transport from downstream channels, (3) support salmonid and pelagic fish transport to regions of suitable habitat, (4) reduce predation effects downstream, and (5) maintain or improve rearing habitat in the north Delta.		
Analytical Range A Operational Criteria[30]	**Initial Operational Criteria**	**Analytical Range B Operational Criteria[1]**
Constant Low-Level Pumping (Dec-Jun): • Diversions up to 10% of river flow for flows greater than 5,000 cfs. No more than 300 cfs at any one intake.	**Constant Low-Level Pumping (Dec-Jun):** • Diversions up to 6% of river flow for flows greater than 5,000 cfs. No more than 300 cfs at any one intake.	**Constant Low-Level Pumping (Dec-Jun):** • Diversions up to 2% of river flow for flows greater than 5,000 cfs. No more than 300 cfs at any one intake.
Initial Pulse Protection: • No pulse flow protection criteria implemented.	**Initial Pulse Protection:** • Low level pumping maintained through the initial pulse period. For the purpose of monitoring, the initiation of the pulse is defined by the following criteria: (1) Wilkins Slough flow changing by more than 45% over a five day period and (2) flow greater than 12,000 cfs. Low-level pumping continues until (1) Wilkins Slough returns to pre-pulse flows (flow on first day of 5-day increase), (2) flows decrease for 5 consecutive days, or (3) flows are greater than 20,000 cfs for 10 consecutive days. After pulse period has ended, operations will return to the bypass flow table (Table 3-6). These parameters are for modeling purposes. Actual operations will be based on real-time monitoring of fish movement. • If the first flush begins before Dec 1, May bypass criteria must be initiated following first flush and the second pulse period will have the same protective operation.	**Initial Pulse Protection:** • No range. (Same as initial operations)
Post-Pulse Operations: • After initial flush(es), go to Level I post-pulse bypass rule (see Table 3-6) until **10** total days of bypass flows above 20,000 cfs. Then go to the Level II post-pulse bypass rule until **20** total days of bypass flows above 20,000 cfs. Then go to the Level III post-pulse bypass rule.	**Post-Pulse Operations:** • After initial flush(es), go to Level I post-pulse bypass rule (see Table 3-6) until **15** total days of bypass flows above 20,000 cfs. Then go to the Level II post-pulse bypass rule until **30** total days of bypass flows above 20,000 cfs. Then go to the Level III post-pulse bypass rule.	**Post-Pulse Operations:** • After initial flush(es), go to Level I post-pulse bypass rule (see Table 3-6) until **20** total days of bypass flows above 20,000 cfs. Then go to the Level II post-pulse bypass rule until 45 total days of bypass flows above 20,000 cfs. Then go to the Level III post-pulse bypass rule.

[30] Analytical ranges represent the operational range limits for which the Effects Analysis will evaluate operational parameters. These analytical ranges are part of the process of identifying adaptive management ranges. It is expected that the eventual adaptive management range limits would fall within these analytical ranges.

Table 3-13. Proposed Long-Term Operational Criteria and Adaptive Range Limits (continued)

South Delta Channel Flows

Minimize take at south Delta pumps by reducing incidence and magnitude of reverse flows during critical periods for pelagic species.

Analytical Range A Operational Criteria

OMR Flows

Old and Middle River flows no less than the values below:

Combined Old and Middle River flows no less than values below* (cfs)					
Month	**W**	**AN**	**BN**	**D**	**C**
Jan	-6000	-6000	-6000	-6000	-6000
Feb	-6000	-6000	-6000	-6000	-6000
Mar	-6000	-6000	-6000	-6000	-6000
Apr	-6000	-6000	-6000	-6000	-6000
May	-6000	-6000	-6000	-6000	-6000
Jun	-6000	-6000	-6000	-6000	-6000
Jul	N/A	N/A	N/A	N/A	N/A
Aug	N/A	N/A	N/A	N/A	N/A
Sep	N/A	N/A	N/A	N/A	N/A
Oct	N/A	N/A	N/A	N/A	N/A
Nov	N/A	N/A	N/A	N/A	N/A
Dec	-7200	-7200	-7200	-7200	-7200

* Values are monthly average for use in modeling. December 20-31 targets are -6000 cfs and are averaged with an assumed background of -8000 cfs for December 1-19.

No Range.

Initial Operational Criteria

OMR Flows

FWS smelt and NMFS BO's model of adaptive restrictions (temperature, turbidity, salinity, smelt presence)

Table below provides a rough representation of the current estimate of "most likely" operation under FWS and NMFS BO's for modeling purposes.

Combined Old and Middle River flows no less than values below* (cfs)					
Month	**W**	**AN**	**BN**	**D**	**C**
Jan	-4000	-4000	-4000	-5000	-5000
Feb	-5000	-4000	-4000	-4000	-4000
Mar	-5000	-4000	-4000	-3500	-3000
Apr	-5000	-4000	-4000	-3500	-2000
May	-5000	-4000	-4000	-3500	-2000
Jun	-5000	-5000	-5000	-5000	-2000
Jul	N/A	N/A	N/A	N/A	N/A
Aug	N/A	N/A	N/A	N/A	N/A
Sep	N/A	N/A	N/A	N/A	N/A
Oct	N/A	N/A	N/A	N/A	N/A
Nov	N/A	N/A	N/A	N/A	N/A
Dec	-6800	-6800	-6300	-6300	-6100

* Values are monthly average for use in modeling. December 20-31 targets are -5000 cfs (W, AN), -3500 cfs (BN, D), and -3000 cfs (C), and are averaged with an assumed background of -8000 cfs for December 1-19. Values are reflective of the "most likely" operation under the FWS Delta Smelt Biological Opinion. Values for modeling may be updated based on review by fishery agencies.

South Delta Export – San Joaquin Inflow Ratio[31]

- Sliding scale for flows above the established OMR to share additional SJR flows between export and environment; export share would increase at higher flows
- Time value of benefit; crediting outside of period in which flows are acquired
- [Note that Conveyance WG/HOTT recommends continuing to evaluate the concept of isolating Old River to address south Delta channel flows.][32]

Analytical Range B Operational Criteria

OMR Flows

- Old and Middle River flows same as proposed Operations during December, January, and June
- Old and Middle River flows no less than -5,000 cfs between July and November

South Delta Export – San Joaquin Inflow Ratio

- 50% Feb & Mar
- 25% April & May

[31] The effects of potential increased San Joaquin River inflows on BDCP goals and objectives will be evaluated separately from the BDCP Effects Analysis.

Table 3-13. Proposed Long-Term Operational Criteria and Adaptive Range Limits (continued)

Fremont Weir/Yolo Bypass		
Considerations include (1) increasing spawning and rearing habitat for splittail and rearing habitat for salmonids for >30 days, (2) providing alternate migration corridor to the mainstem Sacramento River, and (3) increasing effectiveness of habitat and food transport in Cache Slough.		
Analytical Range A Operational Criteria	**Initial Operational Criteria**	**Analytical Range B Operational Criteria**
No Range.	• Sacramento Weir - No change in operations; improve upstream fish passage facilities • Lisbon Weir - No change in operations; improve upstream fish passage facilities • Fremont Weir – Improve fish passage at existing weir elevation; construct opening and operable gates at elevation 17.5 feet with fish passage facilities; construct opening and operable gates at a smaller opening with fish passage enhancement at elevation 11.5 feet	No Range.
Fremont Weir – Improve fish passage at existing weir elevation; construct opening and operable gates at elevation 17.5 feet with fish passage facilities		No Range.
Fremont Weir Gate Operations		
December 1-March 30 open the 17.5 foot elevation gates when Sacramento River flow at Freeport is greater than 25,000 cfs (provides local and regional flood control benefit and coincides with pulse flows and juvenile salmonid migration cues) to provide Yolo Bypass inundation of 3,000 to 6,000 cfs depending on river stage. Operating the gates to allow Yolo Bypass inundation when Sacramento River flow is greater than 25,000 cfs will reduce impacts to water supply associated with Hood bypass flow constraints. Potential impacts to water supply would be avoided or minimized through an operations plan.	December 1-March 30 (extend to May 15, depending on hydrologic conditions and measures to minimize land use and ecological conflicts) open the 17.5 foot and 11.5 foot elevation gates when Sacramento River flow at Freeport is greater than 25,000 cfs (provides local and regional flood control benefit and coincides with pulse flows and juvenile salmonid migration cues, provides seasonal floodplain inundation for food production, juvenile rearing, and spawning) to provide Yolo Bypass inundation of 3,000 to 6,000 cfs depending on river stage. Operating the gates to allow Yolo Bypass inundation when Sacramento River flow is greater than 25,000 cfs will reduce impacts to water supply associated with Hood bypass flow constraints. Potential impacts to water supply would be avoided or minimized through an operations plan.	No Range.
Close the 17.5 foot elevation gates when Sacramento River flow at Freeport recedes to less than 25,000 cfs	Close the 17.5 foot elevation gates when Sacramento River flow at Freeport recedes to less than 20,000 cfs but keep 11.5 foot elevation gates open to provide greater opportunity for fish within the bypass to migrate upstream into the Sacramento River; close 11.5 foot elevation gates when Sacramento River flow at Freeport recedes to less than 15,000 cfs	No Range.

[32] The concept of isolating Old River to address south Delta channel flows will be evaluated separately from the BDCP Effects Analysis.

Table 3-13. Proposed Long-Term Operational Criteria and Adaptive Range Limits (continued)

Delta Inflow & Outflow		
Considerations include (1) Provide sufficient outflow to maintain desirable salinity regime downstream of Collinsville during the spring, (2) explore range of approaches toward providing additional variability to Delta inflow and outflow.		
Analytical Range A Operational Criteria	**Initial Operational Criteria**	**Analytical Range B Operational Criteria**
Delta Outflow: Jul-Jan: Per D-1641 Feb-Jun: Per D-1641*, except no Roe Island triggering * Current relaxation of Collinsville standard to 4,000 cfs in May and June revised to state when the Eight River Index is 10.0 or less as established on May 1. ** Proportional Reservoir Release concept will continue to be evaluated to the extent that it provides similar response to outflow, inflow, and upstream storage conditions	**Delta Outflow:** Jul-Jan: Per D-1641 Feb-Jun: Per D-1641 * Proportional Reservoir Release concept will continue to be evaluated to the extent that it provides similar response to outflow, inflow, and upstream storage conditions	**Delta Outflow:** **Summer, Winter, and Fall:** Jul-Aug & Dec-Jan: Per D-1641 Sep-Nov: Fall X2 per FWS Smelt BO **Spring:** Feb-Jun: NGO X2-Eight River Index approach in all years (storage off-ramps in all year types will be refined to avoid upstream coldwater storage impacts on all reservoirs). * Proportional Reservoir Release concept will continue to be evaluated to the extent that it provides similar response to outflow, inflow, and upstream storage conditions ** Continue analysis of NGO watershed unimpaired runoff approach as it relates to PREs and parties outside of BDCP. Carry into “related action” alternative.
Delta Cross Channel Gate Operations		
Considerations include (1) reduce transport of outmigrating Sacramento River fish into central Delta, (2) maintain flows downstream on Sacramento River, (3) and providing sufficient Sacramento River flow into interior Delta when water quality for M&I and AG may be of concern.		
No Range.	Oct-Nov: DCC gate closed if fish are present (assume 15 days per month; may be open longer depending on presence of fish) Dec-Jun: DCC gate closed Jul-Sep: DCC gate open	No Range.
Rio Vista Minimum Instream Flows		
Maintain minimum flows for outmigrating salmonids and smelt.		
No Range.	Sep-Dec: Per D-1641 Jan-Aug: Minimum of 3,000 cfs	No Range.

Table 3-13. Proposed Long-Term Operational Criteria and Adaptive Range Limits (continued)

Operations for Delta Water Quality and Residence Time		
Considerations include (1) maintain a minimum level of pumping from the south Delta during summer to provide limited flushing for general water quality conditions (reduce residence times), (2) for M&I and AG salinity improvements, and (3) to allow operational flexibility during other periods to operate either north or south diversions based on real-time assessments of benefits to fish and water quality.		
Analytical Range A Operational Criteria	**Initial Operational Criteria**	**Analytical Range B Operational Criteria**
No Range.	**Assumptions for analysis:** Jul-Sep: Prefer south delta pumping up to 3,000 cfs before diverting from north Oct-Jun: Prefer north delta pumping (real-time operational flexibility)	No Range.
In-Delta Agricultural and Municipal & Industrial Water Quality Requirements		
Existing M&I and ag salinity requirements.		
No Range.	Existing D-1641 North and Western Delta AG and MI standards EXCEPT move compliance point from Emmaton to Three Mile Slough juncture. Maintain all water quality requirements contained in the NDWA/ DWR Contract and other DWR contractual obligations.[33]	No Range.

[33] The results of the water quality modeling from the effects analysis will be used to determine if other actions are needed to address water quality issues that may arise, including water quality in the southern and central Delta for both Agricultural and M*I due to the BDCP long-term operations.

Table 3-14. Post-Pulse Operations for North Delta Diversion Bypass Flows

*[**Note to Reviewers:** Table 3-13 and table 3-14 provide the proposed BDCP long term water operations for evaluation in the BDCP Effects Analysis. The criteria in these tables do not represent criteria agreed to by the Steering Committee; its purpose is for use in the Effects Analysis. These two tables are the same as the tables provided to the Steering Committee in February 2010. The operational criteria identified in these tables are the criteria agreed to by the BDCP Steering Committee on January 29, 2010 as documented in the handout titled: "SAIC Consultant Team Recommendations for Long Term Operations (January 29, 2010 draft D) – revised version based on SC input.]*

Level I Post-Pulse Operations

Based on the objectives stated above, it is recommended to implement the following operating criteria:

- Bypass flows sufficient to prevent upstream tidal transport at two points of control: (1) Sacramento River upstream of Sutter Slough and (2) Sacramento River downstream of Georgiana Slough. These points are used to prevent upstream transport toward the proposed intakes and to prevent upstream transport into Georgiana Slough.

Dec - Apr

If Sacramento River flow is over--	But not over--	The bypass is:
0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low level pumping (see main table)
15,000 cfs	17,000 cfs	15,000 cfs plus 80% of the amount over 15,000
17,000 cfs	20,000 cfs	16,600 cfs plus 60% of the amount over 17,000 cfs
20,000 cfs	no limit	18,400 plus 30% of the amount over 20,000 cfs

Level II Post-Pulse Operations

Based on the objectives stated above, it is recommended to implement the following operating criteria:

- Bypass flows sufficient to prevent upstream tidal transport at two points of control: (1) Sacramento River upstream of Sutter Slough and (2) Sacramento River downstream of Georgiana Slough. These points are used to prevent upstream transport toward the proposed intakes and to prevent upstream transport into Georgiana Slough.

Dec - Apr

If Sacramento River flow is over--	But not over--	The bypass is:
0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping (see main table)
11,000 cfs	15,000 cfs	11,000 cfs plus 60% of the amount over 11,000
15,000 cfs	20,000 cfs	13,400 cfs plus 50% of the amount over 15,000 cfs
20,000 cfs	no limit	15,900 cfs plus 20% of the amount over 20,000 cfs

Level III Post-Pulse Operations

Based on the objectives stated above, it is recommended to implement the following operating criteria:

- Bypass flows sufficient to prevent upstream tidal transport at two points of control: (1) Sacramento River upstream of Sutter Slough and (2) Sacramento River downstream of Georgiana Slough. These points are used to prevent upstream transport toward the proposed intakes and to prevent upstream transport into Georgiana Slough.

Dec - Apr

If Sacramento River flow is over--	But not over--	The bypass is:
0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping (see main table)
9,000 cfs	15,000 cfs	9,000 cfs plus 50% of the amount over 9,000
15,000 cfs	20,000 cfs	12,000 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	no limit	13,000 cfs plus 0% of the amount over 20,000 cfs

Table 3-14. Post-Pulse Operations for North Delta Diversion Bypass Flows (continued)

Level I Post-Pulse Operations

May

If Sacramento River flow is over--	But not over--	The bypass is:
0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low level pumping (see separate table)
15,000 cfs	17,000 cfs	15,000 cfs plus 70% of the amount over 15,000
17,000 cfs	20,000 cfs	16,400 cfs plus 50% of the amount over 17,000 cfs
20,000 cfs	no limit	17,900 plus 20% of the amount over 20,000 cfs

Jun

If Sacramento River flow is over--	But not over--	The bypass is:
0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low level pumping (see separate table)
15,000 cfs	17,000 cfs	15,000 cfs plus 60% of the amount over 15,000
17,000 cfs	20,000 cfs	16,200 cfs plus 40% of the amount over 17,000 cfs
20,000 cfs	no limit	17,400 plus 20% of the amount over 20,000 cfs

Jul-Sep: 5,000 CFS
Oct-Nov: 7,000 cfs

Level II Post-Pulse Operations

May

If Sacramento River flow is over--	But not over--	The bypass is:
0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping (see separate table)
11,000 cfs	15,000 cfs	11,000 cfs plus 50% of the amount over 11,000
15,000 cfs	20,000 cfs	13,000 cfs plus 35% of the amount over 15,000 cfs
20,000 cfs	no limit	14,750 cfs plus 20% of the amount over 20,000 cfs

Jun

If Sacramento River flow is over--	But not over--	The bypass is:
0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping (see separate table)
11,000 cfs	15,000 cfs	11,000 cfs plus 40% of the amount over 11,000
15,000 cfs	20,000 cfs	12,600 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	no limit	13,600 cfs plus 20% of the amount over 20,000 cfs

Jul-Sep: 5,000 CFS
Oct-Nov: 7,000 CFS

Level III Post-Pulse Operations

May

If Sacramento River flow is over--	But not over--	The bypass is:
0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping (see separate table)
9,000 cfs	15,000 cfs	9,000 cfs plus 40% of the amount over 9,000
15,000 cfs	20,000 cfs	11,400 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	no limit	12,400 cfs plus 0% of the amount over 20,000 cfs

Jun

If Sacramento River flow is over--	But not over--	The bypass is:
0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping (see separate table)
9,000 cfs	15,000 cfs	9,000 cfs plus 30% of the amount over 9,000
15,000 cfs	20,000 cfs	10,800 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	no limit	11,800 cfs plus 0% of the amount over 20,000 cfs

Jul-Sep: 5,000 CFS
Oct-Nov: 7,000 CFS

The Sacramento River, in addition to its upstream tributaries, is the primary migration corridor and spawning/rearing habitat for Chinook salmon, Central Valley steelhead, green and white sturgeon, and Pacific and river lamprey spawning in the Sacramento River watershed. Further, both delta smelt and longfin smelt are thought to spawn in the lower Sacramento River (Wang 1986, Bennett 2005). Important fishery issues with respect to seasonal river flows include: (1) adult Chinook salmon, steelhead, green and white sturgeon, and Pacific and river lamprey attraction flows and upstream migration; (2) juvenile Chinook salmon, steelhead, and Pacific and river lamprey downstream migration and survival; (3) downstream transport of planktonic fish eggs and larvae; (4) downstream transport of food and other organic material; and (5) habitat for both resident and migratory covered fish species within the lower Sacramento River. The importance of river flows to each life stage of the covered fish species varies seasonally depending life history and habitat requirements for each species. Because of the importance of the Sacramento River as a migration route and habitat for covered fish species, maintaining sufficient flows within the river to support this function is an important operational objective for covered fish species.

Hypotheses: Relocation and operation of the primary point of SWP and CVP water diversions from the south Delta to multiple facilities on the Sacramento River between Freeport and Courtland and conveying water through a tunnel/pipeline facility are hypothesized to provide a broad range of benefits to covered fish species, the Delta ecosystem, and water supply if operated according to an appropriate set of operational parameters, which are described as part of this conservation measure. The following hypotheses provide the justification for the relocation of the primary point of diversion:

1. Relocation and operation of the primary point of diversion to the north Delta will substantially reduce entrainment of the larvae of covered fish species by reducing the spatial overlap of diversion intakes and covered fish species. The location of the existing south Delta export facilities is within the influence of all covered fish species for at least part of the year. However, the population centers of resident estuarine species, particularly delta and longfin smelt, are downstream of the reach of the Sacramento River where the north Delta intakes could be installed (Wang 1986, Bennett 2005).

2. Equipping facility intakes with state-of-the-art positive barrier fish screens will substantially reduce entrainment and impingement losses of juveniles and adults of covered fish species. These screens will be engineered to provide a maximum approach velocity coupled with a minimum unidirectional sweeping velocity to protect covered fish species when fish are within the vicinity of intakes.

3. Constructing multiple intakes (rather than one or few) along the Sacramento River between Freeport and Courtland will substantially reduce entrainment and impingement losses of juveniles and adults of covered fish species. Multiple intakes will reduce the distance fish must travel past each fish screen, allowing individuals to

rest between intake locations. Early estimates indicated that, if one 15,000 cfs intake were constructed, a single fish screen nearly a mile long will need to be constructed to meet approach and sweeping velocity criteria. This distance would expose fish to screens for longer periods, potentially exhausting them, reducing their swimming ability, and increasing their vulnerability to impingement.

4. Reducing water diversions in the tidal region of the Delta will substantially reduce entrainment and impingement losses of juveniles and adults of covered fish species. Reverse flows associated with tidal oscillations increase the zone of influence of existing diversion facilities in many south Delta channels, potentially increasing the risk of entrainment of covered fish species. Relocating the primary point of diversion farther upstream will reduce the tidal influence on diversions, which will reduce entrainment of covered fish species. Further, for positive barrier fish screens to function properly to minimize fish entrainment and impingement risk, a minimum unidirectional sweeping velocity must be maintained. Opportunities for such velocity improve as tidal influence decreases farther upstream.

5. Relocation and operation of the primary point of diversion to the north Delta will reduce the export of nutrients, phytoplankton, zooplankton, macroinvertebrates, and other organic material from the estuary. The location of existing south Delta diversion facilities is thought to be in an area that exports higher concentrations of nutrients, phytoplankton, zooplankton, macroinvertebrates, and other organic material than will occur with the new proposed reach of the Sacramento River. As a result, the loss of Delta productivity may be lower if water is diverted at north Delta facilities compared to existing south Delta facilities.

6. Improving hydrodynamics within Delta channels will improve fishery and aquatic habitat within the Delta. Existing flow patterns in the Delta have been altered to maintain high water quality in the south Delta for project exports, as well as for local agricultural and other urban water uses. Such alterations include north to south flows through the man-made Delta Cross Channel and reverse flows in Old and Middle Rivers, generating adverse effects on fish and aquatic processes.

7. Relocation and operation of the primary point of diversion to the north Delta will reduce or eliminate mortality of covered fish species associated with collection, handling, transport, and release of salvaged fish from the existing export facilities and predation within these facilities. A north Delta diversion facility will be designed to avoid altogether the need to salvage fish by constructing in-river or on-river facilities.

8. Relocation and operation of the primary point of diversion to the north Delta will improve water supply reliability and flexibility under conditions of future environmental change. Because of their location, new diversion facilities could withstand predicted future sea level rise in ways that existing diversion facilities will not. Multiple intakes will add flexibility in operations to handle variation in the location of covered fish and tidally-induced flows.

9. Reducing artificial north-to-south through-Delta flows when covered fish are present will increase hydraulic residence time and improve aquatic productivity in the interior Delta. Existing Delta operations promote north-to-south flow of water via the Delta Cross Channel to offset high salinities and lower inflows from the San Joaquin River. By reducing South Delta diversions, less water will move from north to south, resulting in increased residence time of nutrients and organic matter, allowing these materials to be assimilated into the Delta food web.

10. Reducing the reliance on through-Delta conveyance via the Delta Cross Channel and intakes in the south Delta will provide greater opportunity for effective physical habitat restoration and enhancement in the western, eastern, and southern Delta. Decreased south Delta pumping will reduce the export of primary and secondary ecological production that may result from restored habitat, which would other reduce or eliminate the expected benefits of the habitat restoration also proposed by the BDCP. Restoration in these parts of the Delta, as well as Delta-wide hydrodynamic changes expected from a north Delta diversion, will reestablish ecosystem complexity by improving aquatic ecosystem processes, distribution, connectivity, migration, transport, and residence time in ways that the current water conveyance system cannot accommodate.

11. Reducing the reliance on through-Delta conveyance via the Delta Cross Channel and intakes in the south Delta will substantially reduce the effects of existing water projects on salmonids in the San Joaquin River system and tributaries, Mokelumne River, and other east side tributaries. Such artificial flow patterns are thought to entrain outmigrating juvenile salmonids in these channels towards the pumps and confuse the upstream migration cues of adults. Although the potential for adverse effects on Sacramento River salmonids may increase, these effects are predicted to be avoided or minimized by the positive fish screen and sweeping and approach velocity criteria (see #2-4 above) and other operational parameters.

12. Relocation and operation of the primary point of diversion to the north Delta will facilitate the implementation of some other conservation measures focused on non-flow and non-habitat related stressors.

13. Relocation and operation of the primary point of diversion to the north Delta will allow for the emulation of more natural physical patterns (e.g., salinity regimes, flow patterns) and processes in the Delta under which native resident species evolved. For example, a change in the hydrograph could favor native species by providing proper timing of biological processes from physical cues, such as those needed to initiate upstream or downstream migration, and create conditions that disfavor non-native species, such as reduced summer inflows, which are currently higher than would occur naturally.

The following hypotheses provide the basis for maintaining bypass flows past the proposed new north Delta diversions:

1. Maintaining bypass flows will maintain adequate flows in the mainstem Sacramento River and distributaries downstream of the points of diversion for covered fish species. Of particular interest are flow rates within Sutter and Steamboat Sloughs. These sloughs are existing channels that convey water from the Sacramento River in the general vicinity of Courtland downstream to approximately Rio Vista where they re-enter the lower Sacramento River. Both channels currently have a hydraulic capacity greater than 500 cfs. Benefits maintaining adequate flows in Sutter and Steamboat Sloughs include:

    - Providing an alternative migration route for salmonids (Perry and Skalski 2008) and possibly splittail, sturgeon, and lamprey that circumvents the Delta Cross Channel and Georgiana Slough, thereby reducing the likelihood of covered fish species moving into the interior Delta where they may be exposed to higher predation pressure and entrainment into the south Delta pumps.
    - Providing high quality juvenile rearing habitat and adult holding habitat for salmonids, sturgeon, and splittail. Both slough channels support substantially more woody riparian vegetation and greater habitat diversity (e.g., water depths, velocities, in-channel habitat, etc.) than is present along the mainstem Sacramento River between Courtland and Rio Vista.
    - Providing high quality spawning habitat for splittail during dry periods without floodplain inundation.

    Despite these anticipated benefits, Perry and Skalski (2009) and Perry et al. (2010) indicate that survival rates of juvenile Chinook salmon in Sutter and Steamboat sloughs are highly variable relative to the mainstem Sacramento River; in their studies, they have found that survival has been higher than, lower than, and similar to survival rates in the mainstem Sacramento River rates. Recent hydrodynamic modeling indicates that substantial habitat restoration in the Cache Slough area (see Section 3.4.3.2), in combination with bypass flow requirements for the north Delta diversions, will enhance downstream flows in Sutter and Steamboat sloughs substantially above those present under current conditions without facility north Delta diversion facility (A. Munevar unpubl. data). Further, the BDCP proposes to enhance channel margin habitat in Sutter and Steamboat sloughs in part to create habitat that is unfavorable to non-native predators that may be reducing survival of Chinook salmon, and likely other covered species in these sloughs. Therefore, in combination with these other conservation measures, maintaining bypass flows is expected to improve survival of salmonids, sturgeon, and splittail in Sutter and Steamboat sloughs.

2. Maintaining bypass flows will provide transport flows necessary for downstream movement of delta and longfin smelt. Newly hatched larval delta and longfin smelt, called yolk-sac larvae, have a yolk sac attached to them with an oil globule (Wang

1986). The yolk sac provides nourishment for delta smelt larvae for approximately 4 to 6 days (Bennett 2005) and is thought to be similar for longfin smelt. These larvae are very weak swimmers and drift downstream with flows from the Sacramento River to the low salinity zone, where they can find suitable prey. To avoid starvation, this downstream movement must take place before the entire yolk sac is absorbed. Because downstream yolk-sac larval movement is driven nearly entirely by downstream flows, a minimum bypass flow criteria that allows this movement to occur is necessary.

3. Maintaining minimum bypass flows will provide downstream transport of food and organic material. The Sacramento River is used as a major corridor through which food and other organic material from upstream are transported downstream to the Delta and bays. The Delta and bays acquire production from upstream habitats to support their ecosystems.

4. Maintaining minimum bypass flows will provide necessary attraction flows for upstream migration of adult Chinook salmon, steelhead, and green and white sturgeon, including attraction flows through Sutter and Steamboat Sloughs.

5. Maintaining minimum bypass flows will minimize tidally driven bidirectional flows near diversion intakes, reducing the exposure duration of covered fish species to predators that will likely reside near intake structures. Unidirectional flows past intakes may also affect local current patterns and hydrodynamics in the vicinity of the screen surface that may affect fish entrainment or impingement, debris loading, effectiveness of fish screen cleaning mechanisms in removing debris from the screen surface, and maintaining a uniform approach velocity within the screen design criterion.

Developing bypass flow criteria for the north Delta diversion facilities involved consideration of the seasonal timing of various life stages of covered fish species within the lower Sacramento River, relationships between river flow, water velocity, transport time, and residence time, and the growth, survival, and distribution of various life stages of the covered species.

Adaptive Management Considerations: Results of the biological monitoring would be used adaptively in a variety of ways that include, but are not limited to: (1) changes in diversion operations within a range of adopted diversion parameters that are based on "real-time" monitoring of the occurrence of covered fish in the area; (2) selectively operating diversions based on the geographic distribution of covered fish within the river; and (3) changing diversion operations based on tidal velocity and river flows to increase sweeping velocity and the rate of fish movement past fish screens.

Results of both biological and operational monitoring throughout the Delta could be used within the BDCP adaptive management framework to refine and modify river bypass flow rates. For example, additional information on the actual timing of fish migration downstream within the Sacramento River within a given year could result in modification to the river bypass flows to facilitate migration past the points of diversion and fish screens. The adaptive management ranges provided for operational criteria under this conservation measure (Tables 3-13 and 3-14) provide flexibility to incorporate new knowledge gained through monitoring and research and to respond to changes in the system.

South Delta Diversion Operations and Old and Middle River Flows.

To reduce the impacts of south Delta diversions on covered fish species and the Delta environment, Old and Middle River reverse flows will meet the operational criteria described in Table 3-13. These rivers are subject to reduced or reverse flows as a result of low San Joaquin River inflow, flood tides, and water exports at SWP and CVP facilities. These flow conditions can result in increased risk of entrainment of fish, invertebrates, phytoplankton, and other organic material.

Diversions from the south Delta SWP and CVP facilities will be reduced considerably during wetter periods with dual operation of new north Delta diversion facilities. During wetter periods in the BDCP long-term implementation period, water will be diverted from the south Delta to augment north Delta diversions and may be diverted in appropriate circumstances to improve circulation and maintain water quality conditions in the interior and southern Delta.

Operational Criteria and Adaptive Limits. The operational criteria for south Delta operations and Old and Middle River flows during the BDCP long-term implementation periods are described in Table 3-13.

With operation of north Delta diversion facilities in the long-term implementation period, the existing south Delta SWP and CVP export facilities will be operated as part of a dual conveyance facility and exports from the south Delta will be substantially reduced (the north Delta diversion facilities will be equipped with state-of-the-art positive barrier fish screens and will be the primary point of long-term diversion during wetter periods). The dual export system will be operated to meet water supplies.

> **Problem Statement:** Export operations of the SWP and CVP diversion facilities in the South Delta, in combination with San Joaquin and Sacramento River flows, tidal effects, and substantially reduced inflows into the Delta, have been identified as primary factors in altering hydrodynamic conditions within Delta channels and associated fishery habitat (DWR 2006, Baxter et al. 2008). Export operations of the SWP and CVP pumping plants contribute to local changes in water current patterns, water quality, and direct entrainment and losses of fish, macroinvertebrates, nutrients, phytoplankton, and zooplankton from the Delta environment (DWR 2006).
>
> Although the response of various lifestages of covered species to flows within Old and Middle rivers is dynamic and variable within and among species, there is a positive relationship between the magnitude (average monthly) of reverse flows within Old and Middle rivers and the occurrence of pre-spawning adult delta smelt in SWP and CVP fish

salvage during the winter months (Kimmerer 2008, USFWS 2009c). Further, particle tracking model simulations predict that there is a greater risk that planktonic early lifestages of covered fish species (e.g., larval delta smelt) will be vulnerable to entrainment at the SWP and CVP export facilities when reverse flows within Old and Middle rivers increase. In addition, a number of the covered fish, including the juvenile and adult lifestages of Chinook salmon, steelhead, delta smelt, longfin smelt, sturgeon, lamprey, and splittail are expected to use hydrodynamic cues (e.g., channel flow direction and magnitude) to help guide movement through the Delta. Reverse flows in Delta channels are thought to contribute to false attraction to migration cues, longer migration routes that may expose fish to sources of mortality such as predation, exposure to seasonally elevated water temperatures and other stressors, and increased vulnerability to entrainment at the SWP and CVP south Delta export facilities.

Reverse flows within the channels of Old and Middle rivers are also hypothesized to affect local and regional habitat conditions for covered fish and other aquatic species. Changes in channel velocity and flow patterns affect hydraulic residence time in the area and the production of phytoplankton and zooplankton that are important to the diet of covered fish. Channel velocities, scour, and deposition patterns affect habitat for benthic organisms and other macroinvertebrates. Changes in tidal hydrodynamics, especially channel velocity, affect habitat suitability for covered fish and other aquatic species in the area.

Relationships between the magnitude of reverse flows in Old and Middle rivers and corresponding changes in salvage of various covered fish, such as juvenile Chinook salmon, steelhead, splittail, longfin smelt, lamprey, and sturgeon, are highly variable. Analyses and evaluations are ongoing to further assess the potential biological benefits of managing SWP and CVP south Delta exports based on direct diversion rates or changes in the magnitude of reverse flows in Old and Middle rivers.

Hypotheses: Reducing diversions in the South Delta are hypothesized to:

- Reduce the risk of entrainment mortality of salmonids, smelt, splittail, sturgeon and lamprey;
- Reduce the risk of predation mortality of salmonids, smelt, lamprey, and splittail in Clifton Court Forebay; and
- Reduce the risk of entrainment of organic matter and food for salmonids, smelt, splittail, and sturgeon.

Adaptive Management Considerations: Results of biological monitoring will be used within the BDCP adaptive management framework to refine and modify seasonal operations of Old and Middle River flows. The adaptive management ranges provided for operational criteria under this conservation measure (Tables 3-13 and 3-14) provide flexibility to incorporate new knowledge gained through monitoring and research and to respond to changes in the system.

Delta Cross Channel Gate Operations

The Delta Cross Channel gates will be operated during the long-term implementation period to improve fish migration, hydrodynamics (including hydraulic residence time), and food and organic material transport while minimizing changes to water quality for agriculture, municipal, and industrial uses in the interior and southern Delta.

Delta Cross Channel gates are located on the Sacramento River near Walnut Grove (Figure 3-52). The Delta Cross Channel serves as a conveyance facility for water to move from the Sacramento River into the interior Delta. Water quality in the central and south Delta can degrade during low San Joaquin River flows. The Delta Cross Channel was constructed to move higher quality Sacramento River towards the central and south Delta to improve water quality there. Juvenile Chinook salmon, and presumably a number of other fish species, move from the Sacramento River into the interior Delta when the gate is open (Brandes and McLain 2001). Results of survival studies using coded wire tagged and radio tagged fish suggest that survival juvenile Chinook salmon passing into the Delta through the Delta Cross Channel is lower than survival of those migrating down the mainstem Sacramento River (Brandes and McLain 2001, Perry and Skalski 2009, Perry et al. 2010). Based on results of these studies, closure of Delta Cross Channel gates between February 1 and May 20 was established under D-1641 for fish benefits.

Operational Criteria and Adaptive Limits. The operational criteria for the Delta Cross Channel gates during the BDCP long-term implementation period are described in Table 3-13.

Problem Statement: When the Delta Cross Channel is open, fish move into the interior Delta with Sacramento River water (Brandes and McLain 2001). Survival of juvenile Chinook salmon, and likely other fish species, within the interior Delta is lower than survival in the mainstem Sacramento River (Baker and Morhardt 2001, Brandes and McLain 2001, CALFED 2001, Perry and Skalski 2009, Perry et al. 2010), although it is unknown whether this reduced survival has a population level effect on Chinook salmon (Manly 2002, 2008).

Current seasonal operations of the Delta Cross Channel gates designated by D-1641 are designed to prohibit the migration of juvenile fish from the Sacramento River into the interior Delta through the Delta Cross Channel during the spring. However, adverse effects of an open DCC operation to anadromous fish, and other fish, also occur outside of this closure period. Furthermore, open gates decrease velocities and increase bi-directional flows in the Sacramento River and its distributaries, slowing the migration of covered species and increasing their vulnerability to predation or mortality from poor habitat. Therefore, lengthening the closure period or operating on a tidal or daily cycle may improve survival of salmonids and other covered fish species.

Hypotheses: Revised operations of Delta Cross Channel gates are hypothesized to:

- Increase the survival of juvenile Chinook salmon and possibly other covered fish species by: (1) improving downstream migration of fish in the Sacramento River and tributaries, which will reduce their risk to predation and other sources of mortality; and (2) reducing the proportion of fish entering the interior Delta, where survival of juvenile Chinook salmon is lower (Baker and Morhardt 2001, Brandes and McLain 2001, CALFED 2001, Perry and Skalski 2009, Perry et al. 2010). Several hypotheses have been suggested to explain reduced survival of juvenile Chinook salmon in the interior Delta relative to the mainstem Sacramento River, including, but not limited to: (1) increased exposure to unscreened water diversions within the Delta channels; (2) exposure to seasonally elevated water temperatures and potentially toxic contaminants; (3) increased residence time and longer migration routes leading to longer exposure to environmental conditions within the Delta and increased vulnerability to predation mortality; (4) delayed migration as a result of altered hydrologic conditions in Delta channels as a result of SWP and CVP export operations; and (5) direct losses as a result of entrainment, predation, or salvage mortality at the south Delta SWP and CVP export facilities (Baxter et al. 2008).

- maintain sufficient water quality in the south Delta in combination with minimal year-round pumping in the south Delta (see Section 3.4.2.1, CM1). Seasonally elevated water temperatures and an accumulation of toxics can occur in the central and south Delta, likely as a result of high residence times associated with low inflows from the San Joaquin River. These impairments can have lethal and sublethal effects on covered fish species inhabiting the south and central Delta. In addition, modeling results indicate that drinking water quality standards for the south Delta under D-1641 would not be violated under this revised set of operational criteria (A. Munevar pers. comm.).

- Improve the strength of migration cues and avoid false cues for adult migrating steelhead, Chinook salmon, and sturgeon on the Sacramento and San Joaquin Rivers. When the Delta Cross Channel is open, water from the Sacramento River mixes with water from the Mokelumne, Cosumnes, and San Joaquin Rivers, reducing the strength of migration cues to salmonids and sturgeon migrating upstream. Therefore, increasing the duration of Delta Cross Channel closure will allow more anadromous fish below the Delta Cross Channel to directly sense migration cues to upstream habitat, thus increasing the ability to move upstream and reducing delays to spawning; and

- Improve downstream flows and downstream transport of fish eggs, larvae, juveniles, food, and organic material within the Sacramento River into the Delta.

Adaptive Management Considerations: Results of biological monitoring will be used within the BDCP adaptive management framework to refine and modify seasonal operations of Delta Cross Channel gates.

Rio Vista Flows

Sufficient Rio Vista flows will be maintained during the long-term implementation period for the benefit of covered fish species. The lower Sacramento River serves as an important part of the aquatic habitat within the Delta. Diversion of water at new north Delta Diversion Facilities, as well as diversion of water from the mainstem river into side channels (e.g., Delta Cross Channel) or seasonally inundated floodplain habitat (e.g., Yolo Bypass), has a direct effect on flow rates in the Sacramento River at Rio Vista. Identification of a minimum flow requirement at Rio Vista is intended to support fishery and aquatic habitat in the reach of the Sacramento River located between Sacramento and Rio Vista. Flow in the mainstem Sacramento River at Rio Vista is augmented by the flow contribution from Cache Slough, the Yolo Bypass, Sutter and Steamboat Sloughs, and other local tributaries. Minimum river flows at Rio Vista in the fall are included in current regulations (D-1641, biological opinions).

Operational Criteria and Adaptive Limits. The operational criteria for Rio Vista flows during the BDCP long-term implementation periods are described in Table 3-13.

Problem Statement: The Sacramento River, in addition to its upstream tributaries, is the primary migration corridor in the Delta for Chinook salmon, Central Valley steelhead, sturgeon, and lamprey from the Sacramento River basin. In addition, both delta and longfin smelt likely spawn in the lower river in the general vicinity of Rio Vista. Key fishery issues with respect to seasonal river flows at Rio Vista have primarily focused on adult Chinook salmon and steelhead attraction and upstream migration flows during the fall months. The importance of river flows to each of the species and lifestages of covered fish species varies seasonally depending on the life history and habitat requirements of the species.

Hypotheses: Maintaining sufficient flows past Rio Vista is hypothesized to:

- Maintain sufficient attraction and upstream migration flows for adult salmonids, sturgeon, and lamprey in the Sacramento River;
- Maintain sufficient downstream migration of juvenile Chinook salmon, steelhead, and lamprey from the Sacramento River basin;
- Maintain sufficient downstream transport of planktonic fish eggs and larvae;
- Maintain sufficient downstream transport of organic material, phytoplankton, and zooplankton; and
- Provide high quality habitat for both resident and migratory species within the lower river.

Adaptive Management Considerations: Results of biological monitoring will be used within the BDCP adaptive management framework to refine and modify the seasonal river flow criteria at Rio Vista.

Delta Outflows

Sufficient Delta outflows will be maintained during the long-term for the benefit of covered fish species. Delta outflows provide for downstream transport of fish and other aquatic organisms as well as organic material and prey for covered species into the lower reaches of the Delta and Suisun Bay. In balance with upstream salinity intrusion from the bay, Delta outflows also control the location of the low salinity region of the estuary (Baxter et al. 1999, Kimmerer 2004). The abundance of life stages of a number of fish species, including some covered fish species (longfin smelt), has been positively correlated with the location of the low salinity zone (generally measured as X2) within the estuary (Baxter et al. 1999, Kimmerer 2004). Suisun Bay and the western Delta represent important low salinity habitat areas within the estuary. Open water habitat in this region serves as larval and juvenile rearing, adult holding, and foraging habitat for resident and anadromous fish and a wide variety of other aquatic and wildlife species, and as a migration corridor for anadromous species such as salmon, steelhead, sturgeon, and lamprey. Based on the information regarding the relationship between fish abundance and X2 location, the State Water Quality Control Board's D-1641 and the USFWS Biological Opinion include requirements for maintaining the X2 location during the late winter and spring within Suisun Bay.

Operational Criteria and Adaptive Limits. The operational criteria for Delta outflow during the BDCP long-term implementation period are described in Table 3-13.

Problem Statement: Fishery monitoring studies conducted by DFG (Baxter et al. 1999) suggest that abundances of juvenile lifestages of many fish (e.g., starry flounder, splittail, longfin smelt, and striped bass) and macroinvertebrates are correlated with the location of the low salinity zone during the late winter and spring (e.g., February through June [Kimmerer 2004]). For example, longfin smelt juvenile abundance indices increased as the location of X2 moved further downstream (west) within Suisun Bay (Kimmerer 2004). Recent analyses have suggested that previous correlations between X2 location and fish abundance indices have changed (Kimmerer 2004). The changes observed in these relationships have been hypothesized to be the result of the introduction and rapid colonization of Suisun Bay by the filter feeding Asian overbite clam (*Corbula*) and a subsequent reduction in phytoplankton and zooplankton as food supplies for juveniles within Suisun Bay (Kimmerer 2004). Another change in this relationship has occurred since 2001 in conjunction with the pelagic organism decline, although the cause of this change is currently unknown (Baxter et al. 2008).

Factors that may contribute to the relationship between Delta outflow (as well as X2 location) and juvenile fish abundance are heavily debated, but may include increased productivity and availability of high quality habitat within Suisun Bay; downstream transport of fish, food, and organic matter; reduced temperature and/or toxics exposure with lower X2; inundation of backwater and floodplains with high flows; and the distribution of early lifestages of fish into habitats that are located further downstream with decreased vulnerability to direct and indirect effects of south Delta SWP and CVP export operations.

Hypotheses: Allowing Delta outflow in the adaptable range above is hypothesized to:

- Provide for downstream transport of fish and other aquatic organisms into the lower reaches of the Delta and Suisun Bay;
- Provide sufficient flushing of the Delta to avoid and prolonged exposure to high water temperatures and toxics by covered fish species;
- Provide a suitable location for the low salinity zone; and
- Provide for downstream transport of organic material and prey for covered species into the lower reaches of the Delta and Suisun Bay.

Adaptive Management Considerations: Based on results and analysis of monitoring data, adaptive modifications to management of Delta outflow under the BDCP adaptive management framework could occur by modifying operational criteria by season or water-year type (hydrology) or by addressing other stressors and factors that may affect the survival or abundance of a covered fish species.

Delta Water Quality Maintenance.

Dual conveyance facilities in the Delta will be operated during the long-term implementation period to balance flows and exports for fish protection and water quality for both fish and humans while maintaining water supply reliability. Preferential south Delta operations during summer months when flows in the San Joaquin River are lowest will provide flushing the south and central Delta water with fresh Sacramento River water, thus reducing hydraulic residence time and improving water quality for fish, agriculture, and M&I uses in the south and central Delta.

Considerations regarding dual operations of conveyance facilities include: (1) providing limited flushing for general water quality conditions (reduce residence times) during low San Joaquin River flow periods, (2) maintaining adequate M&I and agricultural salinity in the central and south Delta, and (3) allowing operational flexibility during other periods to operate either north or south Delta diversions based on real-time assessments of benefits to fish, water quality, and operational constraints.

Operational Criteria and Adaptive Limits. The operational criteria for dual conveyance operations, including operations to maintain Delta water quality, during the BDCP long-term implementation periods are described in Table 3-13.

Problem Statement: The balance of fish protection, water supply reliability, and water quality for both fish and humans is dependant, in part, on hydrologic and water quality (e.g., salinity, dissolved oxygen, etc.) conditions occurring within Delta channels, densities of covered fish in the general region of the central and south Delta, and the magnitude of effect of south Delta exports on reverse flows in Old and Middle rivers.

Hypotheses: Dual operation of conveyance facilities in the long-term implementation period according to the operational criteria in Table 3-13 is hypothesized to:

- Reduce entrainment mortality of all covered fish species at south Delta facilities;
- Reduce toxic-related mortality and sublethal effects to all covered fish species in the central and south Delta;
- Reduce the effects of the proliferation of noxious algae, such as Microcystis, in the central and south Delta. Microcystis tends to grow in warm, slowly moving water (Lehman et al. 2008). Microcystis is known to disrupt the food web by being toxic to zooplankton and macroinvertebrates (Resources Agency 2007, Baxter et al. 2008); and
- Reduce the effects of the proliferation of SAV, such as Egeria, in shallow areas of the central and south Delta. Egeria tends to establish and grow at faster rates in warm, slowly moving water (Barko and Smart 1981, Gantes and Caro 2001) (see Section 3.4.3.10 *SAV/FAV Control* for detail on effects to these covered species),

Adaptive Management Considerations: Effectiveness monitoring of water quality parameters, including EC, temperature, selenium, and other toxics as deemed necessary by the BDCP Implementation Office, in central and south Delta before and after preferential south Delta operations begin will inform adaptive management decisions to change pumping rates at the south Delta.

In-Delta Agricultural, Municipal, and Industrial Water Quality Requirements.

In the long-term implementation period, D-1641 North and Western Delta agricultural and municipal and industrial (M&I) standards will be maintained, except that the D-1641 compliance point will be moved from Emmaton to the Three Mile Slough juncture. All water quality requirements contained in the North Delta Water Agency/DWR Contract and other DWR contractual obligations will be maintained.

Operational Criteria and Adaptive Limits. The operational criteria for in-Delta agricultural, municipal, and industrial water quality requirements during the BDCP long-term implementation period are described in Table 3-13.

Problem Statement. Salinity in the Delta is primarily a function of freshwater flowing from tributary rivers and saltwater intrusion from the Pacific Ocean. Areas located downstream such as Suisun Bay and further west are characterized by increasing salinity gradients. The northern and eastern Delta is characterized by primarily freshwater aquatic habitats. The lower San Joaquin River and southern Delta are characterized by low salinity waters, primarily resulting from saline agricultural drainage returns with elevated salt concentrations discharging into the San Joaquin River (DWR et al. 2006). If salinity increases to levels above standards dictated in D-1641, agricultural and M&I use of exported water can be severely limited.

Hypotheses. Maintaining existing D-1641 North and Western Delta agricultural and municipal and industrial (M&I) standards and all water quality requirements contained in the North Delta Water Agency/DWR Contract and other DWR contractual obligations would permit existing agricultural and M&I uses of water in these areas.

Adaptive Management Considerations. Within the BDCP framework of adaptive management, the BDCP Implementing Entity will monitor and adaptively manage salinity in the Delta in response to any adverse impacts resulting from the operational criteria described above

Montezuma Slough Salinity Control Gate Operations.

Coordination will occur with the Suisun Marsh Charter Group over the term of the BDCP to seek amendments to the Suisun Marsh Plan (in development) that will provide for reducing the long-term operation of the Montezuma Slough Salinity Control Gate. This action will allow more water to flow past Chipps Island and will improve access of covered fish species to existing and future restored intertidal marsh habitats.

Suisun Marsh is currently managed largely to provide seasonal freshwater wetland habitat, primarily to support waterfowl habitat and recreation. There are approximately 150 waterfowl hunting clubs in the Suisun Marsh, and wetland managers flood their ponds in early October and drain them after the end of the waterfowl season in January. The Montezuma Slough Salinity Control Gate was originally installed and operated as a tidal pump to reduce salinity within the marsh: the one-way gates were opened on the ebb tide to allow freshwater from upstream to enter the slough and closed on the flood tide to prohibit saline water from entering the slough. Operation of the gates also results in a net flow of water from east to west. The salinity control structure (the gates and associated flashboards) not only alters local hydrodynamics and water quality conditions but also impedes the migration and passage of various fish species. The gates are operated on average 10 days every year, all during the period of early October through May (B. Burkhard, pers. comm.). Operation of the gates is based on tidal stage and triggered by high salinity readings in the marsh. DWR and USBR are required to meet water salinity standards for the Suisun Marsh established by the SWRCB under D-1641.

Operational Criteria and Adaptive Limits. In the beginning of BDCP implementation, Montezuma Slough Salinity Control Gates will continue to operate in the same way as existing standards. However, as land use changes during the 50 year implementation period, the gates may stay open for longer up to possibly remaining open year-round, as determined through adaptive management (see Section 3.7 *Adaptive Management*).

Problem Statement. The Montezuma Slough Salinity Control Gate has been identified as an impediment to migration and passage of species such as Chinook salmon, steelhead, and green sturgeon through Montezuma Slough (Fujimura et al. 2000). In addition, existing operations of the control structure alter local current patterns and tidal hydrodynamics within Montezuma Slough, in large regions of Suisun Marsh, and in the main river channel between the control gate and Suisun Bay (DWR 1999). For example, operation of the control structure during the late fall in dry years can cause a significant upstream shift in X_2 location, potentially increasing the risk of entrainment at the SWP/CVP export facilities of smelt and other species that are situated near X_2 location (D. Fullerton pers. comm. 1). These changes in environmental conditions are thought to have resulted in adverse effects on covered species and other aquatic resources within the area.

As levees are breached for tidal restoration, salinity levels may increase through much of Suisun Marsh, complicating the feasibility of discontinuing the operation of the salinity control gates, or eliminating the gates. First, rising salinity could negatively affect the managed wetlands of the remaining waterfowl hunting clubs. Secondly, salinity standards at the Suisun Marsh may have to be revised. Assuming that the Suisun Marsh's current salinity standards are maintained, tidal restoration could even lead to an increase in the operation of the salinity control gates under the Suisun Marsh Plan (S. Chappell pers. comm.).

Hypotheses: A reduction in operation of the Montezuma Slough Salinity Control Gate is hypothesized to:

- Reduce delays in outmigration of juvenile salmonids and sturgeon by allowing more water and fish to flow past Chipps Island; and
- Improve access of splittail, salmonids, and sturgeon to existing and future restored intertidal marsh habitats in Suisun Marsh.

Adaptive Management Considerations: As land use changes over the period of the Plan, monitoring and adaptive management could be used to alter operations of the salinity control gates.

3.4.2.2 CM2 Yolo Bypass Fishery Enhancement

*[**Note to Reviewers:** Yolo County has proposed specific edits to the content of this conservation measure that will be posted to the BDCP website. These proposed edits will be considered in subsequent versions of this conservation measure developed prior to the release of the public draft of the BDCP in 2011.]*

The purpose of this conservation measure is to improve upstream and downstream fish passage, reduce straying and stranding of native fish, increase availability of floodplain fish rearing and spawning habitat, and stimulate the food web in the Yolo Bypass and to investigate the potential for food web export from the Yolo Bypass to the Delta. The conservation measure requires the preparation and implementation of a Yolo Bypass Fishery Enhancement Plan (YBFEP) that details the specific actions to be implemented to achieve the biological objectives of this measure. Key benefits to covered fish species include reduced migratory delays and loss of salmon, steelhead, and sturgeon at Fremont Weir and other structures; enhanced rearing habitat for Sacramento River Basin salmonids; enhanced spawning and rearing habitat for splittail; and potential improvement of food sources of Delta smelt in habitat downstream of the Bypass. The YBFEP will:

- Evaluate alternative actions to restore passage and reduce stranding, including, but not limited to, physical modifications to the Fremont Weir and Yolo Bypass to manage the timing, frequency, and duration of inundation of the Yolo Bypass (Figure 3-53) with gravity flow from the Sacramento River, and to improve upstream fish passage past barriers including Fremont and Lisbon Weirs;
- Based on the evaluation, identify the actions, including, but not limited to, the physical modifications to the Fremont Weir and the Yolo Bypass, that will be implemented;
- Describe the YBFEP's biological objectives, performance goals, and monitoring metrics in detail;
- Ensure compatibility with the flood control functions of the Yolo Bypass;
- Identify specific funding sources from the BDCP funding commitments;
- Discuss regulatory and legal constraints and how the constraints will be addressed; and
- Provide an implementation schedule with milestones for key actions.

The BDCP Implementing Entity will consult with the U.S. Army Corps of Engineers, DWR, DFG, NMFS, and USFWS in development of the YBFEP and will coordinate with Yolo and Solano counties, affected reclamation districts, other flood control entities, and the Yolo Bypass Working Group on a wide range of issues during preparation of the YBFEP. During implementation of this conservation measure, the BDCP Implementing Entity will coordinate with the U.S. Army Corps of Engineers, DWR, reclamation districts, and other flood control entities, as appropriate, to ensure that fish passage improvements, bypass improvements, and Fremont Weir improvements and operations are constructed in accordance with the YBFEP and particularly the compatibility with the flood control functions of the Yolo Bypass.

The YBFEP analysis of alternative actions will focus on the construction of physical improvements and modifications from Fremont Weir downstream to the Lisbon Weir to (1) reduce migratory delays and loss of salmonids and sturgeon at Fremont Weir; and (2) enhance seasonal floodplain habitats for salmonids, splittail, and other covered aquatic species. The YBFEP will also evaluate the need for actions that may be necessary to optimize the number of juvenile salmonids entering the bypass when the water is being diverted through the modified Fremont Weir. In addition, a gated channel that could provide flows from the Sacramento River, Colusa Basin Drain, Knights Landing Ridge Cut, or other sources into the Yolo Bypass along the west side will be evaluated.

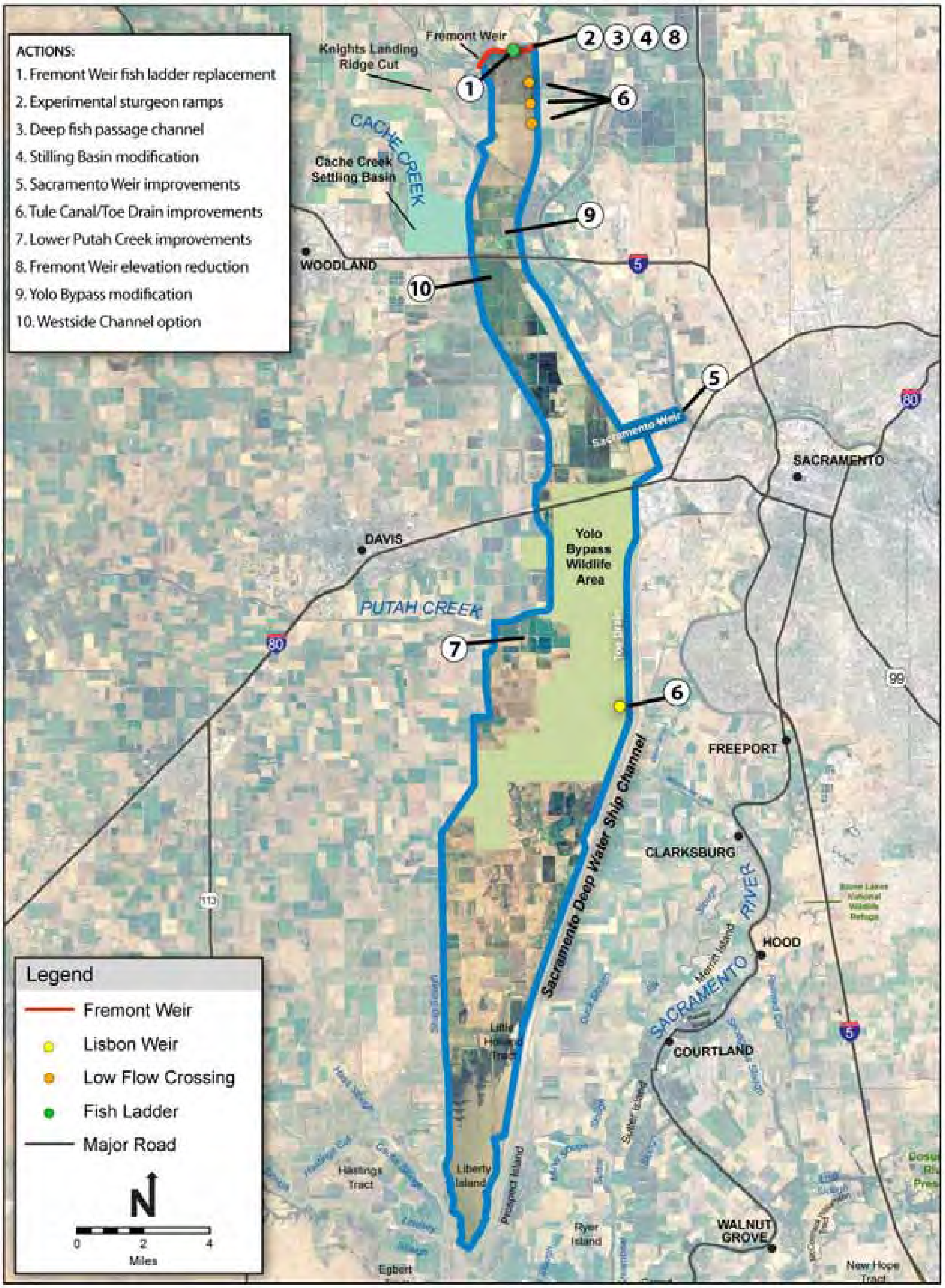

Figure 3-53. Yolo Bypass Fishery Enhancement Conservation Measure (CM2)

All of the actions identified below will be evaluated in the YBFEP. If supported by the evaluation (i.e., would achieve the biological objectives of this conservation measure), all of these actions will be further developed in the YBFEP and implemented. If the YBFEP evaluation does not support implementation of one or more of the actions--because the action would not be effective, is not needed because of the effectiveness of other actions, would have unacceptable effects on flood control, or for other reasons--the action will not be implemented. However, the YBFEP will identify for implementation specific actions that together are sufficient to achieve the biological objectives identified in the YBFEP.

Actions to Reduce Migratory Delays and Loss of Salmonids and Sturgeon at Fremont Weir

1. Fremont Weir Fish Ladder Replacement. The existing Fremont Weir Denil fish ladder will be removed and replaced with new salmonid passage facilities designed to allow for the effective passage of adult salmonids and sturgeon from the Yolo Bypass past the Fremont Weir and into the Sacramento River when the river overtops the weir. Specific design criteria of the ladder have not yet been determined. This facility will incorporate monitoring technologies to allow for collection of information to evaluate its efficacy at passing adult fishes.

2. Experimental Sturgeon Ramps. An experimental ramp(s) will be constructed at the Fremont Weir to allow for the effective passage of adult sturgeon and lamprey from the Yolo Bypass over the Fremont Weir and into the Sacramento River at flows when the new Fremont Weir Fish Ladder will also be operated when the river overtops the weir by approximately 3 feet (Figure 3-54). Specific design criteria of ramps have not yet been determined. This facility will incorporate monitoring technologies to allow for collection of information to evaluate its efficacy at passing adult fishes.

3. Deep Fish Passage Gates and Channel. To enhance adult fish passage through the Fremont Weir, as part of modifications to the Fremont Weir (see action #8, below), a deep fish passage notch will be cut through a much smaller section of the Fremont Weir to an elevation of 11.5 feet (NAVD88). This notch will be fitted with operable “fish passage gates” that will allow controlled flow into the Yolo Bypass when the Sacramento River stage is between 11.5 and 17.5 feet (NAVD88). A “fish passage channel” will be excavated to convey water from the Sacramento River to the new fish passage gates, and from the fish passage gates to the Tule Canal to convey water from the Sacramento River, through the gates, and to the Tule Canal and Toe Drain.

4. Stilling Basin Modification. Modifications will be made to the existing Fremont Weir stilling basin to ensure that the basin drains sufficiently into the deep fish passage channel. Effective drainage of the stilling basin will prevent stranding of juvenile and adult fish that are attracted to pooled water in the stilling basin during drainage of the floodplain.

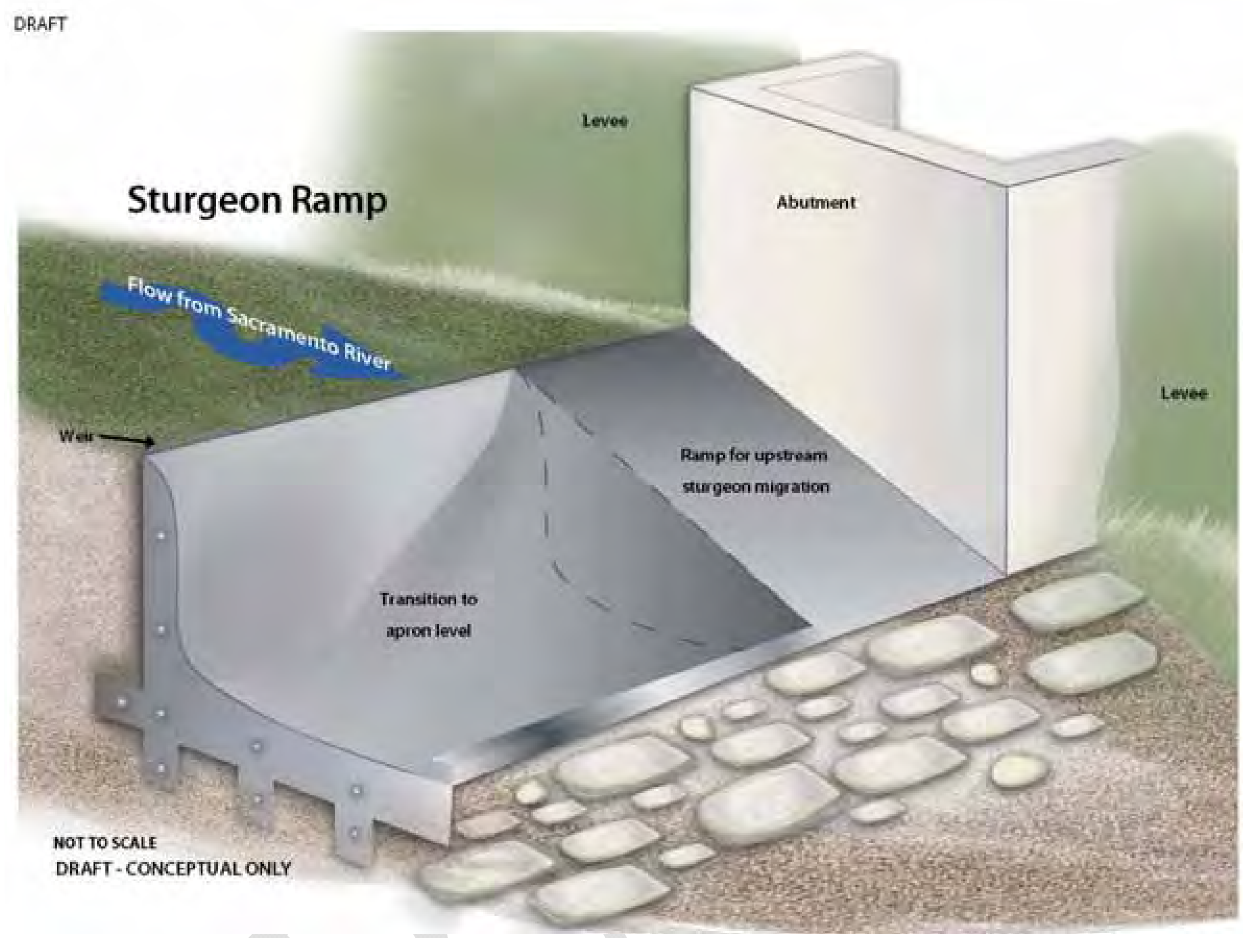

Figure 3-54. Conceptual Design for Experimental Sturgeon Ramp (CM2)

5. Sacramento Weir Improvements. Modifications will be made to reduce leakage at the Sacramento Weir and therefore reduce attraction of fish from the Yolo Bypass to the weir where they are blocked and could become stranded. For comparative analysis purposes, the plan will review the benefits and necessity of constructing fish passage facilities at the Sacramento Weir to reduce juvenile fish stranding and improve upstream adult fish passage. This action may require excavation of a channel to convey water from the Sacramento River to the Sacramento Weir and from the Sacramento Weir to the Toe Drain, construction of new gates at a portion of the weir, and minor modifications to the stilling basin of the weir to ensure proper basin drainage. Specific design criteria of ramps would need to be determined.

6. Tule Canal/Toe Drain and Lisbon Weir Improvements. The YBFEP will include physical modifications to passage impediments, including road crossings and agricultural impoundments in the Tule Canal/Toe Drain to improve fish passage and survival. The plan will evaluate the benefits of replacing three existing structures at the northern end of the Tule Canal with bridges or other structures to allow adult fish passage. Lisbon Weir will be redesigned to improve fish passage while maintaining or improving water capture efficiency for irrigation.

7. Lower Putah Creek Improvements. The YBFEP will include a realignment of Lower Putah Creek. The YBFEP will include a realignment sufficient to improve upstream and downstream passage of Chinook salmon and steelhead in Putah Creek and floodplain habitat restoration to provide benefits for multiple species on existing public lands. This action will be designed so that it will not create stranding or migration barriers for juvenile salmon.

Actions to Increase Seasonal Floodplain Habitats for Salmonids, Splittail, and other Covered Aquatic Species

1. Fremont Weir Modification. The YBFEP will include engineering designs to physically modify the Fremont Weir to manage the timing, frequency, and duration of inundation of the Yolo Bypass with Sacramento River flows. In the BDCP Effects Analysis, it was assumed a section of the Fremont Weir will be lowered to 17.5 feet (NAVD88) (lower elevations may be considered if necessary to satisfy inundation targets or fish passage needs) and fitted with operable gates that will allow for controlled flow into the Yolo Bypass when the Sacramento River stage at the weir exceeds 17.5 feet. Separate operable gates will be designed and operated to provide for the efficient upstream and downstream passage of sturgeon and salmonids to and from the Yolo Bypass into the Sacramento River (as described in action #3 above). The YBFEP will explain how this modification will provide significantly increased acreage of seasonal floodplain rearing habitat with biologically appropriate durations and magnitudes on a return rate of one to three years, depending on water year type.

2. Yolo Bypass Modification. Grading, removal of existing berms, levees, and water control structures, construction of berms or levees, re-working of agricultural delivery

channels, and earthwork or construction of structures to reduce Tule Canal/Toe Drain channel capacities will be conducted to the extent necessary to improve the distribution (e.g., wetted area) and hydrodynamic characteristics (e.g., residence times, flow ramping, and recession) of water moving through the Yolo Bypass. The YBFEP will include modifications that will allow water to inundate in certain areas of the bypass to maximize biological benefits and keep water away from other areas to reduce stranding of covered fish species in isolated ponds, minimize impacts to terrestrial covered species, including giant garter snake, and accommodate other existing land uses (e.g., wildlife, public, and agricultural use areas). If necessary, lands will be acquired, in fee-title and through conservation or flood easements.

3. Westside Option. The YBFEP will include a feasibility study and evaluation of a gated channel to provide flows into Yolo Bypass along the west side. Potential flow sources are the Sacramento River, Colusa Basin Drain or Sacramento River flows through Knights Landing Ridge Cut, or augmentation of other western tributaries. Some modification of the existing configuration of the discontinuous channels along the western edge of the Yolo Bypass may also be required. If effective at meeting biological objectives, this option could be included in the implementation of the conservation measure.

Operational Criteria and Adaptive Limits

The YBFEP will include operational criteria as well as a strategy for adaptive management. The YBFEP will describe how a modified Fremont Weir will be operated to manage the timing and increase the frequency and duration of inundation of a portion of the Yolo Bypass with Sacramento River flows via the Fremont Weir to achieve the biological goals and objectives. The YBFEP will take into account both Weir and tributary inflows.

In the Effects Analysis, inundation timing, frequency, and duration in the Yolo Bypass within the period of December 1 through March 31 (with occasional extension to May 15, depending on hydrologic conditions and measures to minimize land use and ecological conflicts) at the reduced weir elevation of 17.5 feet was considered. In evaluating this scenario, target flows into the bypass were between 3,000 and 6,000 cfs. In the Effects Analysis, flow through modified Fremont Weir gates was limited to maximum spills of 6,000 cfs when the Sacramento River was not spilling over the 33 foot crest of the weir. For the Effects Analysis, no management of the gates was assumed to limit lower flows (e.g., <3,000 cfs). The YBFEP will further refine these operational criteria to provide the specific biological objectives, restoration actions, and locations necessary to meet performance goals including habitat attributes, juvenile and adult metrics, and inundation depth and duration criteria. The YBFEP will include criteria for rare situations to limit flooding when, as determined by the BDCP Implementing Entity, inundation could cause more harm than benefit to covered species. Gates will remain closed in such situations

Under existing conditions the Fremont Weir is overtopped and spills into the Yolo Bypass in about 70 percent of years. The proposed notch and gates could increase that frequency to about 75-95 percent of years with a modified weir height of 17.5 feet (NAVD88) compared to the existing weir height of 33 feet (NAVD88). The frequency of Fremont Weir spills of at least 30 days at 3,000 cfs between 1984 and 2007 would double with a modified weir height of 17.5 feet compared to the existing weir height of 33 feet (Table 3-15). Once the targeted duration of inundation is achieved and the river is below the top of the Fremont Weir, the weir gates could be operated to reduce diversion of flow from the Sacramento River to allow for drainage of the Bypass while still allowing for fish passage. The basic flood control functions of the Fremont Weir will not be changed; at flood stage, the weir will overtop as it does currently.

Table 3-15 Number of Floodwater Spills Overtopping the Fremont Weir under Current and Proposed Weir Elevations.

	Events during Water Years 1984-2008[1]		*Events during Water Years 1929-2008*[1]	
	Current Weir[2]	**Proposed Notch**[2]	**Current Weir**[2]	**Proposed Notch**[2]
Less than 30 days	17[3] (10)[4]	42[3] (20)[4]	48[3] (29)[4]	137[3] (62)[4]
At least 30 days	9 (9)	18 (14)	11 (10)	70 (52)
At least 45 days	4 (4)	11 (11)	5 (5)	46 (41)

[1]Flows between October 1, 1929 and December 31, 1983 have been reconstructed from the hydrologic record

[2]Current weir elevation = 33 ft NAVD88; Proposed weir elevation = 17.5 ft NAVD88.

[3]Number of events with consecutive spills producing at least 3,000 cfs over the Fremont Weir. Assumes no more than a 7-day gap in flooding to count as the same event

[4]Number of water years in which events took place with spills producing at least 3,000 cfs over the Fremont Weir. Water Year is defined as August 1 of the previous year through July 31 of the current year. For example, Water Year 2005 is August 1, 2004 to July 31, 2005.

Problem Statement

The majority of historical floodplain in the Sacramento and San Joaquin River systems have been lost, particularly floodplains that flow directly into the Delta. This loss of floodplains has resulted in a reduction of highly productive rearing habitat for juvenile salmon and spawning and rearing habitat for other native species such as splittail. Loss of floodplain habitat has reduced the seasonal input of organic and inorganic material and food resources into adjoining riverine habitat and the downstream bay and estuary. Inundation of the Yolo Bypass from the Sacramento River is currently limited to times when the Fremont Weir is overtopped, limiting the availability of habitat for covered fish species and inputs to the food web from the Yolo Bypass.

The current configuration of the Yolo Bypass and Fremont Weir creates passage impediments and potential stranding for adult Chinook salmon, steelhead, green and white sturgeon, and river and Pacific lamprey and stranding hazards for juvenile Sacramento splittail, sturgeon, Chinook salmon, and steelhead. First, the Denil fish ladder at the Fremont Weir, designed for adult salmonid passage, is not effective at passing salmon, adult sturgeon and lamprey. Second, the stilling basins immediately downstream of the Sacramento and Fremont weirs have higher stranding rates of juvenile Chinook salmon than do earthen ponds as floodwater recedes (Sommer et al. 2005). Third, there are road crossings and agricultural impoundments in the Tule Canal/Toe Drain that block hydrologic connectivity, and therefore, fish passage. Fourth, the Lisbon Weir, which was built to impound agricultural water in the Toe Drain upstream of the weir, creates a passage impediment for fish at low stage when riprap is exposed or shallowly submerged.

Putah Creek is used for spawning habitat by a small population of Chinook salmon and steelhead. The Los Rios Check Dam, an irrigation impoundment structure, is seasonally removed but remains in place for several months while adult salmon and steelhead are attempting to migrate upstream. The reach of channel downstream of the check dam runs through a straight ditch to the Toe Drain. Putah Creek often breaks through its bank a short distance upstream of the Los Rios Check Dam, requiring periodic road maintenance at the Yolo Bypass Wildlife Area.

Hypothesized Benefits

Modifying the Fremont Weir and its operations and improving fish passage will reduce the adverse effects of stressors related to food availability, habitat availability, passage, harvest, stranding, predation, and entrainment for some of the covered fish species. Specifically, this conservation measure will:

- Create additional spawning habitat for Sacramento splittail (Sommer et al. 2001a, 2002, 2007b, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006). Because splittail are primarily floodplain spawners, successful spawning is predicted to increase with increased floodplain inundation;
- Create additional juvenile rearing habitat for Chinook salmon, Sacramento splittail, and possibly steelhead (Sommer et al. 2001a,b, 2002, 2007b, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006). Growth and survival of larval and juvenile fish is higher in the floodplain compared to those rearing in the mainstem Sacramento River (Sommer et al. 2001b);
- Increase downstream juvenile passage of Chinook salmon, Sacramento splittail, river and Pacific lamprey, and possibly steelhead. An inundated Yolo Bypass is used as an alternative to the mainstem Sacramento River for downstream migration of salmonids, splittail, river lamprey, and sturgeon. Sommer et al. (2003, 2004a) found that, other than steelhead and Pacific lamprey, juveniles from all of these species inhabit the Yolo Bypass during periods of inundation. Based on the timing and life history traits of steelhead relative to Chinook salmon, steelhead likely also benefit from inhabiting the Yolo Bypass. Similarly, based on the timing and life history traits of Pacific lamprey relative to river lamprey, Pacific lamprey likely also benefit from inhabiting the Yolo Bypass
- Increase adult upstream passage of fall-, late fall-, winter-, and spring-run Chinook salmon, steelhead, green and white sturgeon, and river and Pacific lamprey. It is thought that an inundated Yolo Bypass is used as an alternative route by upstream migrating adults of these species when Fremont Weir is spilling ;

- Increase food production for rearing salmonids, splittail, and other covered species on the floodplain (Sommer et al. 2001a,b, 2002, 2007b, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006). During periods when the bypass is flooded, there is relatively high production of zooplankton and macroinvertebrates that serve, in part, as the forage base for many of the covered fish species (Benigno and Sommer 2008);
- Increase the availability and production of food in the Delta, Suisun Marsh, and bays downstream of the bypass, including restored habitat in Cache Slough, for delta smelt, longfin smelt, and other covered species by exporting organic material and phytoplankton, zooplankton, and other organisms produced from the inundated floodplain into the Delta (Schemel et al 1996, Jassby and Cloern 2000, Mitsch and Gosselink 2000, Moss 2007, Lehman et al. 2008). The co-occurrence of suitable food supplies (zooplankton) and various life stages of delta smelt (e.g., larval and juvenile life stages) has been assumed to be an important factor affecting delta smelt survival and abundance (Feyrer et al. 2007a, Miller 2007b). The relationship between longfin smelt abundance and Delta outflow has experienced two step-declines: one after the invasion of *Corbula* and one during the POD years, although the slope of the relationship has not changed, suggesting that longfin smelt are food-limited (Baxter et al. 2008). Hobbs et al. (2006) found evidence of food limitation in early-stage juvenile longfin smelt, although spatially and temporally variable;
- Increase the duration that the floodplain is inundated during periods that the Yolo Bypass is receiving water from both the Fremont Weir and the westside tributaries (e.g., Cache and Putah Creeks);
- Reduce losses of adult Chinook salmon, sturgeon, and other fish species to stranding and illegal harvest by improving upstream passage at the Fremont Weir. When flows in the Sacramento River recede, the Fremont Weir stops spilling, trapping fish downstream of the weir. Many of these fish remain in the shallow water near the weir, providing easy access to illegal harvesters. Under this conservation measure, the Fremont Weir will be modified to reduce stranding when Sacramento River flows recede;
- Reduce the exposure and risk of outmigrating juvenile fish migrating from the Sacramento River into the interior Delta through the Delta Cross Channel and Georgiana Slough, thus decreasing the risk for predation losses (Brandes and McLain 2001);
- Reduce the exposure of outmigrating juvenile fish to entrainment or other adverse effects associated with the intakes of the proposed north Delta water diversion facilities by passing juvenile fish into the Yolo Bypass upstream of the proposed intake locations; and
- Improve fish passage, and possibly increase and improve seasonal floodplain habitat availability, by retrofitting Los Rios Check Dam with a fish ladder, or creating another, fish-passable route for water from Putah Creek to reach the Toe Drain.

Increasing the frequency and duration of inundation within the Yolo Bypass is the largest opportunity for enhancing seasonally inundated floodplain habitat in the Central Valley . The

Yolo Bypass provides the only opportunity for increasing the frequency and duration of inundation of a floodplain in the Planning Area without restoration of historical floodplain surfaces presently in more highly developed, year-round land uses.

Adaptive Management Considerations

Implementation of this conservation measure by the Management Entity will be informed through effectiveness monitoring that will be conducted as described in Section 3.6, *Monitoring and Research Program,* and the adaptive management process described in Section 3.7, *Adaptive Management Program*. Results of both biological and operational monitoring in the Yolo Bypass and the mainstem Sacramento River will be used within the BDCP adaptive management framework to refine and modify project structures and operations and fish passage improvements.

Timeline for Implementation

The Yolo Bypass Fishery Enhancement Plan will be completed within 6 months of approval of BDCP. The Plan shall include: (1) specific biological objectives, restoration actions, and locations; (2) specific operational criteria; (3) a timeline with key milestones, (4) performance goals and associated monitoring, including habitat attributes, juvenile and adult metrics, and inundation depth and duration criteria; (5) specific actions to minimize stranding or migration barriers for juvenile salmon; and (6) identification of regulatory and legal constraints that may delay implementation, and a strategy to address those constraints. Construction of capital improvements identified in the Plan will be completed within five years of completion of the Plan.

3.4.2.3 CM3 Natural Communities Protection

This conservation measure provides the mechanism and guidance for the acquisition of lands and the establishment of a system of conservation lands in the Plan Area necessary to meet natural community and species habitat protection objectives established in Section 3.3, *Biological Goals and Objectives*. This system of conservation lands will be built over the term of the BDCP implementation to protect and enhance areas of existing natural communities and covered species habitat, protect and maintain occurrences of selected plant species with very limited distributions, provide sites suitable for restoration of natural communities and covered species habitat, and provide habitat connectivity among the various BDCP conservation land units in the system. This conservation measure describes the overall approach to land acquisition procedures including the extent of land acquisition, a discussion of pre-acquisition surveys, as well as site selection criteria.

Approach to Land Acquisition

The BDCP Implementation Office will establish a system of conservation lands that encompasses all BDCP protected and restored natural communities. Lands may be acquired through the following mechanisms:

- Purchase in fee title;
- Permanent conservation easements;
- Limited term conservation easements;
- Change to more protective land use designation on federal or state owned lands ;
- Permanent agreements with state, federal, and local flood control agencies that enable the restoration, enhancement, and management of floodplain and channel margin habitats along levees and lands under flood easements; and
- Purchase of mitigation credits from private mitigation banks.

The BDCP Implementation Office may acquire conservation lands in partnership with other conservation organizations or through grants of land from participating entities where such lands will serve to achieve the biological goals and objectives of the Plan. The conservation lands system will be comprised of: 1) conservation areas (lands that are under direct management of the Implementation Office or a Supporting Entity and lands protected through permanent conservation easements); and 2) lands that are covered by limited term conservation easements.

It is anticipated that lands acquired for habitat restoration and enhancement actions will primarily be those that are currently in public ownership or those that are acquired in fee title because these conservation measures could preclude other land uses. Lands acquired for the protection and maintenance of existing habitat functions may be acquired through conservation easements that specify the range of permitted land uses and practices that will maintain the intended habitat functions of the acquired lands. Limited-term conservation easements may be used to conserve agricultural habitats for a specified period, after which the easement would expire and the Implementation Office will be required to conserve additional habitat to replace the habitat that was protected through the expired conservation easement.

The BDCP habitat conservation target acreage commitments for the natural communities are presented in Table 3-4. Acquisition of these lands will also fulfill the target acreage requirements for each of the covered species for which habitat conservation targets are established (Table 3-5). These targets represent the minimum extent of land that will be acquired; the actual extent that will be acquired will likely be greater because acquired parcels may not be comprised wholly of habitat types that contribute towards achieving conservation target acreage.

Pre-acquisition Surveys and Assessments

The BDCP Implementation Office will develop and implement protocols for assessing physical and biological resources and infrastructure present on lands being considered for acquisition to determine the degree to which they are suitable for achieving habitat protection and restoration objectives. Pre-acquisition surveys would be conducted by qualified biologists and other qualified scientists or technical experts as appropriate under agreements with the landowners. Surveys will assess the physical and biological attributes of the lands, including, but not limited to:

- The extent and quality of existing covered species habitats;
- Connectivity with other habitat areas;
- Presence of covered species;
- Infrastructure supporting existing habitats or necessary to restore habitats;
- Potential constraints to long-term management and maintenance of habitats; and
- Other conservation-related opportunities and constraints.

The BDCP Implementation Office will apply, and revise when necessary, the following criteria for evaluating and prioritizing acquisition of lands for achieving habitat protection and restoration targets. Criteria for evaluating the suitability of lands supporting grassland, alkali seasonal wetland complex, and vernal pool complex include:

- Level of benefits the acquisition will provide for covered species;
- Presence and abundance of covered species;
- Presence of uncommon site specific attributes (e.g., soil types) required by covered species with narrow range of habitat requirements;
- Likely effects of adjacent land uses on the ability to maintain or improve desired ecological functions into the future;
- Habitat patch size relative to the habitat patch size of the covered species intended to benefit from the habitat;
- Opportunities for effectively implementing management actions to enhance ecological functions;
- Level of contribution for maintaining local and regional ecological processes;
- Level of connectivity provided between and among existing preserved habitat areas;
- Level of contribution for preserving natural environmental gradients;
- Level of contribution towards establishment of large preserve areas;
- Likely effects of climate change on future ecological functions;

- Role in maintaining and complementing the habitat functions of adjoining natural communities for covered and other native species;
- Level of contribution towards protection of a heterogeneous mix of natural communities and native species, including native grasses and forbs;
- Effectiveness in contributing towards achieving multiple biological goals and objectives;
- Likely contribution towards achieving biological objectives for approved and planned HCPs and NCCPs overlapping or adjacent to the Plan Area; and
- Additionally, restoration of vernal pool complex will only be permitted on lands that historically supported vernal pools and that currently support suitable soils for restoration.

Criteria for the selection of agricultural habitats to be maintained under the Plan include:

- Proximity to active Swainson's hawk nesting territories;
- Proximity to greater sandhill crane roost sites;
- Ability to support crops that provide high value Swainson's hawk and/or greater sandhill crane foraging habitat;
- Proximity to habitat occupied by the Caldoni Marsh/White Slough and Yolo Bypass/Willow Slough giant garter snake populations;
- Opportunities to incorporate riparian corridors into agricultural preserves; and
- Opportunities to preserve patches of other high value non-agricultural habitats (e.g., oak groves, wetlands, tree and hedge rows) that are supported among farmed fields.

For acquisition of land for restoring tidal, riparian, nontidal marsh, and seasonally inundated floodplain habitats, the BDCP Implementation Office will develop site selection criteria based on the ability of lands under consideration to:

- Achieve biological goals and objectives;
- Suitability and cost effectiveness for restoring target habitats;
- Suitability for supporting the restored habitat over time; and
- Level of management necessary to maintain desired ecological functions into the future.

Lands acquired for protection of existing habitats must be acquired within the Conservation Zones indicated in Table 3-4 to be credited as contributing towards achieving the biological goals and objectives. Land acquired for restoration of tidal habitat is expected to be located within the ROAs as indicated in CM4 Tidal Habitat Restoration, but may occur elsewhere if suitable lands are available. Seasonally inundated floodplain restoration and channel margin habitat enhancement may be located at appropriate sites within the geographic boundaries indicated in CM6 Channel Margin Habitat Enhancement and CM5 Seasonally Inundated Floodplain Restoration. Riparian habitats are expected to be restored within tidal habitat restoration, channel margin habitat enhancement, and seasonally inundated floodplain restoration sites (see CM7 Riparian Habitat Restoration). The Implementation Office is committed to the acquisition of a sufficient extent of land to achieve the seasonally inundated floodplain, channel margin habitat, and riparian habitat conservation targets described in CM5 (*Seasonally Inundated Floodplain Restoration*), CM6 (*Channel Margin Habitat Enhancement*), and CM7 (*Riparian Habitat Restoration*); these commitments, however, are not tied to specific Conservation Zones, but rather to the geographies identified in the conservation measures and therefore are not described in the Conservation Zone acquisition requirements described below.

The existing extent of unprotected and protected natural communities and their distribution within each of the Conservation Zones are presented in Tables 3-1a through 3-1c.

Conservation Zone 1 Acquisition Requirements

Land acquisition (includes fee title and easement) requirements for Conservation Zone 1 are directed at protecting and restoring grassland and associated seasonal wetlands, acquiring lands necessary for the restoration of tidal and associated riparian habitats, protecting cultivated agricultural foraging habitats, and protecting occurrences of selected plant species with very limited distributions.

Tidal Aquatic and Wetland Natural Communities. Lands sufficient to restore at least 5,000 acres of tidal habitat within the Cache Slough Complex ROA, which includes lands in Conservation Zones 1and 2, will be acquired. Additional lands will be acquired to the extent that additional restoration of tidal habitat is needed in this Conservation Zone to achieve the total conservation target of restoring 65,000 acres of tidal habitat. Restored tidal habitat includes restored gradient of habitats ranging from shallow subtidal aquatic habitat, to mudflat, emergent marsh plain, riparian (in suitable locations) and transitional uplands. Transitional uplands will include sufficient land to accommodate future upslope establishment of marsh plain vegetation with sea level rise and will support habitat for grassland associated species. Restored tidal aquatic, marsh plain and associated transitional upland habitats are expected to support habitat for the California black rail; aquatic and possible upland nesting habitat for the California least tern; nesting habitat for the tricolored blackbird; upland and aquatic habitat for the giant garter snake where a narrow tidal range exists; and upland and aquatic habitat for the western pond turtle. The restoration of tidal marsh communities in CZ1 may help achieve the recovery objectives for giant garter snake identified in the giant garter recovery plan (USFWS 1999a). Tidal marsh plain and mudflat habitats are also expected to support substrates suitable for colonization and establishment of Delta tule pea and Suisun Marsh aster, Mason's lilaeopsis, and Delta mudwort.

Grasslands and Associated Seasonal Wetland Natural Communities. The grassland and associated seasonal wetland community group is comprised of the grassland, alkali seasonal wetland complex, and vernal pool complex natural communities. A portion of the 300 acres of existing vernal pool complex, 400 acres of existing alkali seasonal wetland, and 8,000 acres of existing grassland to be protected under the BDCP will be acquired and protected in Conservation Zone 1. The goal of these acquisitions is to protect lands in large contiguous grassland landscapes that encompass the range of vegetation, hydrologic, and soil conditions that characterize these communities within the Conservation Zone. The extent of existing protected and unprotected grassland, alkali seasonal wetland complex, and vernal pool complex is shown in Figure 3-1a.

Conserved lands will be located to maintain habitat connectivity with protected grassland landscapes immediately adjacent to the Plan Area (e.g., Jepson Prairie Preserve) and with transitional uplands associated with tidal habitats restored in the Cache Slough Complex ROA. Specific land acquisition requirements include the protection of at least two occurrences of Heckard's peppergrass. This approach to the conservation of these natural communities will conserve foraging habitat for the tricolored blackbird, western burrowing owl, Swainson's hawk, and white-tailed kite; upland habitat for the giant garter snake and western pond turtle; breeding and upland habitat for the western spadefoot toad and California tiger salamander; and habitat for the covered vernal pool shrimp species, alkali milk-vetch, San Joaquin spearscale, dwarf downingia, Boggs Lake hedge-hyssop, Heckard's peppergrass, legenere, heartscale, brittlescale, Delta button-celery, and Carquinez goldenbush (see details on benefits to each of these species in Section 3.3, *Biological Goals and Objectives*).

These conserved lands will be evaluated and managed to maintain and enhance their existing habitat functions for these species over the term of the BDCP (see Conservation Measure CM11, Natural Communities Enhancement and Management). The protection and restoration of vernal pool complex will help achieve the recovery objectives for Conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, mid- valley fairy shrimp, vernal pool tadpole shrimp, alkali milk-vetch, Boggs Lake hedge-hyssop, and legenere identified in the Vernal Pool Recovery Plan (USFWS 2005).

Some or all of the 2,000 acres of grassland and 200 acres of vernal pool complex to be restored under the Plan may be restored within Conservation Zone 1. Lands that are suitable for the restoration of these habitats as described in Conservation Measures CM9 Vernal Pool Complex Restoration, and CM8 Grassland Communities Restoration will be acquired. Lands acquired for grassland restoration will be located such that they will increase connectivity among currently fragmented patches of grassland and seasonal wetlands and/or provide high value transitional upland habitat adjacent to restored tidal marsh plain habitats. Lands acquired for vernal pool complex restoration will be located on lands that historically supported vernal pools and will be inoculated with seeds of vernal pool plants, and soil inoculum where the donor vernal pools are free of exotic species such as swamp timothy, perennial pepperweed, and Italian ryegrass, collected from vernal pools in Conservation Zones 1 and/or 2. These restored habitats are expected to support habitat for the covered species described above for lands acquired to protect grassland and associated seasonal wetlands.

*Agricultural Lands and Managed Wetlands***.** Agricultural lands will be acquired in Conservation Zone 1 to achieve a substantial proportion of the overall agricultural habitat conservation target established for the Plan Area (Table 3-4). Agricultural lands will be acquired that support foraging habitat for tricolored blackbird, Swainson's hawk, and other agricultural-associated species. These conserved lands will be located within 8 miles of Swainson's hawk foraging flight distances from riparian nesting habitats to ensure that conserved habitats function as foraging habitat for the species. Individual agricultural land acquisitions will be at least 80 acres in size unless high value sites are contiguous or potentially contiguous with other conserved lands; with the intent of creating contiguous agricultural preserves of at least 400 acres. As indicated in CM11 agricultural lands will be managed to provide high value foraging habitat for Swainson's hawk, white-tailed kite, and tricolored blackbird. A portion of the conserved agricultural lands will be maintained as pasture to also meet the foraging habitat requirements of burrowing owl. Other habitat elements on protected agricultural lands (e.g., wetlands, riparian corridors, grasslands, hedgerows, tree rows and groves, and isolated trees) will be retained and enhanced as needed as covered species habitat within the agricultural matrix. The specific parcels of conserved agricultural habitat will vary among years to the extent that they are acquired through limited term conservation easements.

*Plant Species Occurrences***.** Protect and enhance at least 3 occurrences of alkali milk-vetch, brittlescale, and heartscale in Conservation Zones 1, 8, and/or 11. Protect and enhance 2 occurrences of Heckard's peppergrass in Conservation Zones 1, 8, and/or 11. Preserve at least 3 occurrences of Carquinez goldenbush in Conservation Zones 1 and/or 11.

Conservation Zone 2 Acquisition Requirements

Land acquisition (includes fee title and easement) requirements for Conservation Zone 2 are directed at protecting and restoring grassland and associated seasonal wetlands, acquiring lands necessary for the restoration of tidal and associated riparian habitats and nontidal wetlands, and protecting cultivated agricultural foraging habitats.

Tidal Aquatic and Wetland Natural Communities. Lands sufficient to restore at least 5,000 acres of tidal habitat within the Cache Slough Complex ROA, which includes lands in Conservation Zones 1and 2, will be acquired. The criteria for restoring tidal habitat and the anticipated benefits for associated covered species are the same as described above for restoration of tidal habitat in Conservation Zone 1.

*Grasslands and Associated Seasonal Wetland Natural Communities***.** There is no specific acquisition target for grassland and associated seasonal wetlands established for Conservation Zone 2. However, acquisitions may occur if there are high value grassland or seasonal wetland habitats that connect to existing protected grassland landscapes (e.g., Yolo Bypass Wildlife Area). Conserved lands will be evaluated and managed to maintain and enhance their existing habitat functions for covered species over the term of the BDCP. In addition, small and fragmented patches of grassland associated with maintained agricultural habitats (e.g., vegetated levee slopes), however, may be protected that will serve as upland habitat for giant garter snake and western pond turtle, and foraging habitat for Swainson's hawk and white-tailed kite. Grassland conservation in Conservation Zone 2 will conserve habitat for the tricolored blackbird, western burrowing owl, Swainson's hawk, white-tailed kite, giant garter snake, and western pond turtle (see details on benefits to each of the species in Section 3.3, *Biological Goals and Objectives*).

*Nontidal Aquatic and Wetland Natural Communities***.** The nontidal aquatic and wetland natural communities group is comprised of nontidal freshwater perennial emergent wetland and nontidal aquatic natural communities. Lands will be acquired in Conservation Zone 2 to restore up to 200 acres of nontidal marsh that functions as aquatic habitat for the giant garter snake. Nontidal freshwater marsh will be restored in locations to benefit the Yolo/Willow Slough subpopulation of giant garter snake. The specific amount of marsh that will be restored will be determined based on results of site-specific habitat assessments of the Yolo/Willow Slough and Caldoni Marsh/White Slough (Conservation Zone 4) subpopulations to determine the extent of marsh needed to be restored in each location to maximize conservation benefits for the species. Marsh will be restored within or adjacent to habitats occupied by these subpopulations and within larger patches of protected giant garter snake upland and agricultural habitats. The BDCP Implementation Office will consult with species experts and use guidance provided in the giant garter snake recovery plan (USFWS 1999a) to determine specific locations, patch sizes, and develop specific restoration design criteria and implementation guidance (e.g., vegetation associations, edge habitat, bank slopes, wetland to upland ratio, etc.). In addition to benefiting the giant garter snake, restored tidal marsh habitats are expected to provide nesting habitat for tricolored blackbird and aquatic habitat for the western pond turtle. Increased flying insect production associated with restored marshes relative to the existing upland habitats that will be restored to marsh is expected to improve foraging habitat conditions for the Townsend's Big-eared Bat.

*Agricultural Lands and Managed Wetlands***.** Agricultural lands will be acquired in Conservation Zone 2 to achieve a substantial proportion of the overall agricultural habitat conservation target established for the Plan Area (Table 3-4). Agricultural lands will be acquired that support foraging habitat for tricolored blackbird, Swainson's hawk, giant garter snake, and other agricultural-associated species. A total of 4,600 acres will be maintained in rice or equivalent habitat value to provide habitat for the giant garter snake. Other conserved agricultural lands will be located within 8 miles of Swainson's hawk foraging flight distances from riparian nesting habitats to ensure that conserved habitats function as foraging habitat for the species. Agricultural lands will be managed to provide high value foraging habitat for Swainson's hawk, white-tailed kite, and tricolored blackbird. Other habitat elements on protected agricultural lands (e.g., wetlands, riparian corridors, grasslands, hedgerows, tree rows and groves, and isolated trees) will be retained and enhanced as needed as covered species habitat within the agricultural matrix. Criteria for acquisition of agricultural lands to provide habitat for Swainson's hawk are the same as described above for Conservation Zone 1. A portion of the conserved agricultural lands may also be maintained as pasture to meet the foraging habitat requirements of western burrowing owl.

A portion of the conserved agricultural lands will need to be acquired and maintained within or adjacent to habitat occupied by the Yolo/Willow Slough subpopulation of giant garter snake to establish a 1,000-acre preserve for this subpopulation. The Implementation Office will consult with giant garter snake species experts to determine appropriate agricultural land acquisitions relative to the proximity of the existing subpopulation, proximity and connectivity with existing and restored nontidal freshwater marsh, and opportunities for population protection and expansion. The specific parcels of conserved agricultural habitat will vary among years to the extent that they are acquired through limited term conservation easements.

Conservation Zone 3 Acquisition Requirements

No specific conservation land acquisition targets are identified for Conservation Zone 3. Agricultural lands that support Swainson's hawk and greater sandhill crane foraging habitats, which may be conserved in multiple Conservation Zones to achieve the objectives for these species, may be acquired in Conservation Zone 3. Any acquired Swainson's hawk foraging habitat will be located within 8 miles of its riparian nesting habitat and acquired greater sandhill crane foraging habitat will be located within 2 miles of roosting habitat to ensure that conserved habitats function as foraging habitat for these species.

Conservation Zone 4 Acquisition Requirements

Land acquisition (includes fee title and easement) requirements for Conservation Zone 4 are directed at acquiring lands necessary for the restoration of tidal and associated riparian habitats and nontidal wetlands, and protecting cultivated agricultural habitats.

Tidal Aquatic and Wetland Natural Communities. Lands sufficient to restore at least 1,500 acres of tidal habitat within the Cosumnes/Mokelumne ROA in Conservation Zone 4 will be acquired. The criteria for restoring tidal habitat and the anticipated benefits for associated covered species are the same as described above for restoration of tidal habitat in Conservation Zone 1. The restoration of tidal marsh communities in CZ4 may help achieve the recovery objectives for giant garter snake identified in the giant garter snake recovery plan (USFWS 1999a) by providing additional habitat connectivity between the Caldoni Marsh/White Slough subpopulation and the Stone Lakes National Wildlife Refuge lands to the north and additional connectivity between the Delta and the Badger Creek giant garter snake subpopulation to the east.

Grasslands and Associated Seasonal Wetland Natural Communities. There is no specific acquisition target for grassland and associated seasonal wetlands established for Conservation Zone 4 because high value grassland habitats in the Conservation Zone are currently protected. Small and fragmented patches of grassland associated with maintained agricultural habitats (e.g., vegetated levee slopes), however, may be protected that will serve as upland habitat for giant garter snake and western pond turtle, and foraging habitat for Swainson's hawk and white-tailed kite.

*Nontidal Aquatic and Wetland Natural Communities***.** Lands will be acquired in Conservation Zone 4 to restore up to 200 acres of nontidal marsh that functions as aquatic habitat for the giant garter snake. Nontidal marsh will be restored in locations to benefit the Caldoni Marsh/White Slough giant garter snake subpopulation. The criteria for restoring nontidal marsh and the anticipated benefits for associated covered species are the same as described above for restoration of nontidal marsh in Conservation Zone 2.

*Agricultural Lands and Managed Wetlands***.** Agricultural lands will be acquired in Conservation Zone 4 to achieve a proportion of the overall agricultural habitat conservation target established for the Plan Area (Table 3-4). Agricultural lands will be acquired that support habitat for tricolored blackbird, Swainson's hawk, greater sandhill crane, and giant garter snake. Other habitat elements on protected agricultural lands (e.g., wetlands, riparian corridors, grasslands, hedgerows, tree rows and groves, and isolated trees) will be retained and enhanced as needed as covered species habitat within the agricultural matrix. Criteria for acquisition of agricultural lands to provide habitat for Swainson's hawk are the same as described above for Conservation Zone 1. Protection of agricultural lands in Conservation Zone 4 will also focus on increasing the connectivity of protected lands along the eastern edge of the Plan Area to further facilitate movement and expansion of giant garter snake and other covered species populations between the Stone Lakes National Wildlife Refuge and the Caldoni Marsh/White Slough giant garter snake subpopulation.

A portion of the conserved agricultural land in Conservation Zone 4 will need to be acquired and managed as foraging habitat for the greater sandhill crane to meet the requirements of 4,000 conserved acres within the crane's primary zone. In addition, a portion of the 300 acres of greater sandhill crane managed wetland roosting habitat can be acquired in Conservation Zone 4. Individual agricultural land and managed wetland acquisitions for greater sandhill crane foraging and roosting habitat will be at least 80 acres in size unless high value sites are contiguous or potentially contiguous with other conserved lands. The BDCP Implementation Office will consult with species experts to determine the suitability of potential acquisitions relative to proximity to foraging habitats within the primary zone, and to establish restoration design criteria for crane roosting habitat.

A portion of the conserved agricultural lands will also need to be acquired and permanently maintained within or adjacent to habitat occupied by the Caldoni Marsh/White Slough subpopulation of giant garter snake to establish a 1,000 acre preserve for this subpopulation. The Implementation Office will consult with giant garter snake species experts to determine appropriate agricultural land acquisitions relative to the proximity of the existing subpopulation, proximity and connectivity with existing and restored nontidal perennial freshwater emergent wetland, and opportunities for population protection and expansion. The specific parcels of conserved agricultural habitat will vary among years to the extent that they are acquired through limited term conservation easements.

Conservation Zone 5 Acquisition Requirements

Land acquisition (includes fee title and easement) requirements for Conservation Zone 5 are directed at acquiring lands necessary for the restoration of tidal habitat. Agricultural lands that support Swainson's hawk and greater sandhill crane foraging habitats, which may be conserved in multiple Conservation Zones to achieve the objectives for these species may also be acquired in Conservation Zone 5 if needed to achieve the overall agricultural habitat conservation target (Table 3-4). The extent of subsided lands that may be acquired in Conservation Zone 5, however, is limited to the extent of existing Swainson's hawk and greater sandhill crane foraging habitat located below sea level that would be removed by BDCP actions.

Tidal Aquatic and Wetland Natural Communities**.** Lands sufficient to restore at least 2,100 acres of tidal habitat within the West Delta ROA will be acquired. The criteria for restoring tidal habitat and the anticipated benefits for associated covered species are the same as described above for restoration of tidal habitat in Conservation Zone 1.

Agricultural Lands. Agricultural lands may be acquired in Conservation Zone 5 to achieve a proportion of the overall agricultural habitat conservation target established for the Plan Area (Table 3-4). Agricultural lands would be acquired that support habitat for tricolored blackbird, Swainson's hawk, greater sandhill crane, and giant garter snake. Other habitat elements on protected agricultural lands (e.g., wetlands, riparian corridors, grasslands, hedgerows, tree rows and groves, and isolated trees) will be retained and enhanced as needed as covered species habitat within the agricultural matrix. Criteria for acquisition of agricultural lands to provide habitat for Swainson's hawk and greater sandhill crane are the same as described above for Conservation Zone 1 and 4, respectively.

In addition, lands necessary to create a portion of the 320 acres of greater sandhill crane roosting habitat can be acquired in Conservation Zone 5. Criteria for acquisition is the same as described above for Conservation Zone 4.

Conservation Zone 6 Acquisition Requirements

No specific conservation land acquisition targets are identified for Conservation Zone 6. This Conservation Zone encompasses deeply subsided islands of the Delta that are dominated by agricultural habitats and generally only support small fragmented patches of non-agricultural habitats. Some tidal habitat restoration could occur in Conservation Zone 6 in the West Delta ROA. Agricultural lands that support Swainson's hawk and greater sandhill crane foraging and roosting habitats, which may be conserved in multiple Conservation Zones to achieve the objectives for these species, may be acquired in Conservation Zone 6. Criteria for acquisition of agricultural lands to provide habitat for Swainson's hawk and greater sandhill crane are the same as described above for Conservation Zone 4. The extent of subsided lands that may be acquired in Conservation Zone 6, however, is limited to the extent of existing Swainson's hawk and greater sandhill crane foraging habitat located below sea level that would be removed by BDCP actions.

Conservation Zone 7 Acquisition Requirements

Land acquisition (includes fee title and easement) requirements for Conservation Zone 7 are directed at acquiring lands necessary for the restoration of tidal and associated riparian habitats, restoration of seasonally inundated floodplains and associated riparian habitat, restoration of riparian habitats specifically to support riparian brush rabbit, and protecting cultivated agricultural habitats.

*Tidal Aquatic and Wetland Natural Communities***.** Lands sufficient to restore at least 5,000 acres of tidal habitat within the South Delta ROA will be acquired. The criteria for restoring tidal habitat and the anticipated benefits for associated covered species are the same as described above for restoration of tidal habitat in Conservation Zone 1. In addition, tidal wetland restoration in Conservation Zone 7 is also expected to benefit the greater sandhill crane by providing potential foraging and roosting habitats and facilitating possible expansion of the species' winter range southward.

*Riparian Natural Community***.** Lands sufficient to restore a substantial portion of the 10,000-acre seasonally inundated floodplain target included within would be most of the 5,000-acre riparian natural community target will be acquired. Floodplain habitat and associated riparian habitat would be restored by setting back levees on major river channels including the San Joaquin, Old, and Middle rivers. Riparian habitat restoration would support habitat for riparian brush rabbit, riparian woodrat, Townsend's Big-eared Bat, yellow-breasted chat, white-tailed kite, Swainson's hawk, and valley elderberry longhorn beetle.

Of the 5,000 acres of restored riparian, 300 acres will be specifically restored to meet the ecological requirements of the riparian brush rabbit and 300 additional acres will be restored to meet the ecological requirements of the riparian woodrat. The BDCP Implementation Office will consult with species experts to determine appropriate restoration locations, minimum patch size, species composition, and to develop other restoration design criteria and implementation guidance.

*Grasslands and Associated Seasonal Wetland Natural Communities***.** There is no specific acquisition target for grassland and associated seasonal wetlands established for Conservation Zone 7. Small and fragmented patches of grassland associated with maintained agricultural habitats (e.g., vegetated levee slopes), however, may be protected that will serve as upland habitat for giant garter snake and western pond turtle, and foraging habitat for Swainson's hawk and white-tailed kite.

*Agricultural Lands and Managed Wetlands***.** Agricultural lands will be acquired in Conservation Zone 7 to achieve a substantial proportion of the overall agricultural habitat conservation target established for the Plan Area (Table 3-4). Agricultural lands will be acquired that support foraging habitat for Swainson's hawk and habitat for other agricultural-associated covered species. Other habitat elements on protected agricultural lands (e.g., wetlands, riparian corridors, grasslands, hedgerows, tree rows and groves, and isolated trees) will be retained and enhanced as needed as covered species habitat within the agricultural matrix. Criteria for acquisition of agricultural lands to provide habitat for Swainson's hawk are the same as described above for Conservation Zone 1. The specific parcels of conserved agricultural habitat will vary among years to the extent that they are acquired through limited term conservation easements.

Conservation Zone 8 Acquisition Requirements

Land acquisition (includes fee title and easement) requirements for Conservation Zone 8 are directed at protecting and restoring grassland and associated seasonal wetlands, and protecting occurrences of selected plant species with very limited distributions. Agricultural lands may also be acquired in this Conservation Zone to provide habitat for Swainson's hawk and other agricultural-associated covered species as described above for Conservation Zone 3.

*Grasslands and Associated Seasonal Wetland Natural Communities***.** At least 1,000 acres of existing grassland will be acquired and protected in Conservation Zone 8; and a portion of the 300 acres of existing vernal pool complex and 400 acres of existing alkali seasonal wetland to be protected under the BDCP will be acquired and protected in Conservation Zone 8. The goal of these acquisitions is to protect lands in large contiguous grassland landscapes that encompass the range of vegetation, hydrologic, and soil conditions that characterize these communities within the Conservation Zone south of Highway 4. Conserved lands will be located to maintain habitat connectivity with protected grassland landscapes within and immediately adjacent to the Plan Area. Protection of these habitat areas will maintain connectivity with lands that have been protected or may be protected in the future under the East Contra Costa HCP/NCCP.

This approach to conservation of these natural communities will conserve habitat for the San Joaquin kit fox, tricolored blackbird, western burrowing owl, Swainson's hawk, white-tailed kite, western pond turtle, western spadefoot toad, California red-legged frog, California tiger salamander, the covered vernal pool shrimp species, alkali milk-vetch, San Joaquin spearscale, dwarf downingia, Boggs Lake hedge-hyssop, Heckard's peppergrass, legenere, heartscale, brittlescale, Delta button-celery, and caper-fruited tropidocarpum (see details on benefits to each of these species in Section 3.3, *Biological Goals and Objectives*). Protection and management of grasslands and associated seasonal wetlands in Conservation Zone 8 will help achieve recovery plan objectives for the San Joaquin kit fox (USFWS 1998a), the California red-legged frog (USFWS 2002), Conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, mid-valley fairy shrimp, vernal pool tadpole shrimp, alkali milk-vetch, Boggs Lake hedge-hyssop, and legenere (USFWS 2005). These conserved lands will be evaluated and managed to maintain and enhance their existing habitat functions for these species over the term of the BDCP. Following full BDCP implementation, an estimated __ percent of grassland, vernal pool complex, and alkali seasonal wetland remaining in Conservation Zone 8 will be protected.

*Plant Species Occurrences***.** Protect and enhance at least 3 occurrences of alkali milk-vetch, brittlescale, heartscale in Conservation Zones 1, 8, and/or 11. Protect and enhance 2 occurrences of Heckard's peppergrass in Conservation Zones 1, 8, and/or 11. Protect occurrences of caper-fruited tropidocarpum that reestablish in Conservation Zone 8.

Conservation Zone 9 Acquisition Requirements

No specific conservation land acquisition targets are identified for Conservation Zone 9. This Conservation Zone is comprised primarily of urban lands (e.g., Brentwood and Discovery Bay are located in this zone) and non-urban areas are dominated by agricultural habitats. Non-agricultural habitats generally are present in small patches that are fragmented and disconnected from other natural habitats. Agricultural lands that support Swainson's hawk foraging habitat, which may be conserved in multiple Conservation Zones to achieve the objectives for this species, may be acquired in Conservation Zone 9 as described above for Conservation Zone 3.

Conservation Zone 10 Acquisition Requirements

No conservation land acquisition targets are identified for Conservation Zone 10. This Conservation Zone encompasses the City of Antioch and is comprised almost entirely of urban lands.

Conservation Zone 11 Acquisition Requirements

Land acquisition (includes fee title and easement) requirements for Conservation Zone 11 are directed at protection of grassland and associated seasonal wetland habitats, acquiring lands necessary for the restoration of tidal habitats, and protecting occurrences of selected plant species with very limited distributions.

*Grasslands and Associated Seasonal Wetland Natural Communities***.** A portion of the 300 acres of existing vernal pool complex, 400 acres of existing alkali seasonal wetland, and 8,000 acres of existing grassland to be protected under the BDCP will be acquired and protected in Conservation Zone 11. These communities are located along the upland fringe of Suisun Marsh and the goal of these acquisitions is to protect these lands to maintain connectivity with much larger protected (e.g., Jepson Prairie Preserve) and unprotected grassland landscapes that are immediately adjacent to the zone. Specific land acquisition requirements include the protection of at least three occurrences of alkali milk-vetch. This approach is expected to result in conservation of a gradient of natural habitats that range from grassland upland communities down slope to existing and restored tidal wetland communities.

Grassland, vernal pool complex, and alkali seasonal wetland complex communities fringing Suisun Marsh support several rare plant species that will be brought under protection and management through these acquisitions. This approach to conservation of these natural communities will serve to conserve habitat for the tricolored blackbird, western burrowing owl, Swainson's hawk, white-tailed kite, giant garter snake, western pond turtle, western spadefoot toad, California tiger salamander, the covered vernal pool shrimp species, alkali milk-vetch, San Joaquin spearscale, dwarf downingia, Boggs Lake hedge-hyssop, Heckard's peppergrass, legenere, heartscale, brittlescale, and Carquinez goldenbush (see details on benefits to each of these species in Section 3.3, *Biological Goals and Objectives*). These conserved lands will be evaluated and managed to maintain and enhance their existing habitat functions for these species over the term of the BDCP. The protection and restoration of vernal pool complex will help achieve the recovery objectives for Conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, mid- valley fairy shrimp, vernal pool tadpole shrimp, alkali milk-vetch, Boggs Lake hedge-hyssop, and legenere identified in the Vernal Pool Recovery Plan (USFWS 2005). Following full BDCP implementation, an estimated __ percent of grassland, vernal pool complex, and alkali seasonal wetland remaining in Conservation Zone 11 will be protected.

*Tidal Aquatic and Wetland Natural Communities***.** Lands sufficient to restore at least 7,000 acres of tidal habitat, including 3,000 acres of tidal brackish emergent wetland will also be acquired in Conservation Zone 11 within the Suisun Marsh ROA. Restored tidal habitat includes restored gradient of habitats ranging from shallow subtidal aquatic habitat, to mudflat, emergent marsh plain, and transitional uplands. Transitional uplands will include sufficient land to accommodate future upslope establishment of marsh plain vegetation with sea level rise and will support habitat for grassland associated species. Restored tidal marsh plains and mudflats are expected to support habitat for the salt marsh harvest mouse, Suisun shrew, Townsend's big-eared bat, tricolored blackbird, Suisun song sparrow, California black rail, California clapper rail, western pond turtle, Suisun thistle, soft bird's-beak, Delta tule pea, Suisun marsh aster, Mason's lilaeopsis, and Delta mudwort. Restoration and protection of transitional uplands will provide flood refugia habitat for salt marsh harvest mouse, Suisun shrew, California black rail, and California clapper rail during high water events. Restoration of shallow subtidal aquatic habitat will also support California least tern foraging habitat and aquatic habitat for the western pond turtle.

*Plant Species Occurrences***.** Protect and enhance at least three occurrences of alkali milk-vetch, brittlescale, heartscale in Conservation Zones 1, 8, and/or 11. Protect and enhance 2 occurrences of Heckard's peppergrass in Conservation Zones 1, 8, and/or 11. Protect and enhance 3 occurrences each of Suisun thistle and soft bird's-beak in Suisun Marsh Conservation Zones 11. Preserve at least 3 occurrences of Carquinez goldenbush in Conservation Zones 1 and/or 11.

Inter-Conservation Zone Connectivity

In addition to the spatial distribution requirements among the Conservation Zones for protection of natural communities and covered species, conservation lands will also need to be distributed within and among some Conservation Zones to provide connectivity for some covered species habitats across specific segments within or adjacent to the Plan Area. Specific efforts will focus on two ecological corridors described below. It is expected that the corridors can be established through meeting the natural community conservation targets presented in Table 3-4. Corridor width will follow the recommendations from the *California Essential Habitat Connectivity Project* (DFG/CALTRANS 2010), to the extent that it is practicable and within the natural community conservation targets.

Grassland/Vernal Pool Complex Corridor. Vernal pool complex natural community in Conservation Zones 1 and 11 are situated at elevations that are suitable for serving as upland habitats adjacent to restored tidal habitats and can be protected to build upon existing and planned preserves in Solano County between these conservation zones. Protection of additional vernal pool complex natural community in this area will protect an important connection between Suisun Marsh and the Cache Slough area. Establishing a protected corridor in this area will also facilitate movement of several covered species including California tiger salamander and western spadefoot toad from occupied habitats in the Montezuma Hills and Jepson Prairie into the grassland and vernal pool complex habitats in Conservation Zone 1.

The Implementation Office will explore opportunities through coordination with Solano County to acquire and protect additional lands between Suisun Marsh and the Cache Slough area in order to establish a protected corridor comprised of contiguous patches of grassland, vernal pool complex, tidal wetlands, and other seasonal wetlands.

Giant Garter Snake Corridor. Habitat connectivity, particularly hydrologic connectivity that supports giant garter snake movement and dispersal, is essential for protection of giant garter snake populations, and is a key element of the species' recovery plan (USFWS 1999a). Focusing agricultural land conservation along a north-south corridor within Conservation Zone 4 along with restoration of tidal wetlands in that area, will enhance connectivity and facilitate giant garter snake movement between the Coldani Marsh-White Slough subpopulation north to the Cosumnes River Preserve and to Stone Lakes National Wildlife Refuge.

A corridor will be protected that is comprised of contiguous patches of agricultural, restored tidal and nontidal wetlands, grassland, vernal pool complex, and other seasonal wetlands between the Coldani Marsh/White Slough giant garter snake subpopulation area north to Stone Lakes National Wildlife Refuge and to the extent possible connecting the Cosumnes River Preserve. The corridor will be configured such that there is contiguous giant garter snake movement habitat along this north-south corridor. To serve as a movement corridor to meet the needs of the giant garter snake, the width of the corridor may not be less than 3,200 feet wide in any location.

Invasive Species Control Program

The BDCP Implementation Office will develop and implement a plan for the control of invasive animal and plant species that could substantially degrade the functions of protected natural communities as habitat for covered and other native species on BDCP lands.

Elements of the plan will include:

- Protocols for periodically surveying for and assessing the abundance of nonnative predators and competitors on BDCP lands;
- Protocols for periodically surveying for and assessing the occurrence and abundance of invasive nonnative plants on BDCP lands;

- A brown-headed cowbird monitoring and control program (see discussion below);
- Methods for assessing degree of biological effect nonnative species have on covered and other native species within BDCP lands;
- Methods for assessing threats of establishment of nonnative animals and plants on lands adjacent to BDCP lands;
- Methods for assessing threats of the spread of nonnative plants from BDCP lands onto adjacent lands;
- A decision-making process for determining the need for implementing management actions to control nonnative species;
- A description of potential nonnative species control methods; and
- A process for developing and implementing monitoring necessary to assess the effectiveness of implemented control methods.

Monitoring and control requirements that may be developed for specific preserve lands will be incorporated into preserve-specific management plans (see CM11 Natural Communities Enhancement and Management).

Examples of nonnative plant species currently of concern include waxy mannagrass, Italian ryegrass, barbed goatgrass, medusahead grass, yellow starthistle, Himalayan blackberry, giant reed, and parrot feather. Animal species that could degrade the habitat functions for covered species include feral domesticated animals (e.g., feral cat predation on ground-nesting birds) and brown-headed cowbirds.

The brown-headed cowbird is a native species that has expanded its range substantially with conversion of historical Central Valley habitats to agriculture. The brown-headed cowbird is a frequent brood parasite of yellow-breasted chats and other native birds and can affect local reproduction of chats. On conserved lands that support nesting yellow-breasted chats, surveys will be conducted to identify and monitor brown-headed cowbird populations, the extent of brood parasitism of yellow-breasted chats, and the reproductive trend of nesting yellow-breasted chats. If it is determined that cowbirds are substantially affecting nesting success of yellow-breasted chats such that local populations are or could decline, cowbird control measures will be implemented to reduce local cowbird populations.

3.4.3 Natural Community-Level Conservation Measures

Natural community conservation measures include the protection, restoration, enhancement, and management of natural communities and the covered species that are dependent upon them. The overarching goal of restoration and protection of natural communities is to create and maintain an ecologically functioning landscape that successfully combines both native and working landscape elements and that meets natural community and species goals and objectives. Natural community conservation measures provide the mechanisms for achieving restoration and protection goals and objectives using the following the guiding principles:

- Restore natural communities such that they contribute to and enhance an ecologically functional landscape;
- Manage and enhance working landscapes (e.g., agricultural lands) such that they protect covered species habitat values and facilitate expansion of covered species populations while maintaining their agricultural production and economic value;
- Emphasize natural ecological gradients and connectivity among and between restored and existing natural communities that provide a range of conditions to provide for shifting or expanding species distributions; and
- Protect, restore, and enhance habitats for covered species such that implementation of the BDCP provides a significant contribution to their long-term conservation in the Plan Area.

3.4.3.1 CM4 Tidal Habitat Restoration

BDCP implementation will provide for the restoration of 65,000 acres of freshwater and brackish tidal habitat within the BDCP ROAs (Figure 3-3). The extent of restored tidal habitat includes a contiguous habitat gradient encompassing restored shallow subtidal aquatic habitat[34], restored tidal mudflat, restored tidal marsh plain habitat[35], and adjoining transitional upland habitat. This upland habitat will accommodate approximately 3 feet of sea level rise that could function as tidal marsh plain at some future time, if necessary. Additional upland habitat, however, would be protected and enhanced to provide habitat for terrestrial species.

Of the 65,000-acre restoration target, 22,000 acres will be distributed among the ROAs as described below in Minimum Restoration Targets for Freshwater Tidal Habitat in ROAs and Minimum Restoration Target for Brackish Tidal Habitat in the Suisun ROA. The remaining 43,000 acres of the target total will be distributed among the ROA's at the discretion of the BDCP Implementation Office based on land availability, biological value, and practicability considerations. The freshwater and brackish tidal habitat restoration targets will be achieved on the following time schedule:

- 14,000 acres developed[36] within the first 10 years of plan implementation;
- 25,000 acres (cumulative) developed by year 15 of plan implementation; and
- 65,000 acres (cumulative) developed by year 40 of plan implementation.

[34] Restored shallow subtidal habitat extends approximately from the mean lower low water [MLLW] elevation to 9 feet below the MLLW elevation.

[35] Restored tidal marsh plain extends from the MLLW elevation to the mean higher high water [MHHW] elevation.

[36] In achieving these targets the term "developed" means the completion of reintroduction of tidal inundation to areas expected to develop as tidal habitat. These target values represent the habitat area developed at the points in time identified. Development of fully functioning restored habitat may take years subsequent to initial tidal inundation through the effects of natural processes on the constructed surface.

Actions to restore freshwater and brackish tidal habitat, as appropriate to site-specific conditions, will include:

- Acquiring lands, in fee-title or through conservation easements, suitable for restoration of tidal habitats and protecting sufficient adjacent uplands to accommodate 3 feet of future sea level rise;
- Consulting with covered species experts to assist with the design and implementation of avoidance and minimization measures;
- Breaching and lowering levees and dikes to reintroduce tidal exchange to currently leveed former tidelands;
- Reconnecting disconnected remnant sloughs to Suisun Bay and removing remnant slough levees to reintroduce tidal connectivity to slough watersheds;
- Constructing new or enhancing existing levees to provide flood protection for adjacent landowners and protecting existing land use against seepage and erosion of existing levees;
- Constructing new levees to isolate deeply subsided lands from tidal flooding;
- Restoring natural remnant meandering tidal channels;
- Excavating channels to encourage the development of dendritic channel networks within restored marsh plain;
- Modifying ditches, cuts, and levees to encourage more natural tidal circulation and better flood conveyance based on local hydrology;
- Restoring tributary stream functions to establish more natural patterns of sediment transport to improve spawning conditions for delta smelt and other fish and macroinvertebrates;
- Prior to breaching, re-contouring the surface to maximize the extent of surface elevation suitable for establishment of tidal marsh vegetation ("marsh plain") by scalping higher elevation land to provide fill for placement on subsided lands to raise surface elevations;
- Prior to breaching, importing dredge or fill and placing it in shallowly subsided areas to raise ground surface elevations to a level suitable for establishment of tidal marsh vegetation ("marsh plain");
- Prior to breaching, cultivating stands of tules through flood irrigation for sufficiently long periods to raise subsided ground surface to elevations suitable to support marsh plain and breaching levees when target elevations are achieved; and
- Designing levee and dike breaches to maximize the development of tidal marsh plain and minimize hydrodynamic conditions that favor nonnative predatory fish.

Measures for addressing the potential for methylation of mercury in restored tidal habitats will be addressed through implementation of CM12 Methylmercury Management.

Freshwater Tidal Habitat Restoration

Freshwater tidal habitats will be restored to provide the ecological benefits for covered species described under *Hypothesized Benefits* below. Freshwater tidal habitats will be restored by breaching or removing levees along Delta waterways to reestablish tidal connectivity to reclaimed lands. Tidal habitat restored on deeply subsided Delta tracts and islands may require construction of cross levees or berms to isolate deeply subsided lands from inundation, avoiding the creation of large areas of subtidal habitats that could favor nonnative predator/competitor species and disfavor covered fish species. Where required, levees or berms will be constructed to prevent inundation of adjacent lands.

Where practicable and appropriate, portions of restoration sites will be raised to elevations that will support tidal marsh vegetation following breaching. Depending on the degree of subsidence and location, lands may be elevated by grading higher elevations to fill subsided areas, importing dredged or fill material from other locations, or planting tules or other appropriate vegetation to raise elevations in shallowly subsided areas over time through organic material accumulation. Surface grading will provide for a shallow elevation gradient from the marsh plain to the upland transition habitat. Based on assessments of local hydrodynamic conditions, sediment transport, and topography, restoration activities may be designed and implemented in a manner that accelerates the development of tidal channels within restored marsh plains. Following reintroduction of tidal exchange, tidal marsh vegetation is expected to establish naturally at suitable elevations relative to the tidal range. Depending on site-specific conditions and monitoring results, patches of native emergent vegetation may be planted to accelerate the establishment of native marsh vegetation on restored marsh plain surfaces. A conceptual illustration of restored freshwater tidal habitat is presented in Figure 3-55.

Restoration variables that will be considered by the BDCP Implementation Office in the design of restored freshwater tidal habitat include:

- Spatial distribution of restored tidal marsh habitats within the Delta;
- Extent, location, and configuration of restored tidal habitat areas;
- Predicted tidal range at tidal habitat restoration sites following reintroduction of tidal exchange;
- Size and location of levee breaches;
- Cross sectional profile of tidal habitat restoration sites (elevation of marsh plain, topographic diversity, depth, and slope); and
- Density and size of restored tidal habitat channels appropriate to each restoration site.

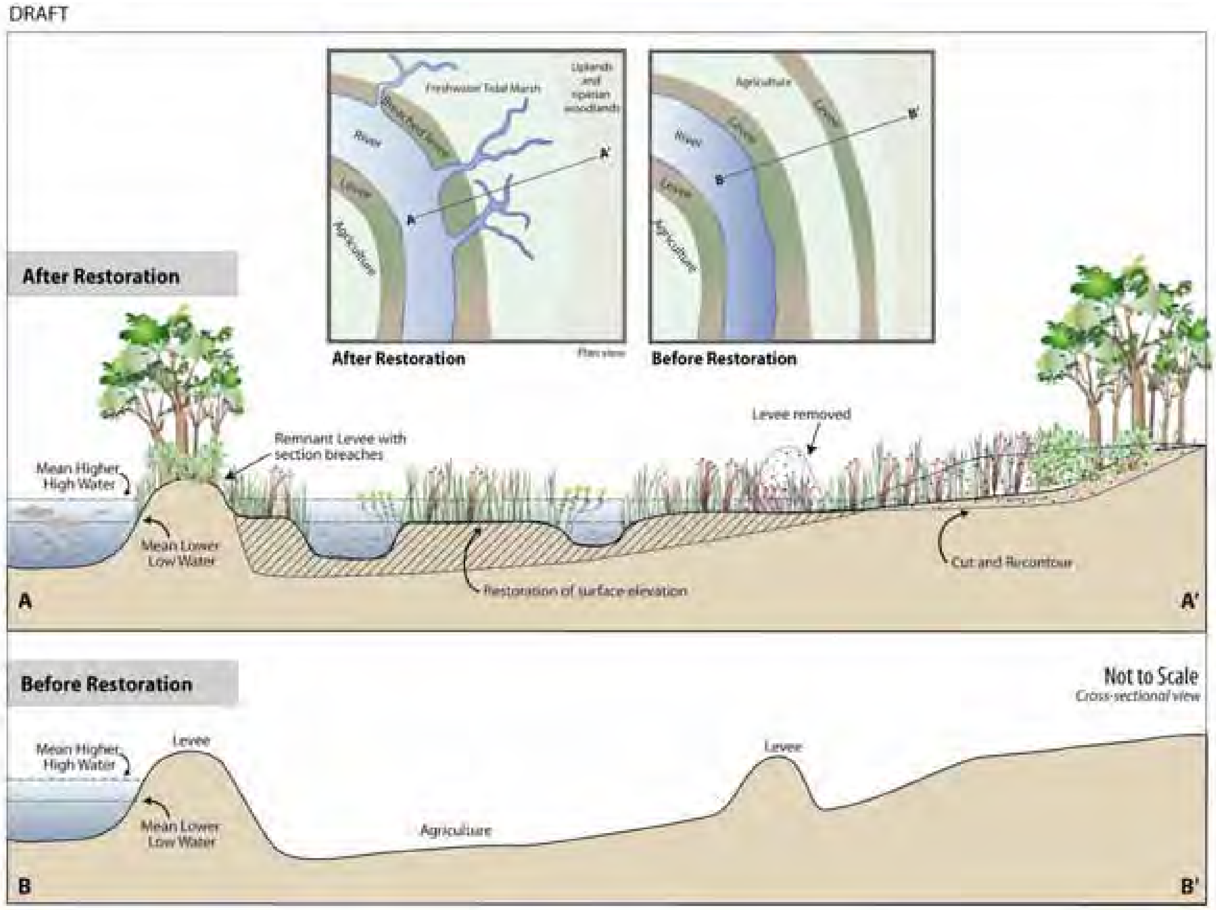

Figure 3-55. Conceptual Design for Restored Freshwater Tidal Marsh Habitat (CM4)

Restoration design considerations for freshwater tidal habitat will include the following.

*Marsh Plain Vegetation***.** To provide for high functioning habitat, restored tidal marsh plains will be vegetated primarily with tules and other native freshwater emergent vegetation to reflect the historical composition and densities of Delta tidal marshes. Following establishment of tidal exchange, restored habitat will be monitored to assess the establishment of native and invasive nonnative plants. If indicated by monitoring results, the Implementation Office will implement invasive plant control measures to help ensure the establishment of native marsh plain plant species.

*Hydrodynamic Conditions***.** Tidal habitat restoration will be designed, within restoration site constraints, to produce sinuous, high density, dendritic networks of tidal channels that promote effective tidal exchange throughout the marsh plain and provide foraging habitat for covered fish species. Effective tidal exchange is expected to enhance ecological functions that support covered species, including:

- The export of productivity from the marsh plain into adjacent Delta waterways in support of aquatic food web processes;
- Production and export of phytoplankton and zooplankton from tidal channels into adjacent Delta waterways in support of the aquatic food web; and
- Maintenance of cooler localized water temperatures preferred by covered fish species through nocturnal thermal exchange on marsh plains.

Marsh channels and levee breaches will also be designed to maintain flow velocities that minimize conditions favorable to the establishment of nonnative submerged and floating aquatic vegetation and habitat for nonnative predatory fish.

Following breaching and reintroduction of tidal action to restoration sites, tidal action will begin the natural process of sediment movement and the restored bottom contours will evolve. A discussion of such the types of changes expected is provided in Appendix N-4 [*marsh evolution document*].

*Environmental Gradients***.** As determined by site-specific constraints, tidal habitat restoration actions will be designed to provide an ecological gradient among subtidal, tidal mudflat, tidal marsh plain, riparian, and upland habitats to accommodate the movement of fish and wildlife species and provide flood refuge habitat for marsh-associated wildlife species during high water events. In addition, by protecting higher elevation lands adjacent to restored marsh plains, these areas will be available for future marsh establishment that may occur as a result of sea level rise.

*Shallow subtidal aquatic habitat***.** Restored shallow subtidal aquatic habitat is expected to support, depending on location, delta smelt, longfin smelt, juvenile salmonid rearing, sturgeon, and lamprey habitat. Shallow freshwater subtidal aquatic habitat in some portions of the Delta support large numbers of nonnative predatory fish and extensive beds of nonnative submerged aquatic vegetation that adversely affect covered fish species. In other portions of the Delta, shallow subtidal habitat provides suitable habitat for native species, such as delta smelt in the Liberty Island/Cache Slough region, and does not promote the growth of nonnative submerged aquatic vegetation. Because it may generate habitat for nonnative predators, it is not a goal of the BDCP to restore large areas of shallow subtidal aquatic habitat; rather, shallow subtidal aquatic habitat will result as part of the restoration of freshwater tidal marsh plain where land surface elevations within restoration sites are subsided below elevations that would support tidal marsh vegetation. Tidal habitat restoration projects will be designed to minimize the likelihood of establishment of nonnative submerged aquatic vegetation, which may serve as habitat for nonnative predators. Early restoration projects will be monitored to assess the response of nonnative species to restoration designs and local environmental conditions. This information will be used to modify restoration designs and implementation methods, if necessary, over time to further improve habitat conditions for covered fish species. As described in CM13 Nonnative Aquatic Vegetation Control, the BDCP Implementation Office will engage in active removal of submerged and floating aquatic vegetation in subtidal portions of tidal restoration sites to reduce the levels of establishment of nonnative predators.

*Minimum Restoration Targets for Freshwater Tidal Habitat in ROAs***.** At a minimum, the BDCP Implementation Office will restore the following amounts of tidal habitat in each of the Delta ROAs (Figure 3-2) as described below.

- **Restore at least 5,000 acres of freshwater tidal habitat within the Cache Slough Complex ROA**. The BDCP Implementation Office will restore a minimum of 5,000 acres of freshwater tidal habitat in the Cache Slough Complex ROA. Areas suitable for restoration include, but are not limited to, Haas Slough, Hastings Cut, Lindsey Slough, Barker Slough, Calhoun Cut, Liberty Island, Little Holland, the Westlands property ("Yolo Ranch"), Shag Slough, Little Egbert Tract, and Prospect Island. The Cache Slough Complex has been recognized as possibly the best functioning existing tidal habitat area of the Delta. The complex includes Liberty Island, which is likely the best existing model for freshwater tidal habitat restoration in the Delta for native fishes. The Complex supports multiple covered fish species and may be one of the last areas where Delta smelt spawn and rear successfully. Restoring the target amount of freshwater tidal habitat within the Cache Slough Complex ROA and protecting associated upland habitat would benefit multiple covered species and the Delta ecosystem. In conjunction with floodplain enhancement in the Yolo Bypass, the habitat restoration in the Cache Slough ROA will re-establish the ecological gradient from river to floodplain to tidal estuary and to provide tidal wetland adjacent to open channel habitat that is characteristic of less altered estuaries. Hydrodynamic modeling indicates that increased tidal exchange in the Cache Slough area resulting from 5,000-10,000 acres of tidal habitat restoration will reduce bidirectional flows in Steamboat and Sutter Sloughs and the mainstem Sacramento River compared to tidal action under present conditions, thus significantly enhancing movement of juvenile salmonids through these waterways and potentially reducing their exposure to predators.

Additionally, the Cache Slough Complex encompasses a substantial area of land with elevations suitable for freshwater tidal habitat restoration that would involve few impacts on existing infrastructure or permanent crops relative to other areas of the north Delta. The Cache Slough Complex provides an excellent opportunity to expand habitat supporting multiple aquatic and terrestrial covered species. Restoration of freshwater tidal habitat will be designed to support the physical and biological attributes that benefit covered species. Based on existing land elevations, approximately 21,000 acres of public and private lands in the area are potentially suitable for restoration of tidal habitat. Areas for restoration would be identified by working with interested landowners.

- **Restore at least 1,500 acres of freshwater tidal habitat within the Cosumnes-Mokelumne ROA.** The BDCP Implementation Office will restore a minimum of 1,500 acres of freshwater tidal habitat in the Cosumnes/Mokelumne ROA. Areas suitable for restoration within the Cosumnes-Mokelumne ROA (Figure 3-2) include McCormack-Williamson Tract, New Hope Tract, Canal Ranch Tract, Bract Tract, Terminous Tract north of State Highway 12, and lands adjoining Snodgrass Slough, South Stone Lake, and Lost Slough. Depending on site-specific conditions, levees may be constructed to avoid inundation of deeply subsided lands.
- **Restore at least 2,100 acres of tidal habitat within the West Delta ROA.** The BDCP Implementation Office will restore a minimum of 2,100 acres of freshwater tidal habitat in the West Delta ROA. The west Delta includes multiple small areas where tidal habitat can be restored. Areas suitable for restoration include Dutch Slough, Decker Island, portions of Sherman Island, Jersey Island, Bradford Island, Twitchell Island, Brannon Island, Grand Island, and along portions of the north bank of the Sacramento River where elevations and substrates are suitable. The purpose of restoring tidal habitat in the west Delta is to provide a continuous reach of tidal marsh and subtidal aquatic habitat associated with food productivity between current and future restored habitats in the Cache Slough Complex and Suisun Marsh and Bay and to provide tidal marsh plain habitat within the anticipated future eastward position of the biologically important low salinity zone of the estuary with sea level rise.
- **Restore at least 5,000 acres of tidal habitat within the South Delta ROA.** The BDCP Implementation Office will restore a minimum of 5,000 acres of freshwater tidal habitat in the South Delta ROA. To maximize benefits associated with restoration of tidal habitat in the south Delta, tidal habitat will not be restored until the north Delta diversion facilities become operational. Potential sites for restoring freshwater tidal habitat include Fabian Tract, Union Island, Middle Roberts Island, and Lower Roberts Island. Sites selected for restoration would be dependent on the location and design of the selected conveyance pathway and operations for the through-Delta component of the dual conveyance facility. Selected sites would be those that would provide substantial species and ecosystem benefits with the selected through-Delta conveyance configuration and most effectively avoid potential adverse effects of south Delta SWP/CVP operations. In conjunction with dual conveyance operations, tidal habitat restoration in the South Delta

ROA may support the expansion of the current distribution of delta smelt into formerly occupied habitat areas.

Tidal habitat restoration sites will be designed to support habitat mosaics and an ecological gradient of shallow subtidal aquatic, tidal mudflat, tidal marsh, transitional upland and riparian habitats, and uplands (e.g., grasslands, agricultural lands) for sea level rise accommodation, as appropriate to specific restoration sites.

Problem Statement

The majority of historical freshwater tidal marsh in the Sacramento/San Joaquin Delta has been lost. Historically, approximately 350,000 acres of tidal marsh was present in the Delta, of which less than 10,000 acres of freshwater tidal marsh remains. This loss of tidal marsh has greatly reduced the availability and quality of spawning and rearing habitat for many native fish species, by reducing the input of organic and inorganic material and food resources into adjoining deep water habitats (sloughs and channels) and the downstream bay and estuary. This loss of freshwater tidal marsh has also greatly reduced the extent and quality of habitat for native wildlife and plants adapted to the tidal marsh environment, including many of the covered species.

Hypothesized Benefits

Restoration of freshwater tidal habitat is hypothesized to provide a range of ecosystem and covered species benefits. These anticipated benefits are described below for the freshwater tidal habitat restoration proposed in each of the ROAs. As described in Chapter 5, *Effects Analysis*, and Appendix F, *DRERIP Evaluation Results*, however, there are a number of uncertainties regarding the level of benefits that may be provided by tidal habitat restored in each of the ROAs as well as risks for adverse consequences. These uncertainties will be addressed through effectiveness monitoring, research, and the adaptive management program (see Sections 3.6 and 3.7).

Restoring freshwater tidal habitat within the Cache Slough ROA is expected to:

- Increase rearing habitat area for Chinook salmon (Sacramento River runs), Sacramento splittail, white sturgeon, and green sturgeon (Healey 1991, Brown 2003, Appendix F, *DRERIP Evaluation Results*);
- Increase the local production of food for rearing salmonids, splittail, delta smelt, green and white sturgeon (Kjelson et al. 1982, Siegel 2007);
- Increase the export of food in the Delta downstream of Rio Vista available to juvenile salmonids, splittail, delta smelt, white sturgeon, and green sturgeon by exporting organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in tidal channels into the Delta and Suisun Marsh (Siegel 2007);
- Expand habitat available for colonization by Mason's lilaeopsis, Suisun Marsh aster, Delta mudwort, and Delta tule pea; and

- Expand habitat for tricolored blackbird, California black rail, and giant garter snake (in locations with a muted tidal range).

Restoring freshwater tidal habitat within the Cosumnes/Mokelumne River ROA is expected to:

- Increase rearing habitat area for Cosumnes/Mokelumne fall-run Chinook salmon, steelhead, delta smelt, and Sacramento splittail (Healey 1991, Brown 2003);
- Increase the local production of food for Cosumnes/Mokelumne fall-run Chinook salmon, steelhead, delta smelt, and Sacramento splittail migrating to and from the Cosumnes and Mokelumne Rivers (Kjelson et al. 1982, Siegel 2007);
- Increase the availability and production of food in the east and central Delta available to juvenile salmonids, splittail, delta smelt, white sturgeon, and green sturgeon by exporting organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in tidal channels into the Delta (Siegel 2007);
- Increase the extent of habitat available for colonization by side-flowering skullcap, Mason's lilaeopsis, Suisun Marsh aster, and Delta tule pea; and
- Expand habitat for tricolored blackbird, California black rail, greater sandhill crane, and giant garter snake (in locations with a muted tidal range).

Restoring freshwater tidal habitat in the West Delta ROA is expected to:

- Increase rearing habitat area for Chinook salmon (Sacramento, San Joaquin, and Mokelumne river runs), Sacramento splittail, and possibly steelhead (Healey 1991, Brown 2003);
- Improve future rearing habitat areas for delta smelt and longfin smelt within the anticipated eastward movement of the low salinity zone with sea level rise;
- Increase the local production of food for rearing salmonids, splittail, and other covered species (Kjelson et al. 1982; Siegel 2007);
- Increase the availability and production of food in the western Delta and Suisun Bay by exporting organic material via tidal flow from the marsh plain and organic carbon, phytoplankton, zooplankton, and other organisms produced in tidal channels into adjacent open water areas (Siegel 2007);
- Provide an important linkage between current and future upstream restored habitat with downstream habitat in Suisun Marsh and Bay;
- Provide additional refugial habitat for migrating and resident covered species;
- Increase the extent of habitat available for colonization by Mason's lilaeopsis, Suisun Marsh aster, Delta mudwort, and Delta tule pea; and
- Expand habitat for tricolored blackbird, California black rail, and giant garter snake (in locations with a muted tidal range).

Restoring freshwater tidal habitat in the South Delta ROA is expected to:

- Increase rearing habitat area for Sacramento splittail, Chinook salmon produced in the San Joaquin River and other eastside tributaries, and possibly steelhead (Healey 1991, Brown 2003);
- Increase the local production of food for rearing salmonids, splittail, and other covered species (Kjelson et al. 1982, Siegel 2007);
- Increase the availability and production of food in the Delta and Suisun Bay by export from the south Delta of organic material via tidal flow from the new marsh plain and organic carbon, phytoplankton, zooplankton, and other organisms produced in new tidal channels (Siegel 2007);
- Increase the extent of habitat available for colonization by Mason's lilaeopsis, Delta mudwort, and Delta tule pea; and
- Expand habitat for tricolored blackbird, California black rail, greater sandhill crane, and giant garter snake (in locations with a muted tidal range).

Adaptive Management Considerations

Implementation of freshwater tidal habitat restoration actions and subsequent management of restored tidal habitats by the BDCP Implementation Office will be informed through effectiveness monitoring that will be conducted for this conservation measure as described in Section 3.6, *Monitoring and Research Program*, and the adaptive management process described in Section 3.7, *Adaptive Management Program*. Based on analysis of monitoring results, likely elements of this measure that could be adjusted through the adaptive management process include considerations for selecting restoration locations and sequencing restoration of tidal habitat among the ROAs; methods for establishing marsh plain vegetation, including the establishment of marsh-associated covered plant species; methods and designs for elevating subsided land surfaces to increase restored marsh plain area; design and location of levee breaches; designs for encouraging the development of a high functioning network of tidal channels; and nonnative vegetation and wildlife control techniques.

Brackish Tidal Habitat Restoration

Brackish tidal habitat will be restored within Suisun Marsh ROA in coordination with the Suisun Marsh Habitat Restoration and Management Plan, currently under development. Brackish tidal habitat will be restored to provide the ecological benefits for covered species described under Hypothesized Benefits below. Brackish tidal habitat will be restored by breaching or removing dikes along Montezuma and other Suisun Marsh sloughs and channels and Suisun Bay to reestablish tidal connectivity to reclaimed lands. Tidal habitat restored adjacent to farmed lands or lands managed as freshwater seasonal wetlands may require construction of dikes to maintain those land uses. Where appropriate, portions of restoration sites will be raised to elevations that would support tidal marsh vegetation.

Depending on the degree of subsidence, location, and likelihood for natural accretion through sedimentation, lands may be elevated by grading higher elevations to fill subsided areas, importing dredged or fill material from other locations, or planting appropriate native vegetation to raise elevations in shallowly subsided areas over time through organic material accumulation prior to breaching dikes. Surface grading will be designed to result in a shallow elevation gradient from the marsh plain to the upland transition habitat. Remnant disconnected tidal channels will be restored if present within restoration sites to accelerate development of marsh functions. Existing tidal channels may also be deepened and or widened if necessary to increase tidal flow. Based on assessments of local hydrodynamic conditions, sediment transport, and topography, restoration sites may be graded to accelerate the development of tidal channels within restored marsh plains. Following reintroduction of tidal exchange, tidal marsh vegetation would be expected to naturally establish at suitable elevations relative to the tidal range. Depending on site-specific conditions and monitoring results, patches of native emergent vegetation may be planted to accelerate the establishment of native marsh vegetation on restored marsh plain surfaces. A conceptual illustration of restored brackish tidal habitat is presented in Figure 3-56.

Restoration variables that will be considered by the BDCP Implementation Office in the design of restored brackish tidal habitat include:

- Extent, location, and configuration of other existing and proposed restored tidal habitat areas;
- Distribution of restored tidal habitats along salinity gradients to optimize the range of habitat conditions for covered species and food production;
- Predicted tidal range at tidal habitat restoration sites following reintroduction of tidal exchange;
- Size and location of dike breaches;
- Cross sectional profile of tidal habitat restoration sites (elevation of marsh plain, topographic diversity, depth, and slope);
- Density and size of tidal marsh plain channels appropriate to each restoration site; and
- Potential hydrodynamic and water quality effects on other areas of the Delta.

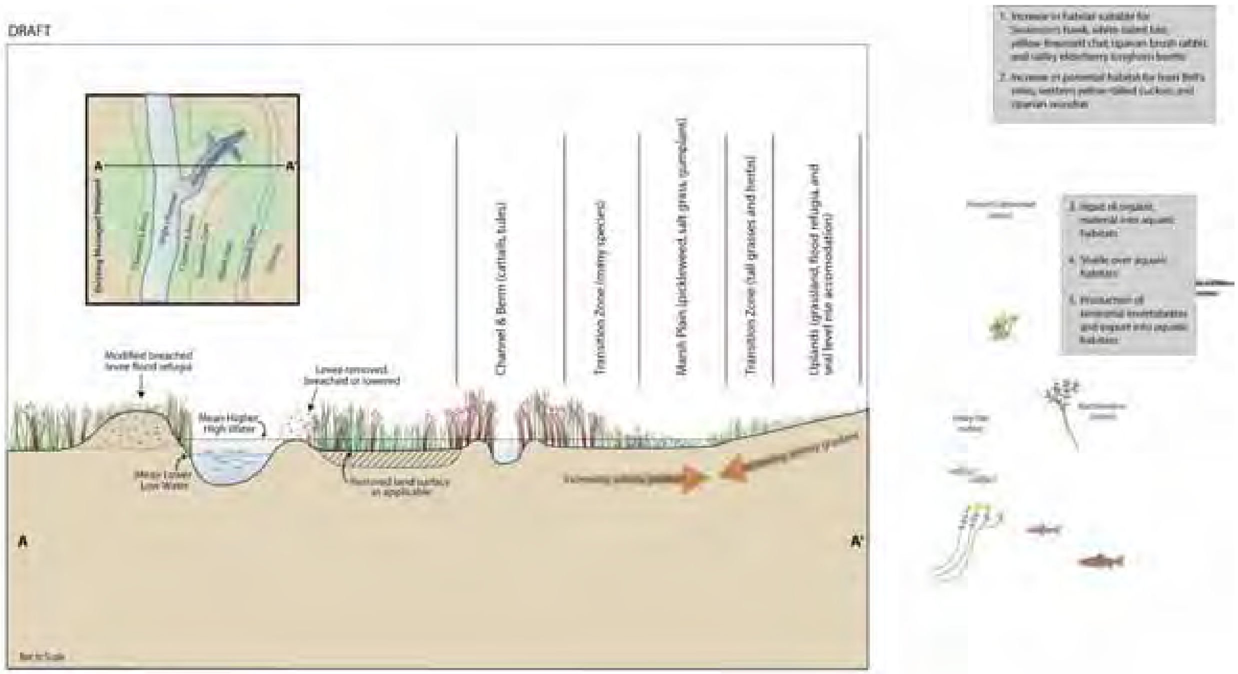

Figure 3-56. Conceptual Design for Restored Brackish Tidal Marsh Habitat (Suisun Marsh ROA) (CM4)

Restoration design considerations for brackish tidal habitat include the following.

*Marsh Plain Vegetation***.** To provide high functioning habitat, restored tidal marsh plains will be dominated by native brackish marsh vegetation (e.g., pickleweed, saltgrass) appropriate to marsh plain elevations, mimicking the composition and densities of historical Suisun Bay brackish tidal marshes. Vegetated marsh plains will also be expected to filter non-point source pollution from surface or subsurface infiltration that otherwise would flow into Suisun Bay. Following establishment of tidal exchange, restored habitat will be monitored to assess the establishment of invasive nonnative plants. If indicated by monitoring results, the BDCP Implementation Office will implement invasive plant control measures to help ensure the establishment of native marsh plain plant species.

*Hydrodynamic Conditions***.** Restored brackish tidal habitat will be designed to provide hydrodynamic conditions similar to those described for freshwater tidal habitat. In addition to desired biological and ecological attributes, the selection and design of restored tidal habitat in Suisun Marsh will need to consider potential hydrodynamic and water quality effects of the proposed restoration, including the effect on salinity intrusion, tidal mixing, and Delta salinity.

*Environmental Gradients***.** Restored brackish tidal habitat will be designed to provide environmental gradients similar to those described for freshwater tidal habitat. Because land surface elevations within Suisun Marsh are relatively homogenous, opportunities to provide linkages to upland habitats are limited to restoration sites that are located along the fringe of Suisun Marsh. Dikes constructed to restore tidal habitat in the interior of Suisun Marsh will be designed with low gradient slopes supporting high marsh and upland vegetation to provide flood refuge habitat. Where appropriate, higher elevation islands of upland habitat within restored tidal habitat may also be created to provide flood refuge for marsh wildlife.

Minimum Restoration Targets for Brackish Tidal Habitat in Suisun ROA. The BDCP Implementation Office will restore at least the following amount of brackish tidal habitat in the Suisun Marsh ROA.

*Restore at least 7,000 acres of brackish tidal habitat within the Suisun Marsh Restoration Opportunity Area***.** The BDCP Implementation Office will restore a minimum of 7,000 acres of brackish tidal habitat in the Suisun Marsh ROA. Restored brackish tidal habitat will be designed to support the physical and biological attributes described above in Brackish Tidal Marsh Habitat Restoration. Restored tidal habitat will be designed to create ecological gradients that support a mosaic of tidal marsh, tide flat, shallow subtidal aquatic, and transitional upland habitats as appropriate to specific restoration sites. The Suisun Marsh ROA encompasses a substantial area with elevations suitable for tidal habitat restoration that would have minimal effect on infrastructure or permanent crops relative to other suitable lands within the Delta.

The Suisun Marsh Habitat Restoration and Management Plan (currently under development) will include an evaluation of alternatives, including options that contemplate the restoration of up to

7,000 acres of brackish tidal habitat. Much of Suisun Marsh is currently at elevations that could be restored to tidal habitat.

Hydrodynamic modeling conducted for the Suisun Marsh Restoration Plan (J. DeGeorge pers. comm.) indicates that restoring tidal habitat north of Montezuma Slough would shift the low salinity zone westward and restoring tidal habitat at sites adjacent to Suisun Bay would shift the low salinity zone eastward, potentially adversely affecting delta smelt habitat and water quality in the west Delta. Consequently, implementation of tidal habitat restoration projects in north and south Suisun Marsh will be sequenced such that these potential effects would be minimized.

As described in CM1 *Water Facilities and Operation*, future reoperation of the Montezuma Slough Salinity Control Gate will increase the benefits of restoring brackish tidal habitat in Suisun Marsh by increasing access for covered fish species to existing and restored tidal aquatic habitat within a large area of Suisun Marsh.

Problem Statement

Suisun Marsh is the largest brackish water marsh complex in the western United States. The majority of historical brackish tidal marsh has been lost, of which approximately 8,300 acres remains in Suisun Marsh. This loss of tidal marsh has greatly reduced the availability and quality of spawning and rearing habitat for many native species, by reducing the input of organic and inorganic material and food resources into adjoining deep water habitats (sloughs and channels) and the downstream bay and estuary. This loss of brackish tidal marsh has also greatly reduced the extent and quality of habitat for native wildlife and plants adapted to the tidal marsh environment, including many of the covered species.

Hypothesized Benefits

Restoration of brackish tidal habitat in Suisun Marsh is hypothesized to provide a range of ecosystem and covered species benefits. As described in Chapter 5, *Effects Analysis,* and Appendix F, *DRERIP Evaluation Results*, however, there are a number of uncertainties regarding the level of benefits that may be provided by tidal habitat restored as well as risks for adverse consequences. These uncertainties will be addressed through effectiveness monitoring, research, and the adaptive management program (see Sections 3.6 and 3.7).

Restoring brackish tidal habitat within the Suisun Marsh ROA is expected to:

- Increase rearing habitat area for Chinook salmon, Sacramento splittail, and possibly steelhead (Healey 1991, Siegel 2007);
- Increase the local production of food for rearing salmonids, splittail, and other covered species (Kjelson et al. 1982);
- Provide an important linkage between current and future upstream restored habitat, such as Yolo Bypass/Cache Slough with Suisun Marsh/Bay;

- Increase the availability and production of food in Suisun Bay for delta and longfin smelt by exporting organic material via tidal flow from the marsh plain and phytoplankton, zooplankton, and other organisms produced in tidal channels into the Bay;
- Locally provide areas of cool water refugia for delta smelt (C. Enright pers. comm.);
- Reduce periodic low dissolved oxygen events associated with the discharge of waters from lands managed as seasonal freshwater wetlands that would be restored as brackish tidal habitat (Siegel 2007, C. Enright pers. comm.);
- Increase the extent of habitat available for colonization by Suisun marsh aster and soft-bird's-beak; and
- Enhance and increase the extent of salt marsh harvest mouse, Suisun shrew, California clapper rail, California black rail, and Suisun song sparrow habitat.

Adaptive Management Considerations

Implementation of brackish tidal habitat restoration actions and subsequent management of restored brackish tidal habitats by the BDCP Implementation Office will be informed through effectiveness monitoring that will be conducted for this conservation measure as described in Section 3.6, *Monitoring and Research Program*, and the adaptive management process described in Section 3.7, *Adaptive Management Program*. Based on analysis of monitoring results, likely elements of this measure that could be adjusted through the adaptive management process include considerations for selecting restoration locations and sequencing restoration of tidal habitat within Suisun Marsh to maintain desirable salinity gradients; methods for establishing marsh plain vegetation, including the establishment of marsh-associated covered plant species; methods and designs for elevating subsided land surfaces to increase restored marsh plain area; design and location of dike breaches; designs for encouraging the development of a high functioning network of tidal channels; and nonnative vegetation and wildlife control techniques.

3.4.3.2 CM5 Seasonally Inundated Floodplain Restoration

The BDCP Implementation Office will provide for the restoration of 10,000 acres of seasonally inundated floodplain habitat within the north, east, and/or south Delta. Because of the long-lead time needed to plan for and implement floodplain restoration it is not expected that new floodplain would be restored in the first 10 years of Plan implementation. The following are the temporal targets for seasonally inundated floodplain restoration:

- At least 1,000 acres restored by year 15 of plan implementation; and
- 10,000 acres (cumulative) restored by year 40 of plan implementation.

Although seasonally inundated floodplain may be restored along channels in many locations in the north, east, and south Delta, the most promising opportunities for large-scale restoration are in the south Delta along the San Joaquin River, Old River, and Middle River channels based on benefits to covered fish species, practicability considerations, and compatibility with potential flood control projects. Criteria that will be considered in selecting seasonally inundated floodplain restoration sites include:

- Relative importance of the adjacent channel as migration pathways for juvenile salmonids;
- Estimated frequency and duration of inundation periods; and
- Compatibility with flood control programs and level of flood control benefits provided relative to other potential restoration sites.

Actions to restore seasonally inundated floodplain habitats, as appropriate to site-specific conditions, include but are not limited to:

- Acquiring lands, in fee-title or through conservation easements, suitable for restoration of seasonally inundated floodplain;
- Setting back levees along the selected river corridor and removing the existing levees or sections of the existing levees;
- Removing existing riprap along channel banks to allow for channel meander between the set-back levees through the natural processes of erosion and sedimentation;
- Grading restored floodplain surfaces to provide for drainage of over bank flood waters such that the potential for fish stranding is minimized ;
- Lowering the elevation of restored floodplain surfaces to increase inundation frequency and duration and to establish elevations suitable for the establishment of riparian vegetation;
- Discontinuing farming within the setback levees and allowing riparian vegetation to naturally establish on the floodplain;
- Where farming is continued consistent with achieving biological and flood control objectives, engaging in farming practices and crop types that provide high benefits for covered fish species; and
- Actively establishing riparian habitat where necessary to accelerate formation of habitat for specific covered species (see the description of CM7 Riparian Habitat Restoration).

Measures for addressing the potential for methylation of mercury in restored tidal habitats will be addressed through implementation of CM12 Methylmercury Management.

A conceptual illustration of restored seasonally inundated floodplain is presented in Figure 3-57. Because restoration requires modification of levees that serve flood control functions, restored floodplain habitats will be implemented such that flood control functions are maintained or improved.

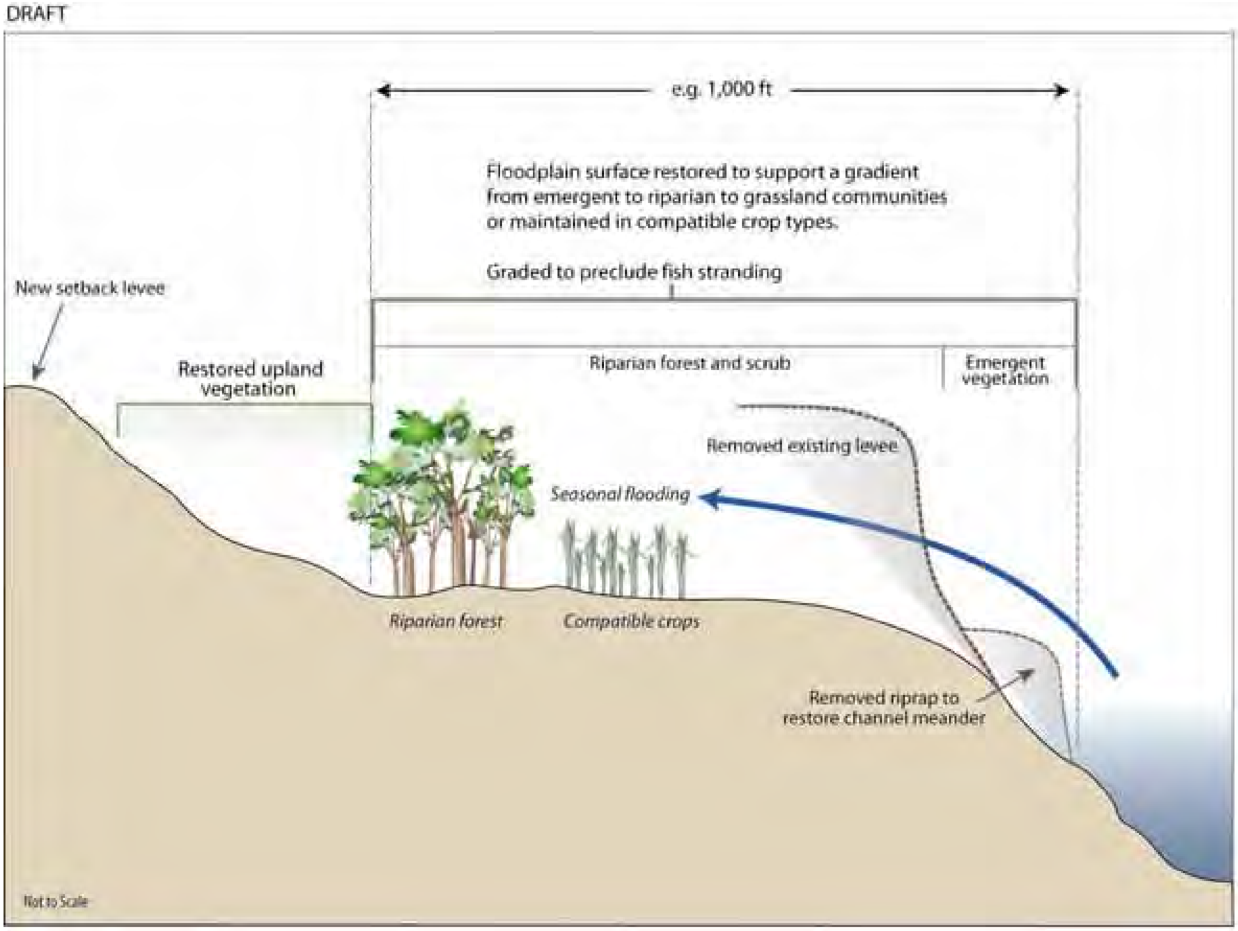

Figure 3-57. Conceptual Design for Restored Seasonally Inundated Floodplain Habitat (CM5)

The BDCP Implementation Office will coordinate floodplain restoration planning with the flood control planning efforts of USACE, DWR, the Central Valley Flood Protection Board, and other flood control agencies to assess the desirability and feasibility for setting back levees in potentially suitable locations. Seasonally inundated floodplain habitat will be designed to support the physical and biological attributes described below in Seasonally Inundated Floodplain Habitat Restoration Concepts and to provide the ecological benefits for covered species described below in Hypothesized Benefits.

Seasonally Inundated Floodplain Habitat Restoration Concepts

Restoration variables that will be considered in the design of restored seasonally inundated floodplain habitat include:

- Modeled timing, duration, interannual frequency, and spatial extent of inundation;
- Connectivity with tidal marsh and channel habitats;
- Accessibility to migrating fish;
- Stranding risk and effects on fish passage;
- Vegetation type and cover;
- Dry season land use (compatible farming practices); and
- Topography and slope.

Restoration design considerations for seasonally inundated floodplain habitat include the following.

Floodplain Topography. Where appropriate, the topography of restored floodplains would be sculpted to reduce the risk for fish stranding by improving drainage and to provide topographic variability to increase hydrodynamic complexity.

Connectivity. Where suitable landform is present, restored floodplains will be located and designed such that flows exiting the floodplain would pass through existing or restored tidal marsh to recreate historical landscape relationships and to provide for connectivity with adjacent uplands that result in transitional habitats and accommodate species movement.

Habitat Restoration on Restored Floodplains. Riparian forest and scrub vegetation will be actively and passively established in restored floodplain areas to the extent consistent with floodplain land uses and flood control requirements. Restored floodplains provide the largest area for meeting the 5,000-acre target for restoration of woody riparian habitat under CM7 Riparian Habitat Restoration, and it is expected that about four-fifths of the riparian habitat restoration will occur at these restored floodplain sites. Established woody riparian vegetation would support habitat for riparian-associated covered species and provide cover and hydrodynamic complexity for covered fish species during inundation periods. Riparian vegetation would also serve as sources of instream woody material for fish habitat, organic carbon in support of the aquatic food web, and macroinvertebrates (e.g., insects) that provide food for covered fish species.

*Land Use on Restored Floodplains***.** Restored floodplains will be managed for ongoing agricultural uses or to support native wildlife habitats. Farmed floodplains will be managed to minimize the use of persistent herbicides and pesticides that are toxic to aquatic organisms and to provide structure and types of residual crop biomass to provide cover and hydrodynamic complexity for fish and provide sources of organic carbon in support of aquatic food web processes during inundation periods.

Problem Statement

Extensive channelization and levee construction has disconnected river channels from their historical floodplains over much of the Central Valley, including the Planning Area, resulting in substantial reduction in the availability of high functioning spawning and rearing habitats that historically support several of the covered fish species. Restoring connectivity of Delta river channels to their historical floodplains will substantially increase the extent of floodplain that can be inundated by overbank flows, thus restoring high functioning spawning and rearing habitat for Sacramento splittail and rearing habitat for salmonids. The restoration of floodplain habitat would allow for establishment of riparian forest and scrub natural community that would support habitat for a large number of covered wildlife and plant species.

Hypothesized Benefits

Restoration of seasonally inundated floodplain habitat is hypothesized to provide the ecosystem and covered species benefits described below. As described in Chapter 5, *Effects Analysis*, and Appendix F, *DRERIP Evaluation Results*, however, there are a number of uncertainties regarding the level of benefits that may be provided by restored floodplain habitats as well as risks for adverse consequences. These uncertainties will be addressed through effectiveness monitoring, research, and the adaptive management program (Sections 3.6 and 3.7).

Restoring seasonally inundated floodplain habitat is expected to:

- Increase spawning habitat for Sacramento splittail by expanding floodplain habitat area and providing in-channel spawning habitat by creating backwaters (Sommer et al. 2001a, 2002, 2007b, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006).
- Depending on the location of restored floodplain, increase rearing habitat for Sacramento and San Joaquin Basin runs of Chinook salmon, Sacramento splittail, and possibly steelhead (Sommer et al. 2001a,b, 2002, 2007, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006).

- Increase the production of food for rearing salmonids, splittail, and other covered species (Sommer et al. 2001a,b, 2002, 2007b, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006).
- Increase the availability and production of food in Delta channels downstream of restored floodplain habitat for delta smelt, longfin smelt, and other covered species by exporting organic material and phytoplankton, zooplankton, and other organisms produced from the inundated floodplain into Delta channels (Mitsch and Gosselink 2000, Moss 2007).
- Increase in nesting habitat for Swainson's hawk and white-tailed kite and habitat for yellow-breasted chat, least Bell's vireo, yellow-billed cuckoo, and valley elderberry longhorn beetle associated with riparian forest and scrub established in floodplain restoration sites.
- Increase in habitat for riparian brush rabbit and riparian woodrat within riparian scrub established in the south Delta restored floodplains (CITATION).
- Increase in habitat area for the establishment of slough thistle and Delta button-celery depending on the location of restored floodplain.

Adaptive Management Considerations

Implementation of seasonally inundated floodplain restoration actions and subsequent management of restored floodplain habitats by the Implementation Office will be informed through effectiveness monitoring that will be conducted for this conservation measure as described in Section 3.6, *Monitoring and Research Program*, and the adaptive management process described in Section 3.7, *Adaptive Management Program*. Based on analysis of monitoring results, likely elements of this measure that could be adjusted through the adaptive management process include modifications to floodplain surfaces to increase inundation frequency and duration, reduce the potential for fish stranding, and changes in floodplain vegetation to increase functions related to food production and habitat conditions during periods of inundation.

3.4.3.3 CM6 Channel Margin Habitat Enhancement

The BDCP Implementation Office will provide for the enhancement of 20 linear miles of channel margin habitat in the Delta. This conservation measure is directed at improving habitat conditions for covered fish, wildlife, and plant species along Delta channel banks (as measured along one bank line of channels) by improving channel geometry and restoring riparian, marsh, and mudflat habitats along levees. Channel margin habitat will be enhanced only along channels that serve as important rearing and outmigration habitat for juvenile salmonids. Although channel margin enhancements are intended to provide specific benefits for salmonids, enhancement of these habitats is also expected to improve or restore habitat for other species of covered fish, wildlife, and plants that inhabit channel margin habitats. This measure will be implemented along channels protected by federal Project and/or non-Project levees within the

Plan Area. Channel margin habitat enhancements associated with Project levees will be not be implemented on the levee, but rather on benches to the outboard side of such levees (Figure 3-X [*to come*]). Based on results of effectiveness monitoring for this conservation measure, the BDCP Implementation Office may elect to enhance up to an additional 20 miles of channel margin (for a total of 40 miles) through the adaptive management decision making process. Channel margin habitat enhancement is measured along one side of a channel.

Channel margin enhancement actions will be located along channels that serve as primary rearing and outmigration habitat for juvenile salmonids. These locations include the Sacramento River between Freeport and Walnut Grove, the San Joaquin River between Vernalis and Mossdale, and Steamboat and Sutter Sloughs that are protected by federal Project levees and salmonid migration channels in the interior Delta, such as the North and South Forks of the Mokelumne River, that are protected by non-Project levees. The following are minimum geographic requirements for the 20 miles of channel margin enhancement under this measure:

- At least 5 miles will be located along the Sacramento River between Freeport and Walnut Grove;
- At least 5 miles will be located along the San Joaquin River between Vernalis and Mossdale; and
- The remaining 10 miles will be distributed among the channels described in the preceding paragraph.

The following are the temporal targets for implementation of the 20 miles of channel margin habitat enhancements:

- At least 5 miles enhanced by year 10 of Plan implementation;
- At least 5 miles enhanced by year 20 of Plan implementation;
- At least 5 miles enhanced by year 25 of Plan implementation; and
- At least 5 miles enhanced by year 30 of Plan implementation.

Actions to enhance channel margin habitats, as appropriate to site-specific conditions include, but are not limited to:

- Modifying the outboard side of levees or setting back levees to create low floodplain benches designed with variable surface elevations to create hydrodynamic complexity and that support emergent vegetation to provide an ecological gradient of habitat conditions, and higher elevation benches that support riparian vegetation;
- Planting riparian and emergent wetland vegetation on created benches;
- Installing large woody material (e.g., tree trunks and stumps) could be anchored into constructed low benches or into existing riprapped levees to provide similar habitat functions;

- Removing riprap from channel margins where levees are setback to restore seasonally inundated floodplain habitat under CM5 Seasonally Inundated Floodplain Restoration; and
- Modifying channel geometry in unconfined channel reaches or along channels where levees are setback to restore seasonally inundated floodplain habitat under CM5 Seasonally Inundated Floodplain Restoration, to create backwater salmonid and splittail rearing and splittail spawning habitat.

A conceptual depiction of how channel margin habitat may be enhanced is presented in Figure 3-X [*to come*].

Because channel margin habitat enhancement is expected to require modification of channels and levees that serve flood control functions, channel margin habitat enhancements will be implemented such that flood control functions are maintained or improved. The BDCP Implementation Office will coordinate channel margin habitat enhancement planning with the flood control planning efforts of USACE, DWR, the Central Valley Flood Protection Board, and other flood control agencies to assess the desirability and feasibility for channel modifications. Channel margin habitat enhancements will be designed to support the ecological benefits for covered species described below in *Hypothesized Benefits*.

Restoration variables that will be considered in the location and design of enhanced channel margin habitat include:

- The length of habitat that can be practicably enhanced along channel margins;
- Connectivity with existing channel margin habitats supporting high functioning salmonid rearing habitat;
- The cross sectional profile of enhanced channels (elevation of habitat, topographic diversity, width, variability in edge and bench surfaces, depth, and slope);
- The amount and distribution of installed woody debris along enhanced channel margins; and
- The extent of shaded riverine aquatic overstory and understory vegetative cover needed to provide future input of large woody debris.

Problem Statement

Primary Delta channels serve as movement corridors for the covered fish species and support splittail spawning and salmonid, sturgeon, and splittail rearing habitat. These channels are now leveed and, as such, channel margin habitats lack the diversity and complexity of habitat conditions associated with unmodified channels. Increasing the diversity and complexity of channel margin habitats is expected to increase their function as habitat for covered fish species. Specifically, providing for channel margin habitat complexity along migration corridors for outmigrating juvenile Chinook salmon may increase survivorship through reductions in predation and increases in food availability.

Hypothesized Benefits

Enhancement of channel margin habitat is hypothesized to provide the following ecosystem and covered species benefits. As described in Chapter 5, *Effects Analysis,* and Appendix F, *DRERIP Evaluation Results*, however, there are a number of uncertainties regarding the level of benefits that may be provided by enhancing channel margin habitat as well as risks for adverse consequences. These uncertainties will be addressed through effectiveness monitoring, research, and the adaptive management program (Sections 3.6 and 3.7).

Enhancing channel margin habitats is expected to:

- Increase the quality of rearing habitat area for Chinook salmon, sturgeon, and possibly steelhead (Sommer et al.2001a,b, 2002, 2007b, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006);
- Reducing the risk for predation on covered fish species by nonnative fish predators;
- Increase the extent of shaded riverine aquatic cover and increase instream cover by through contributions of instream woody material (USFWS 2004);
- Increasing connectivity among salmonid rearing and outmigration habitat areas;
- Provide inputs of organic material (e.g., leaf and twig drop) in support of aquatic foodweb processes;
- Increase production and export of terrestrial invertebrates into the aquatic ecosystem (Nakano and Murakami 2001);
- Create additional spawning habitat for Sacramento splittail by creating low velocity backwater habitats (Sommer et al. 2001a, 2002, 2007b, 2008, Moyle 2002, Moyle et al. 2004, Feyrer et al. 2006); and
- Create tidal mudflat substrate suitable for the establishment of Suisun Marsh aster, Mason's lilaeopsis, Delta mudwort, and Delta tule pea and coarse woody debris substrate suitable for side-flowering skullcap.

Restoration of riparian forest and scrub that is incorporated into channel margin enhancements is also expected to support habitat for valley elderberry longhorn beetle, Swainson's hawk, white-tailed kite, and potentially, depending on vegetative structure and patch size, yellow-breasted chat and least Bell's vireo. Increasing the extent of large woody material will enhance habitat for western pond turtle.

Adaptive Management Considerations

Implementation of channel margin habitat enhancement actions by the BDCP Implementation Office will be informed through effectiveness monitoring that will be conducted for this conservation measure as described in Section 3.6, *Monitoring and Research Program*, and the adaptive management process described in Section 3.7, *Adaptive Management Program*. Based on analysis of monitoring results, likely elements of this measure that could be adjusted through the adaptive management process include adjusting the design of subsequent channel margin restoration actions to improve habitat functions for covered fish species and increasing the effectiveness of emergent and riparian vegetation establishment techniques.

3.4.3.4 CM7 Riparian Habitat Restoration

The BDCP Implementation Office will restore 5,000 acres of riparian forest and scrub. It is anticipated that riparian forest and scrub will be restored primarily in association with the restoration of tidal and floodplain habitats and channel margin habitat enhancements. The following are the temporal targets for riparian restoration:

- 400 acres restored by year 15 of Plan implementation; and
- 5,000 acres (cumulative) restored by year 40 of Plan implementation.

Anticipated actions to restore riparian forest and scrub, as appropriate to site-specific conditions, include, but are not limited to:

- Acquiring lands, in fee-title or through conservation easements, suitable for restoration of riparian forest and scrub;
- Allowing for the natural establishment of riparian vegetation;
- Site preparation, planting of native riparian vegetation, and maintenance of plantings;
- Irrigation of plantings; and
- Control of nonnative plants.

Patches of restored riparian forest and scrub are expected to support the range of riparian habitat conditions necessary to support habitat for each of the riparian-associated covered wildlife species. Once established, it is expected that restored riparian forest and scrub will be self-sustaining and will be monitored to determine if subsequent management actions may be required to ensure successful regeneration of native riparian plant species.

Riparian Restoration in Restored Floodplains

To the extent consistent with flood control requirements, restored floodplain habitat areas (Figure 3-57 and CM5) will allow for the natural establishment and growth of woody riparian vegetation on portions of restored floodplains that support appropriate soils and hydrology and along channels within restored floodplains. Restored floodplain riparian vegetation is expected to establish in large extensive patches relative to the typically narrow stringers of riparian vegetation that exist along channels and agricultural water conveyance features within much of the Plan Area.

Native riparian vegetation (e.g., Fremont cottonwood, Goodings' willow, box elder) will be planted if site-specific restored floodplain conditions indicate that such plantings will substantially increase the establishment of riparian forest and scrub. Elderberry shrubs will be a component of such plantings to provide habitat for the valley elderberry longhorn beetle. The development of riparian vegetation will be monitored to determine if nonnative vegetation needs to be controlled to facilitate the establishment of native riparian vegetation or if restoration success could be improved with supplemental plantings of native riparian vegetation. If indicated by monitoring, nonnative vegetation control measures and supplemental plantings will be implemented.

Riparian Restoration in Restored Tidal Habitats

Woody riparian vegetation will be allowed to naturally reestablish along the upper elevation margins of restored tidal marsh habitats within ROAs (Figure 3-2 and CM4) where soils and hydrology are suitable, including segments of stream channels that drain into restored marshes. Suitable soils for restoration are expected to be most extensive in the Cosumnes/Mokelumne, East Delta, West Delta, and South Delta ROAs. In these ROAs, riparian vegetation is expected to generally form as a band of riparian forest and scrub of variable width depending on site-specific soil and hydrologic conditions between high marsh vegetation and herbaceous uplands.

Soil salinity in the Suisun Marsh ROA and extensive clayey soils in the Cache Slough ROA are expected to limit the extent of riparian vegetation that will become established. In these ROAs, riparian vegetation is expected to generally establish in narrow stringers (e.g., along dikes) and small patches where suitable soil conditions are present. Additionally, where conditions are appropriate woody riparian vegetation will be planted on new levees that are constructed by the BDCP Implementation Office within ROAs to provide for the restoration of tidal habitat. As described for riparian restored in floodplains, native riparian vegetation may planted to initiate establishment of riparian forest and scrub and restoration areas will be monitored to determine the need for vegetation control and supplemental plantings.

Riparian Restoration on Channel Margins

Where compatible with site-specific channel margin habitat objectives, native woody riparian vegetation, including elderberry shrubs, will be planted along channel margins on benches outboard of existing levees (Figure 3-X [to come] and CM6) to enhance covered fish and wildlife species habitat. Riparian vegetation restored in these locations is expected to form narrow stringers of riparian forest and scrub along enhanced channel margins.

Directed Riparian Restoration. At least 300 acres of the 5,000 acres of restored riparian forest and scrub will be located in Conservation Zone 7 and/or 8 (Figure 3-5) within or contiguous with occupied or potentially occupied riparian brush rabbit habitat along the San Joaquin River, Old River, and/or Middle Rivers or suitable tributaries. This restored habitat will be designed and managed to specifically support riparian scrub with an open overstory that includes dense brush and thickets of wild rose, wild grape, and blackberry that supports this species habitat. An additional 300 acres will be restored in similar locations within Conservation Zone 7 to provide suitable habitat for the riparian woodrat. This restored habitat will be designed and managed to specifically support riparian habitat that includes a moderately dense midstory of willow scrub and an overstory of valley oak.

Problem Statement

Substantial reduction in the extent, distribution, and condition of Valley/foothill riparian communities that historically occurred along the upper elevational margins of the Delta and along natural levees along Delta and Suisun Marsh channels has reduced the extent and diversity of valley/foothill riparian habitats for associated covered and other native species. Most existing levees were not designed (e.g., steep banks, rip-rap) to incorporate riparian vegetation that support habitat for covered fish and wildlife species and have created increased habitat for nonnative predatory fish and thus contribute to increased predation losses of covered fish species.

A lack of riparian habitat associated with existing and restored tidal aquatic and marsh habitats limits the ecological benefits to fish and wildlife by limiting important ecological gradients and ecosystem functions that a full suite of these habitats would provide. Restoring Valley/foothill riparian habitats to establish a more natural ecological gradient extending from shallow subtidal aquatic to upland transitional habitats is expected, along with BDCP conservation of other natural communities, to increase the abundance and distribution of associated covered and other native species, improve connectivity among habitat areas within and adjacent to the Planning Area and Suisun Bay, improve genetic interchange among native riparian-associated species' populations, and contribute to the long-term conservation of riparian-associated covered species.

Hypothesized Benefits

Restoration of valley/foothill riparian forest and scrub is hypothesized to provide the following ecosystem and covered species benefits described below. As described in Appendix F, DRERIP Evaluations, however, there are a number of uncertainties regarding the level of benefits that may be provided by restored riparian habitats as well as risks for adverse consequences. These uncertainties will be addressed through effectiveness monitoring, research, and the adaptive management program (Sections 3.6 and 3.7).

Restoring valley/foothill riparian forest and scrub is expected to:

- Provide inputs of organic material (e.g., leaf and twig drop) where riparian forest and scrub is restored adjacent to channels resulting in increased production of phytoplankton, zooplankton, and macroinvertebrates that serve as or support production food for covered fish species;
- Increase the extent of shaded riverine aquatic cover and increase instream cover where riparian forest and scrub is restored adjacent to channels through contributions of instream woody material (U.S. Fish and Wildlife Service 2004);
- Increase in the production and export of terrestrial invertebrates into the aquatic ecosystem (Nakano and Murakami 2001) where riparian forest and scrub is restored adjacent to channels;
- Increase the extent of riparian brush rabbit, riparian woodrat, Swainson's hawk, white-tailed kite, yellow-breasted chat, and valley elderberry longhorn beetle habitat; and
- Increase the extent of least Bell's vireo, western yellow-billed cuckoo, and riparian woodrat for potential future occupancy by these species through future expansion of their range; and
- Create coarse woody debris substrate suitable for side-flowering skullcap.

Adaptive Management Considerations

Implementation of riparian restoration actions and subsequent management of restored riparian habitats by the BDCP Implementation Office will be informed through effectiveness monitoring that will be conducted for this conservation measure as described in Section 3.6, *Monitoring and Research Program*, and the adaptive management process described in Section 3.7, *Adaptive Management Program*. Based on analysis of monitoring results, likely elements of this measure that could be adjusted through the adaptive management process include riparian vegetation establishment methods, locations selected for restoration of riparian forest and scrub, and post-restoration management actions that may be need to be implemented to ensure that intended habitat functions of restored riparian habitats are maintained over time.

3.4.3.5 CM8 Grassland Communities Restoration

The BDCP Implementation Office will provide for the restoration of 2,000 acres of grassland within the BDCP CZs 1, 8, and/or 11 (Figure 3-6). The restored grassland habitat will be designed and located such that it supports habitat for associated covered species, improves connectivity among existing patches of grassland and other natural habitats, and improves the native wildlife habitat functions of transitional uplands adjacent to BDCP restored tidal habitats. Opportunities for improving connectivity and increasing the habitat functions of existing grassland habitats include linking or providing wildlife movement corridors to much larger habitat areas immediately outside of the Plan Area. The most strategically important areas are a connection between CZs 1 and 11 in the Jepson Prairie area and connecting BDCPs CZ 8 to other high quality grassland habitat to the west and southwest of the Plan Area.

Anticipated actions to restore grassland habitat, as appropriate to site-specific conditions, will include, but not be limited to:

- Acquiring lands, in fee-title or through conservation easements, that have site characteristics (e.g., soils, proximity to high value habitat areas) that support restoration of high functioning grassland high value habitat.
- Restoring grassland by sowing native species using a variety of techniques that include seed drilling, native hay spreading, and plugs as appropriate. Seed sown on the sites will be from collections or increases from seed collected at the nearest practicable natural site with similar ecological conditions. Restoration actions my require the recontouring of graded land as appropriate and should generally be targeted to parcels with low soil fertility and which have not been used for intensive crop production. These areas could also function as seed nurseries to produce seed that could be planted on other portions of the site.
- Potentially restoring grazing grassland habitat to modify its vegetation; this is a complex management problem if the grassland contains native bunchgrasses, geophytes, vernal pool complex, or alkali seasonal wetland complex and will require site and pasture specific solutions like those described in CM9 Vernal Pool Complex Restoration.

Problem Statement

Implementation of BDCP actions will result in the removal of grassland natural community. Restoration of grasslands, therefore, is necessary to ensure that the current habitat functions supported by affected grasslands for associated covered and other native species are maintained.

Hypothesized Benefits of BDCP Actions

Grassland habitat is distributed around the upland margin of the Sacramento/San Joaquin Delta and Suisun Bay system, and much has been lost to development and conversion to agriculture. Restoration of grassland habitat will increase the extent and quality of grassland habitat available for use by covered and other native associated species and thus contribute to their conservation. BDCP covered species predicted to benefit from restored grasslands include San Joaquin kit fox, salt marsh harvest mouse, riparian brush rabbit, Townsend's big-eared bat, tricolored blackbird, western burrowing owl, greater sandhill crane, Swainson's hawk, white-tailed kite, giant garter snake, western pond turtle, California red-legged frog, western spadefoot toad, California tiger salamander, heartscale, brittlescale, San Joaquin spearscale, Carquinez goldenbush, and caper-fruited tropidocarpum (see *Appendix A, Covered Species*, for specific life history requirements met by the grasslands natural community).

<ins>*Adaptive Management Considerations*</ins>

Implementation of grassland habitat restoration actions will be informed through effectiveness monitoring that will be conducted for this conservation measure as described in Section 3.6 *Monitoring and Research Program*, and the adaptive management process described in Section 3.7, *Adaptive Management Program*. Based on analysis of monitoring results and data compiled from other sources, likely elements of this measure that could be adjusted through the adaptive management process include considerations for selecting restoration locations; methods for establishing and maintaining the desired plant species in restored grasslands, and nonnative vegetation control techniques.

3.4.3.6 CM9 Vernal Pool Complex Restoration

The BDCP will provide for the restoration of 200 acres of vernal pool complex within Conservation Zones 1, 8, and/or 11 (Figure 3-6). The extent of restored vernal pool complex will include a matrix of grassland or alkali seasonal wetland complex in which vernal pools, swales, and saturated alkaline soil areas are adjacent or interspersed and which are found in habitat gradients that vary by Conservation Zone and include tidal freshwater or tidal brackish emergent wetlands, adjoining transitional upland habitat, grassland, alkali seasonal wetlands, and agriculture. The 200 acres will be distributed in Conservation Zones 1, 8, and 11 in a manner that will achieve conservation objectives for associated covered species. The BDCP Implementation Office will select specific restoration sites within these Conservation Zones based on the suitability of available lands for restoration, biological value, and practicability considerations.

Anticipated actions to restore vernal pool complex habitat, as appropriate to site-specific conditions, include but are not limited to:

- Acquiring lands, in fee-title or through conservation easements, suitable for restoration of vernal pool complex habitat;
- Restoring remnant natural vernal and swale topography by excavating or recontouring historical vernal pools and swales to natural bathymetry based on their characteristic visual signatures on historical aerial photographs, other historical data, and on the arrangement and bathymetry of natural reference vernal pools and swales;
- Restoring and maintaining natural hydrology by removing impediments to natural runoff such as roads, berms, field drains, storm drains, etc.;
- Restoring and maintaining natural hydrology by removing non-natural supplemental sources of surface water originating from flood irrigation, drainage and irrigation canal turnouts, impermeable surfaces, leaking stock ponds, culverts, etc.;
- Restoring and maintaining natural salt and suspended clay concentrations in vernal pool water;

- Significantly reducing or preventing the deposition of substances that increases the fertility of the habitat such as manure, runoff from cattle or sheep congregation areas, runoff from dairies, etc.;
- Controlling the cover of invasive nonnative plant species such as perennial pepperweed, swamp timothy, Italian ryegrass, etc.;
- Adjusting livestock grazing regimes in vernal pool complexes to improve habitat functions of vernal pools for covered and other native vernal pool species;
- Preventing the introduction of the propagules of invasive species during restoration, maintenance, outreach, and other activities that occur on the site; and
- Hand collecting seed and vernal pool invertebrates from the vicinity of the vernal pools to be restored will be used to establish native species. Soil inoculum should not be used to establish vernal pool plants and animals in these Conservation Zones unless the source vernal pools are free of perennial pepperweed, swamp timothy, and Italian ryegrass which establish more rapidly than native species and create dense populations that are likely to reduce the establishment success of the native plants and also create thatch problems in the vernal pools (see Barona et al. 2007 for problems of nonnative species thatch buildup due to soil inoculum).

Restored vernal pool complex habitat will be designed and managed to provide the ecological benefits for covered species described under the Hypothesized Benefits section below. Habitat will be restored on sites that historically supported vernal pool complex, thus ensuring that soil types that support vernal pools are present.

Restoration variables that will be considered by the BDCP Implementation Office in the design of restored vernal pool complex habitat include:

- The spatial distribution of existing restored vernal pool complex habitat within the Delta;
- The distribution of soils that historically supported vernal pool complex;
- An analysis of historical aerial photography, survey records, or other information and vernal pool and swale restoration will be limited to the visual signatures indicated in that data and contoured using bathymetry data from similar vernal pools in the same Conservation Zone; and
- The predicted tidal range adjacent to tidal habitat restoration sites in Conservation Zone 1 and 11.

Restoration design considerations for vernal pool complex habitat will include the following:

Vernal Pool Complex Vegetation. To provide for high functioning habitat, restored vernal pool complex will be vegetated with hand collected seed from appropriate areas within the same Conservation Zone as the planned restoration action. Soil inoculum will not be used unless the source vernal pools are free of perennial pepperweed, swamp timothy, and Italian ryegrass.

However, prior to any seed collection actions occurring, where physical restoration actions such as excavation are undertaken to restore the hydrology of vernal pool complex habitat, the hydrographs, inundation depths, and water chemistry (particularly salt and boron concentrations) of the restored vernal pool complex will be compared with reference vernal pool complex habitat in the same areas. Following establishment of restored habitat will be monitored to assess the establishment of invasive nonnative plants. If indicated by monitoring results, the BDCP Implementation Office will implement invasive plant control measures to help ensure the establishment of native vernal pool plant species.

Vernal Pool Complex Invertebrates. Propagules of covered vernal pool invertebrate species may be introduced into the restored vernal pools through the movement of individuals. Introductions will not be made through the use of soil inoculum unless the source vernal pools are free of perennial pepperweed, swamp timothy, and Italian ryegrass.

Hydrological Conditions. Vernal pool complex habitat restoration will be designed based on the historical patterns of vernal pools and swales present on the restoration site as indicated by aerial photography and vernal pool bathymetry will be based on natural undisturbed vernal pools in the same area.

Problem Statement

Implementation of BDCP actions will result in the removal of vernal pool complex. Restoration of vernal pool complex, therefore, is necessary to ensure that the current habitat functions supported by affected vernal pools for associated covered and other native species are maintained.

Hypothesized Benefits

Restoration of vernal pool complex habitat will increase the extent of habitat for vernal pool complex-dependent covered species.

Adaptive Management Considerations

Implementation of vernal pool complex habitat restoration actions and subsequent management of restored vernal pool complex habitats by the BDCP Implementation Office will be informed through effectiveness monitoring that will be conducted for this conservation measure as described in Section 3.6, *Monitoring and Research Program*, and the adaptive management process described in Section 3.7, *Adaptive Management Program*. Based on analysis of monitoring results and data compiled from other sources, likely elements of this measure that could be adjusted through the adaptive management process include considerations for selecting restoration locations within the distribution of vernal pool complex habitat among CZs 1 and 8, methods for restoring and maintaining the necessary hydrology and water chemistry, methods for establishing the desired species in the habitat, and nonnative vegetation and wildlife control techniques.

3.4.3.7 CM10 Nontidal Marsh Restoration

The BDCP will provide for the restoration of 400 acres of nontidal freshwater marsh within Conservation Zones 2 and 4 (Figure 3-4). Restored habitat will be distributed in patches of at least 25 acres and associated with occupied giant garter snake habitat within the proposed 1,000-acre giant garter snake preserves designed to enhance the Caldoni Marsh/White Slough and the Yolo Basin/Willow Slough giant garter snake populations.

Restored nontidal wetlands will also be designed and managed to support other native wildlife functions including waterfowl foraging, resting, and brood habitat and shorebird foraging and roosting habitat. Restored habitat will include preserved transitional upland habitat to provide upland habitat for giant garter snake and western pond turtle, and nesting habitat for waterfowl.

Though not a conservation target, patches of existing nontidal freshwater perennial emergent wetland present on lands acquired to protect other natural communities will also be protected and enhanced to improve habitat functions and values for covered and other native species.

Anticipated actions to restore nontidal freshwater perennial emergent wetland, as appropriate to site-specific conditions, include, but are not limited to:

- Acquiring lands, in fee-title or through conservation easements, suitable for restoration of nontidal freshwater perennial emergent wetland;
- Securing sufficient annual water to sustain habitat function;
- Creating complex habitat with open water and edge habitats, tule-dominated vegetation, bank slopes with variable angles, adjacent upland with open canopy and elevational gradient to promote mammal burrows and higher elevation refugia;
- Establishing connectivity with the existing water conveyance system and habitats occupied by giant garter snakes;
- Allowing for the natural establishment of marsh vegetation;
- Site preparation, planting of native marsh vegetation, and maintenance of plantings; and
- Control of nonnative plants.

Patches of restored nontidal freshwater perennial emergent wetland are expected to support the range of habitat conditions necessary to support habitat for each of the nontidal freshwater perennial emergent wetland-associated covered wildlife species. Once established, it is expected that restored nontidal freshwater perennial emergent wetland will be self-sustaining and will be monitored to determine if subsequent management actions may be required to ensure successful regeneration of native marsh plant species.

Nontidal freshwater perennial emergent wetland will be established where soils and hydrology are suitable through conversion of existing agricultural lands to a freshwater marsh-perennial aquatic complex. Restored marshes will also occur in association with adjacent grassland, pastureland, or cultivated uplands. Grading will be required to establish an elevation gradient to support both open water perennial aquatic habitat intermixed with shallower marsh habitat. Marsh vegetation will be allowed to naturally reestablish along the edges of perennial aquatic habitat, but will also be planted as needed to facilitate marsh development and to manage species composition. The development of marsh vegetation will be monitored to determine if nonnative vegetation needs to be controlled to facilitate the establishment of native marsh vegetation or if restoration success could be improved with supplemental plantings of native species. If indicated by monitoring, nonnative vegetation control measures and supplemental plantings will be implemented.

Problem Statement

The ecological function of nontidal freshwater perennial emergent wetland is limited because it occurs in highly fragmented and small patches within the Planning Area and adjacent lands. Associated with nontidal permanent aquatic and riparian communities, a substantial reduction in the extent, distribution, and condition of nontidal freshwater perennial emergent wetland communities that historically occurred throughout the Central Valley and along the perimeter of the Delta has reduced the extent and diversity of nontidal freshwater perennial emergent wetland habitats for many native species including the giant garter snake (Gilmer et al. 1982, The Bay Institute 1998).

While there are records of giant garter snake in tidal marshes within the Central Delta, the species is known primarily from nontidal freshwater perennial emergent wetland within the interior of the Central Valley including along the eastern perimeter of the Sacramento-San Joaquin Delta. Agricultural conversion and stream channelization have removed nontidal freshwater perennial emergent wetlands, leading to widespread giant garter snake population declines and restricting extant populations to remaining degraded or suboptimal habitats, such as irrigation channels and rice fields. A lack of nontidal freshwater perennial emergent wetland limits the ecological benefits to fish and wildlife by limiting important ecological gradients and ecosystem functions that these habitats would provide, particularly in association with other native habitats including nontidal permanent aquatic, grassland, and riparian habitats. Restoring nontidal freshwater perennial emergent wetland to re-establish a more natural ecological gradient and incorporating aquatic, riparian, and upland transitional habitats is expected, along with BDCP conservation of other natural communities, to increase the abundance and distribution of associated covered and other native species, improve connectivity among habitat areas within and adjacent to the Plan Area, improve genetic interchange among native freshwater perennial emergent wetland species' populations, and contribute to the long-term conservation of giant garter snake and other native species.

Hypothesized Benefits

Restoring nontidal freshwater perennial emergent wetland is expected to:

- Provide essential marsh and aquatic habitat for giant garter snake and western pond turtle;
- Enhance the Caldoni Marsh-White Slough and Yolo Basin-Willow Slough giant garter snake populations by increasing the extent and quality of available habitat;
- Provide nesting habitat for tricolored blackbird; and
- Increase the spatial extent and distribution of habitat available to associated covered and other native wildlife and will increase the diversity and complexity of the mosaic of habitats supported in the Plan Area and adjacent lands.

Adaptive Management Considerations

Implementation of nontidal freshwater perennial emergent wetland restoration actions and subsequent management of restored marsh habitats by the BDCP Implementation Office will be informed through effectiveness monitoring that will be conducted for this conservation measure as described in Section 3.6, *Monitoring and Research Program*, and the adaptive management process described in Section 3.7, *Adaptive Management Program*. Based on analysis of monitoring results, likely elements of this measure that could be adjusted through the adaptive management process include marsh vegetation establishment methods, locations selected for restoration of nontidal freshwater perennial emergent wetland, and post-restoration management actions that may need to be implemented to ensure that intended habitat functions of restored nontidal freshwater perennial emergent wetland are maintained over time.

3.4.3.8 CM11 Natural Communities Enhancement and Management

Site-Specific Management Plans

The BDCP Implementation Office will prepare and implement management plans for protected natural communities and covered species habitats that are found within those communities. Management plans may be prepared for specific reserves or multiple reserve areas within a specified geographic area. Management plans will provide the information necessary to guide habitat enhancement and management actions necessary to achieve the biological objectives established for the conserved lands addressed by each plan. Within two years of acquisition of conserved parcels, the Implementation Office will conduct surveys to collect the information necessary to assess the level of ecological condition and function of conserved species habitats and supporting ecosystem processes. Based on results of the assessment, the Implementation Office will identify habitat enhancement actions to be implemented to enhance habitat functions for the target covered species and any subsequent ongoing management actions that are necessary to maintain habitat functions over time. Survey data will also collect the information necessary to establish base ecological conditions from which the effectiveness of enhancement and management measures can be evaluated through subsequent effectiveness monitoring.

The content of management plans will include, but not be limited to, a description of:

- The biological goals and objectives to be achieved with the preservation and management of the parcels;
- Base ecological conditions (e.g., habitat maps, assessment of covered species habitat functions, occurrence of covered and other native wildlife species, vegetation structure and composition, assessment of nonnative species abundance and effect on habitat functions, occurrence and extent of nonnative species);
- Vegetation management actions that: benefit covered communities, habitats, and species and reduce fuel loads as appropriate; are necessary for implementing community conservation measures; and are necessary for implementing species specific conservation measures;
- The incorporation of a fire management plan developed in coordination with the appropriate agencies and to the extent practicable, consistent with achieving the biological objectives of the BDCP;
- Infrastructure, hazards, and easements;
- Existing land uses and management practices and their relationship to covered species habitat functions;
- Applicable permit terms and conditions;
- Terms and conditions conservation easements when applicable;
- Management actions and schedules;
- Monitoring requirements and schedules;
- Established data acquisition and analysis protocols;
- Established data and report preservation, indexing, and repository protocols;
- The adaptive management approach; and
- Any other information relevant to management of the preserved parcels.

Management plans will be periodically updated to incorporate changes in maintenance, management, and monitoring requirements as they may occur over the term of the BDCP.

Based on the assessment of existing site conditions (e.g., soils, hydrology, vegetation, occurrence of covered species) and site constraints (e.g., location and size), and depending on biological objectives of the conserved lands, management plans will specify measures for enhancing and maintaining habitat as appropriate.

Management Actions

Listed below are enhancement and management actions for the natural communities described in Section 3.3.2.2, *Natural Community Goals and Objectives*. The application of these or other management actions will depend on site-specific conditions and targeted biological values. Specific management actions will be included in each site-specific management plan described above. Management actions are designed to meet the biological goals and objectives of each natural community and covered species.

Tidal Aquatic and Wetland Natural Communities

Approximately 65,000 acres of tidal habitat restoration is planned for the Plan Area. This includes 7,000 acres of brackish tidal habitat in the Suisun Marsh ROA in Conservation Zone 11 and approximately 14,000 acres of freshwater tidal habitat distributed among 4 ROAs, including 5,000 acres in the Cache Slough ROA in Conservation Zones 1 and 2; 1,500 acres in the Cosumnes/Mokelumne ROA in Conservation Zone 4; 2,100 acres in the West Delta ROA in Conservation Zones 5 and 6; and 5,000 acres in the South Delta ROA in Conservation Zone 7. This restoration will create and protect substantial habitat for several covered species including salt marsh harvest mouse, Suisun shrew, California clapper rail, California black rail, Suisun song sparrow, California least tern, Mason's lilaeopsis, Suisun Marsh aster, Delta tule pea, Delta mudwort, and soft bird's-beak. Tidal wetland restoration in Conservation Zones 4, 5, 6, and 7 is also expected to provide additional habitat for tricolored blackbird, greater sandhill crane, and giant garter snake. The following measures will be implemented to manage and enhance the tidal wetland conservation lands.

- Create or maintain upland areas that can serve as refugia during high tide events (e.g., grassland patches for salt marsh harvest mouse);
- Create two nesting habitat areas consisting of gravel or sandy elevated mounds for California least terns along the margins of tidal perennial aquatic natural community areas on BDCP lands. The BDCP Implementation Office will collaborate with species experts to determine appropriate locations, materials, and dimensions of created sites.
- Restore brackish marsh habitats in a sequenced manner to minimize disturbance to adjacent habitats;
- Maintain habitat connectivity and corridors for species' movement between restored sites and restored and existing habitats;
- Maintain appropriate habitat patch sizes for covered species. The BDCP Implementation Office will consult with species experts to determine appropriate patch sizes and other elements of restoration design relevant to covered species;
- Nonnative predatory species are an important stressor for several covered species (e.g., California black and clapper rails). The establishment and abundance of nonnative predatory species will be controlled with habitat manipulating techniques or trapping;

- Where California least terns or tricolored blackbirds are found nesting, and to the extent feasible, protect and establish appropriate buffer zones around occupied sites to minimize disturbance;
- Reduce and then maintain the population size of feral pigs in Suisun Marsh to levels at which their rooting impacts on tidal marsh plain vegetation does not significantly impact covered species;
- Exclude cattle grazing from Suisun thistle and soft bird's-beak habitat;
- Reduce and then maintain the cover of nonnative invasive plant species such as perennial pepperweed, bull thistle, and annual grasses in Suisun Marsh to levels that do not significantly impact covered species;
- Conduct research to determine if fire is beneficial for tidal marsh management and its effects on covered communities and species; and
- Conduct research to determine effective methods for increasing the extent of Suisun thistle and soft bird's-beak in Suisun Marsh.

*[**Note to reviewers:** Additional management tools to address fisheries habitat will be added to this section.]*

Nontidal Aquatic and Wetland Natural Communities

In association with the development of two 1,000 acre preserves for the giant garter snake, 400 acres of nontidal freshwater marsh will be restored. A portion of the 400 acres will be restored to support the protection and expansion of the Yolo/Willow Slough subpopulation in Conservation Zone 2 and a portion will be restored to support the protection and expansion of the Caldoni Marsh/White Slough subpopulation in Conservation Zone 4. The BDCP Implementation Office, through consultation with species experts will determine the number of acres that will be restored in each area based on the level of existing protection and available habitat, and restoration opportunities. The marsh restoration, which will include both emergent wetland and open water habitats, will be coordinated with acquisition of agricultural lands that will make up the 1,000 acre preserves. It is expected that agricultural lands within the preserves, in additional to providing the water conveyance system that will be managed as suitable giant garter snake aquatic habitat and adjacent upland habitat, will also provide suitable foraging habitat for Swainson's hawk, white-tailed kite, and tricolored blackbird. It is also expected that the restored nontidal wetland will provide habitat for nesting tricolored blackbirds and aquatic and cover habitat for western pond turtle. Management plans will be prepared for the Coldani Marsh/White Slough and the Yolo/Willow Slough giant garter snake preserves to guide nontidal wetland restoration activities and associated agricultural land management. The Implementation Office will consult with species experts to develop these plans that will describe site selection, configuration and channel design, water management, vegetation composition, and long-term management of the preserves. The following measures will be addressed in the management plans and implemented to manage and enhance the nontidal wetland and associated giant garter snake preserves.

- Vegetation density and composition, water depth, and other habitat elements will be managed to enhance habitat values for giant garter snakes;
- Upland refugia (islands or berms) will be created and maintained within the restored marsh;
- Permanent buffer zones at least 200 feet wide will be established around all developed wetland habitats to provide undisturbed (uncultivated) upland cover and aestivation habitat immediately adjacent to aquatic habitat;
- Bank slopes and upland buffer habitats will be managed to enhance giant garter snake use, provide cover, and encourage burrowing mammals for purposes of creating aestivation sites for giant garter snake;
- Establish seasonal buffer zones around aquatic habitats to reduce disturbance and improve foraging habitat for tricolored blackbirds;
- Control human and pet access into wetland areas;
- Nontidal and wetland communities may be dominated by bullfrogs and other nonnative predatory species limiting the abundance of covered amphibians and reptiles. Habitat management and enhancement will include trapping and other techniques to control the establishment and abundance of nonnative predators; and
- Limit cattle access to wetland vegetation to the extent necessary to prevent significant deterioration of habitat of covered species.

Riparian Natural Community

Over 5,000 acres of riparian scrub and woodland will be restored in the Plan Area. The majority is expected to develop in Conservation Zone 7 associated with the San Joaquin, Old, and Middle River systems, but riparian habitat will also develop in other Conservation Zones in association with tidal habitat, floodplain, and channel margin restoration. Restored valley/foothill riparian is expected to provide substantial habitat for several riparian-associated covered species. Yellow-breasted chat, least Bell's vireo, riparian brush rabbit, and riparian woodrat will benefit from the establishment of willow scrub and early successional riparian habitats that are expected to develop in association with tidal habitat and floodplain restoration; yellow-billed cuckoo, Swainson's hawk, and white-tailed kite will benefit from the future development of cottonwood-willow forest; and Swainson's hawk and white-tailed kite will benefit from all mature riparian habitats that provide suitable nesting structure. Nesting habitat for Swainson's hawk and white-tailed kite is expected to develop in association with tidal habitat and floodplain restoration and from the restoration of planted riparian habitats along channel margins. Riparian brush rabbit and riparian woodrat will also benefit from directed riparian restoration along channel margins. The following measures include those that will apply to all conserved riparian communities and where noted others apply to lands acquired to manage species-specific values.

- Control nest parasitism (e.g., through cowbird trapping);

- Control the establishment and abundance of nonnative predatory species (e.g., bullfrogs);
- Plant native plant species to improve habitat functions for covered and other native species (e.g., blue elderberry for valley elderberry longhorn beetle, willows for yellow-breasted chat);
- Establish buffers along riparian habitats to minimize the disturbance affects to nesting covered species;
- Establish uncultivated buffers adjacent to riparian habitats to protect the integrity of the stream corridor and associated riparian vegetation and to promote regeneration of riparian species;
- Manage the structure and composition of restored riparian areas to meet the habitat objectives established for riparian brush rabbit, riparian woodrat, Swainson's hawk, white-tailed kite, yellow-breasted chat, least Bell's vireo, and yellow-billed cuckoo;
- Install woody debris in stream channels to create pools to increase the diversity of micro-habitats;
- Where appropriate, remove riprap along channel banks and alter stream channel geomorphology to improve hydrologic conditions that support the regeneration of riparian vegetation and improve habitat functions for aquatic species;
- Prepare a restoration plan for the restoration of 300 acres of riparian habitat for the riparian brush rabbit and 300 acres for the riparian woodrat. Consult with species experts to determine appropriate location, species composition, structure, and patch size, and to develop management guidelines;
- Within riparian brush rabbit restoration areas, create upland refugia (i.e., bunny mounds) to provide protection against flooding. Consult with species experts to determine appropriate location, size, and composition.
- Establish and implement a nonnative species control program to control species such as Himalayan blackberry, giant reed, perennial pepperweed, black locust, and fig where their presence is undesirable; and
- Limit cattle access to riparian and other wetland vegetation to the extent necessary to prevent significant deterioration of habitat of covered species.

Grasslands and Associated Seasonal Wetland Natural Communities

Over 10,000 acres of grassland, vernal pool complex, and alkali seasonal wetland will be protected or restored in Conservation Zones 1, 8, and 11 to support and protect San Joaquin kit fox, Swainson's hawk, white-tailed kite, tricolored blackbird, California red-legged frog, California tiger salamander, and western spadefoot toad populations. The following measures include those that will apply to all conserved grassland communities and where noted others apply to lands acquired to manage species-specific values.

- To minimize uncertainty about the appropriate management regime necessary to maintain and enhance each grassland type, pilot experiments will be conducted to test the effects of management actions. The experiments will be designed to test a range of reasonable management alternatives under appropriate spatial scales and seasonal weather patterns. Long term monitoring programs will also include experimental plots that generate information describing the long term trends of management actions, and include experimental treatments for most likely management alternatives, and appropriate controls.

- Where appropriate, manipulate topography or manage vegetation to attract ground squirrels and other small mammals to: (1) increase the availability of aestivation and nesting burrows for California red-legged frog and California tiger salamander; and (2) increase prey availability for San Joaquin kit fox, Swainson's hawk, white-tailed kite, and other native wildlife predators.

- Reduce rodent control (e.g., poisoning, hunting, and trapping), where appropriate, in conserved grasslands. Note that rodent control measures will likely remain necessary in certain areas where dense rodent populations may compromise important infrastructure (e.g., levees, pond berms, road embankments, and water conveyance structures).

- Fence portions of stock ponds in Conservation Zone 8 to prevent livestock entry, encourage emergent wetland growth, and facilitate California red-legged frog and California tiger salamander use.

- Develop management protocols for stock ponds (e.g., seasonal draining) in Conservation Zone 8 grassland habitats to control bullfrogs and predatory fish and facilitate use by California red-legged frogs and California tiger salamanders.

- Protect grassland movement corridors between aquatic and upland California red-legged frog and California tiger salamander aestivation sites.

- Where lands neighboring preserves require ground squirrel management to protect agricultural uses or public health, establish a buffer zone in the preserve within which ground squirrel colonies will not be encouraged or may be controlled. The width of this buffer will be determined by the preserve manager in consultation with neighboring landowners and BDCP Implementation Office scientists. The buffer width will depend on site conditions, the size and density of the local ground squirrel population, and the intensity of control methods used adjacent to the preserve.

- Where appropriate, install artificial nesting burrows or create elevated berms, mounds, or debris piles for western burrowing owl to facilitate use of unoccupied areas.

- Install perching structures to facilitate use by western burrowing owl, Swainson's hawk, and white-tailed kite.

- For vernal pool complex and alkali seasonal wetland complex, restore and maintain natural hydrology and eliminate supplemental sources of water and structures that increase or decrease the duration of natural vernal pools. If grazed, provide grazing animals with supplemental sources of water located in the uplands away from vernal pools.

- Livestock grazing can be used to manage vegetation for purposes of maintaining and improving habitat conditions for resident plants and animals and to reduce fuel loads for wildfires. Different grazers and different grazing intensities result in different impacts on vegetation. BDCP will develop an appropriate grazing program for enhancing and maintaining habitat for covered species for each protected area based on site specific characteristics of the community and covered species, the spatial location of important ecological features in each pasture, the history of grazing on the site, species composition of the site, grazer vegetation preference, and other relevant information. Grazing exclusion should be used as a management alternative where appropriate. Grazing practices in effect in each pasture for the 5 years prior to acquisition should be continued unless there is a specific conservation related immediate need to alter them or site specific data is acquired through scientific studies suggests that alternate management actions would better advance the sites conservation goals. Grazing in certain native grassland communities, however, may need to be reduced to maintain or enhance these communities. Note that midsummer grazing may be effective in controlling exotic grassland plant species because most native perennial grasses would be dormant in summer and not substantially damaged by grazing.
- Prescribed burning can be used to mimic short interval fire regimes. Late-spring and fall prescribed burning may be used in some grassland areas to increase native species cover in grasslands and reduce the cover of exotic species, repeating treatment on site as needed. Grazing will be used in conjunction with prescribed burns where appropriate to control exotic grasses as they germinate after winter rains.
- Herbicide application may be necessary to control heavy infestations of nonnative plants and re-seed with native species.
- Any seed supplements in native grasslands must use locally derived genetic stock. To maximize the success of seed addition, pretreatments (e.g., burning one year prior to seeding to reduce weed seeds on the surface and in litter) can be utilized.

Inland Dune Scrub

The BDCP Implementation Office will support ongoing efforts to manage and enhance inland dune scrub and to reestablish dune scrub-associated covered species populations through the following actions:

- Support the funding of the USFWS program for management, enhancement, and monitoring of inland dune scrub natural community at the Antioch Dunes National Wildlife Refuge at an annual amount of $XX.XX for X;
- Provide funding to support the USFWS program for the captive breeding and release of Lange's metalmark butterfly at an annual amount of $XX.XX for X years; and

- Support the funding of the USFWS program for propagation and out-planting programs for Contra Costa wallflower and Antioch Dunes evening primrose at an annual amount of $XX.XX for X years.

No acquisition of lands to protect inland dune scrub natural community is proposed.

Agricultural Lands and Managed Wetlands

Agricultural lands will be acquired and managed to support and protect Swainson's hawk, white-tailed kite, greater sandhill crane, tricolored blackbird, and giant garter snake populations. Between 12,000 and 28,000 acres of non-rice agricultural lands and 4,600 acres of rice lands are included in the conservation strategy and that will be managed to provide value to targeted covered species. Agricultural land acquisition is expected to occur throughout the Plan Area, but primarily in Conservation Zones 1, 2, 4, 5, and 7. The following measures include those that will apply to all conserved agricultural lands and where noted others apply to lands acquired to manage species-specific values.

- Minimize or discontinue pesticide use to reduce negative impacts on wildlife including direct, lethal toxicity, reproductive failures, and teratogenic effects.
- Retain hedgerows, wetlands, riparian communities, grassland edges, ponds, and other natural communities and habitat features that occur within the agricultural matrix.
- Retain tree rows, wood lots or other tree groves, and isolated trees to provide nesting habitat for Swainson's hawk and white-tailed kite.
- Retain or create grassland edges, levee slopes, berms, or patches that provide opportunities for burrowing owl breeding or wintering burrows.
- Enhance burrowing owl habitat along agricultural edges by managing vegetation height, installing perches and artificial nesting structures, where appropriate, and encouraging ground squirrel activity.
- Plant hedgerows on agricultural preserves to provide refugia for rodents, thus increasing rodent prey populations for both the Swainson's hawk and the white-tailed kite.
- Plant small woodlots in field corners or tree rows along field borders to provide nesting habitat for Swainson's hawk and white-tailed kite.
- On agricultural lands managed for Swainson's hawk conservation, crop types will be selected and rotated such that sufficient high value foraging habitat is maintained within the agricultural matrix and that meet the requirements for maintaining the target number of habitat units for this species. This will ensure that Swainson's hawk agricultural foraging value is consistently maintained during the term of the BDCP. To the extent practicable, conserved agricultural lands will focus on the highest value foraging habitat (i.e., alfalfa), but include other crop type rotations and agricultural land uses (e.g.,

irrigated pastures) in order to meet the habitat unit requirement (see species model in Appendix A, *Covered Species Accounts*).

- On agricultural land managed for greater sandhill cranes, crop types will be used that provide high value foraging habitat in order to meet the target number of habitat units for this species. Managed agricultural foraging habitat for cranes will include corn, wheat, alfalfa, and irrigated pasture cover types.
- To increase the value of agricultural lands for sandhill cranes, where feasible, habitat management will include deferment of the tilling of corn and grain fields until later in the fall to increase the amount and availability of forage for sandhill cranes. Also where feasible, a portion of corn or grain fields will be left unharvested to increase the quantity of forage available to sandhill cranes (forage would gradually become available as senescent plant stalks fall over as a result of weathering).
- To increase the foraging and roosting value of agricultural lands for greater sandhill cranes, shallow flooding of some corn, grain, and irrigated pastures during fall and winter will also be used. This will also improve foraging conditions for waterfowl and shorebirds.
- Create and manage two greater sandhill crane roost sites located within Conservation Zones 4, 5, and/or 6. Management actions will include 1) establishing appropriate seasonal wetland vegetation that supports crane roosting habitat; 2) incorporating upland berms situated throughout the seasonal wetland; and 3) maintaining water levels that support crane roosting habitat during the crane winter season. The BDCP Implementation Office will consult with species experts to develop specific design and management criteria for crane roost sites.
- Enhance roosting habitat for greater sandhill cranes by controlling public use.
- Establish seasonal or permanent buffers around riparian and wetland habitats to reduce disturbance of nesting tricolored blackbirds, yellow-breasted chats, and least Bell's vireo.
- Establish upland buffers around canals and ditches that support giant garter snake to reduce disturbance and possible mortality.
- Maintain water in canals and ditches during the activity period (early spring through mid-fall) for the giant garter snake, western pond turtle, and other covered species using waterways.
- Maintain and enhance emergent vegetation in irrigation and other water conveyance canals to provide basking and escape cover for giant garter snakes.
- Where managed wetlands exist, habitat management and enhancement will focus on improving and maintaining site hydrology by grading, excavating, replacing, or installing water control infrastructure.
- On agricultural lands within the giant garter snake preserves (Yolo-Willow subpopulation and Caldoni Marsh-White Slough subpopulation), and other conserved agricultural land

that potentially supports giant garter snake, retain or create connectivity of the water conveyance system to facilitate dispersal and other movement of giant garter snakes.

- To enhance protected lands for wintering waterfowl and shorebird use, where feasible flood harvested corn fields during the fall and winter months.

Results of effectiveness monitoring of enhancement and management actions will provide the information necessary to identify future changes in management of conserved lands to ensure that biological objectives are achieved over the term of the BDCP.

3.4.4 Species Level Other Stressor Conservation Measures

[***Note to Reviewers***: *The text of this section of Chapter 3, including the other stressors conservation measures described, is subject to change and revision as the BDCP planning process progresses. This section, however, has been drafted and formatted to appear as it may in a draft HCP/NCCP. Although this section includes declarative statements (e.g., the Implementation Office will…), it is nonetheless a "working draft" that will undergo further modification based on input from the BDCP Steering Committee, state and federal agencies, and the public.*]

This section describes BDCP conservation measures that address other factors potentially affecting covered fish species. These factors, collectively titled "Other Stressors," go beyond issues associated with water operations and physical habitats to address toxic contaminants, other water quality issues (e.g., dissolved oxygen), non-native species, hatcheries, harvest, and non-project diversions that are individually and collectively affecting the productivity of the Delta. As discussed more fully in the Introduction (Section 3.1) and the Methods and Approaches Used to Develop the Conservation Strategy (Section 3.2), the inclusion of these measures into the BDCP reflects the comprehensive nature of the approach to conservation that underlies the BDCP.

A number of these conservation measures address activities that are not currently within the direct control of the BDCP Implementation Office and therefore are proposed to be implemented through agreements with third parties. These agreements will establish reliable mechanisms for the execution and success of these measures by those third parties. In instances where a third party is proposed to implement the conservation measure funded by the BDCP, the BDCP Implementation Office will enter into binding Memoranda of Agreement (MOA) or similarly binding instruments with the third party. These MOAs will describe respective roles and obligations for funding and implementing conservation measures as identified through the process described in each conservation measure. Specific elements of the MOA will describe:

- the specific activities or improvements that would be funded by BDCP;
- the preparation of annual work plans for these activities and improvements;
- the expected benefits of the action for covered species and the aquatic ecosystem;
- the performance metrics that will be measured to verify that the action being implemented has the expected benefit;

- provisions for monitoring, reporting, and documenting work performed; and
- provisions for modifying or terminating MOAs.

The third party will develop annual work plans, acceptable to the BDCP Implementation Office and the fish and wildlife agencies, that describe activities or capital improvements to be funded by BDCP over the course of that year. The third party will be responsible for implementing the scope of work and submitting reports as specified in the MOA that demonstrate that work plans have been successfully implemented. The third party will also be responsible for demonstrating the effectiveness of the funded activities to meet objectives as specified in the MOA.

The BDCP Implementation Office and the fish and wildlife agencies will review progress or other relevant reports prepared by the third party to assess program effectiveness and to identify adjustments to funding levels, management practices, or other related aspects of the program that will improve the biological effectiveness of the program. Such changes will be effected through the BDCP adaptive management process and will be included in the subsequent annual work plans.

3.4.4.1 CM12 Methylmercury Management

*[**Note to Reviewers:** This completely revised version of CM12 Methylmercury Management was provided to the Steering Committee on November 18, 2010, and the Steering Committee has not had the opportunity to review it at this time.]*

The purpose of this conservation measure is to minimize the potential for habitat restoration actions, implemented under the BDCP (CM4 *Tidal Habitat Restoration*, CM5 *Seasonally Inundated Floodplain Restoration*, and CM6 *Channel Margin Habitat Enhancement*), to increase the bioaccumulation of methylmercury in covered and other native species. It is also intended to reduce potential negative effects of methylmercury on important native species that maintain natural communities through herbivory, physical disturbance activities, predator-prey interactions, and other species interactions, or through species regulation of ecosystem processes.

The BDCP Implementation Office will:

1) Conduct pre-acquisition surveys to characterize the mercury content in the soil and other factors that could lead to high rates of methylation in potential habitat restoration areas;
2) After evaluating site characteristics and site conservation goals, prepare habitat restoration designs using measures that, to the extent practicable, will minimize the bioaccumulation of methylmercury in covered and other native species;
3) Conduct monitoring, to the extent practicable, to provide data that will enable the Implementation Office to track the effects of the restoration actions on the bioaccumulation of methylmercury in covered and other native species; and

4) Implement adaptive management actions when monitoring data indicate it is necessary, to the extent practicable, to reduce the bioaccumulation of methylmercury in covered and other native species resulting from tidal habitat and floodplain restoration actions.

The Implementation Office will coordinate with DWR, DFG, the Central Valley Regional Water Quality Control Board (CVRWQCB), and other entities to identify and implement methods for minimizing the methylation of mercury in BDCP restoration areas and the bioaccumulation of methylmercury in covered and other native species.

Problem Statement

There are high concentrations of mercury in the Plan Area due to the continual transport and deposition of historical gold and mercury mining sediment through Delta tributaries. In aquatic systems, anaerobic organisms transform mercury from an inorganic state to a bioavailable and toxic form of mercury (methylmercury). The consumption and bioaccumulation of methylmercury may cause adverse effects to BDCP covered fish and wildlife species. Methylmercury bioaccumulates within individuals and biomagnifies in higher food chain level consumers (CVRWQCB 2010). Biomagnification results in approximately four-fold increases in tissue concentration with each prey-to-predator step up the food chain (Marvin-DiPasquale et al. 2007). As a result, toxic effects of methylmercury are manifested strongly in upper trophic level organisms.

Most of the covered fish species are exposed to methylmercury primarily through the consumption of pelagic prey, and secondarily through direct exposure to high concentrations in the water column; although the latter is substantially lower than the former (Alpers et al. 2008). In addition to their pelagic food web exposure, white sturgeon, North American green sturgeon, and Sacramento splittail are most likely to be affected by high methylmercury concentrations in benthic prey. These fish species are long lived and thereby may accumulate high levels of methylmercury.

Wildlife may be affected by consuming fish or other aquatic organisms that have bioaccumulated methylmercury, or by consuming tidal marsh vegetation that contains methylmercury. Patterns of methylmercury concentration in tidal marsh plant species are complex, as are the grazing dynamics of the wildlife that feed on tidal marsh plants. These factors make it difficult to predict the effects tidal marsh and floodplain restoration actions may have on wildlife species.

Effects of dietary methylmercury on fish include, but are not limited to, endocrine and reproductive problems, liver necrosis, brain lesions, and altered behavior that can result in an increased risk of predation. Bioaccumulation rates in fish may depend on a number of environmental factors in addition to methylmercury concentrations in the water column and/or prey (Alpers et al. 2008); these include growth rate (e.g., seasonality with respect to methylation cycles and/or varied prey availability), foraging in habitats (e.g., preferences can result in foraging in areas with increased propensity for methylation), and food web structure (e.g., temporal and spatial variability in trophic transfer linkages).

High concentrations of methylmercury also have negative effects on birds and terrestrial wildlife (Wolfe et al. 1998). Deleterious effects on bird species from methylmercury consumption include reproductive impairment and reduced juvenile survival (Heinz 1979, Evers et al. 2004, Albers et al. 2007, Ackerman et al. 2008). Methylmercury consumption effects on mammals include anorexia, ataxia, and death (O'Connor and Nielsen 1981, Wren et al. 1987).

Methylmercury is produced by the bacterial mediated chemical synthesis of inorganic mercury with an organic compound under fluctuating oxidation/reduction conditions. Inorganic mercury is widely distributed throughout the Delta, both from mercury mining in the Coast Range and as a legacy from the gold-mining in the Sierras where mercury was used in the mining process. Conditions most conducive to the methylation of mercury typically occur at shallow depths within inundated sediments but can also occur in anaerobic open water. Methylmercury can be lost to the atmosphere through de-methylation or be buried deeply in sediment. Net methylation, the balance between methylation and de-methylation, is controlled by an extensive set of chemical and biological factors which are not well understood, limiting the ability of current science to predict changes resulting from tidal habitat and floodplain restoration. Even less is known about how methylmercury enters the benthic and pelagic food webs and the rates at which enters. It is also not well understood how or if methylmercury is transferred between the benthic and pelagic food webs.

While the data are still being refined and augmented, the general pattern in the Plan Area is that the total mercury and methylmercury of the sediment are not tightly correlated with methylmercury content in fish and clam tissue. Sentinel species tissue concentrations in the Dutch Slough area are among the lowest in the Plan Area despite high sediment concentrations (Grassetti Environmental Consulting 2008). Perhaps the best available data are from the Blacklock dike breach restoration site in Suisun Marsh from 2006-2009 which shows that tissue concentrations of methylmercury in inland silverside (a fish) decreased in adjacent Nurse Slough despite the continual increase of methlymercury in the sediment (M. Stephensen unpublished data). Additionally, the amount of methylmercury generated by existing land use activities is highly variable with waterfowl management actions in Suisun Marsh generating more methylmercury in managed wetlands than is generated in tidal marsh habitat (USDI et al. 2010).

Methods for minimizing methylation in sediments are being developed and include capping mercury-containing sediment with uncontaminated sediment (as at the Montezuma Wetlands Restoration Project) and the addition of ferrous iron or activated carbon granules to the sediment. Continued transport of contaminated sediment into and within the Plan Area would likely limit the effectiveness of capping, and the addition of chemicals is experimental and would likely be limited to relatively small areas.

Hypothesized Benefits

Through the use of appropriate site selection protocols, design measures, construction techniques, and management actions, tidal habitat and floodplain restoration is hypothesized to:

- Minimize adverse effects of methylmercury on white sturgeon, North American green sturgeon, and Sacramento splittail;
- Minimize, and potentially reduce, adverse effects of methylmercury on covered wildlife such as salt marsh harvest mouse, Suisun shrew, and California least tern in Suisun Marsh as a result of the conversion of managed wetlands to tidal wetlands;

Adaptive Management Considerations

Implementation of this conservation measure will be informed through effectiveness monitoring that will be conducted as described in Section 3.6, *Monitoring and Research Program*, and the adaptive management process described in Section 3.7, *Adaptive Management Program*. Results from the long-term monitoring of sentinel species and covered species tissue concentrations of methylmercury and of sediment concentrations of methylmercury will be used to assess the effects of tidal habitat and floodplain restoration on achieving the methylmercury management objective. Effectiveness monitoring results will be used to determine whether tidal marsh and floodplain restoration actions increase tissue concentrations of methylmercury in sentinel and covered fish and wildlife species.

The following four types of monitoring and research actions could be implemented to inform the adaptive management program: (1) quantification of existing mercury and methylmercury sources; (2) remediation of mercury source areas; (3) quantification of ecological and human health effects of methylmercury in the system; and (4) testing of possible management approaches. Many of these action areas are being addressed by ongoing efforts through regional agencies, research institutions, and stakeholders, such as characterization of mercury and methylmercury in sediment and biota throughout the Plan Area, evaluation of solutions for the Cache Creek Settling Basin, research on methylmercury flux and bioaccumulation in various Delta environments, and pilot studies on management approaches such as application of ferrous iron amendments.

3.4.4.2 CM13 Nonnative Aquatic Vegetation Control

The BDCP Implementation Office will control the growth of Brazilian waterweed (*Egeria densa*), water hyacinth (*Eichhornia crassipes*), and other nonnative submerged and floating aquatic vegetation (SAV and FAV) in BDCP tidal habitat restoration areas (Figure 3-58). To implement this conservation measure, the Implementation Office will apply existing methods used by the Department of Boating and Waterways (DBW) *Egeria densa* and Water Hyacinth Control Programs. Control methods currently employed by DBW include application of herbicides and mechanical removal. BDCP methods of removal will be dictated by site-specific conditions and intended outcome or goal. Application of herbicides or other means to control SAV/FAV will be timed to eliminate or minimize potential negative effects of SAV/FAV removal on covered species.

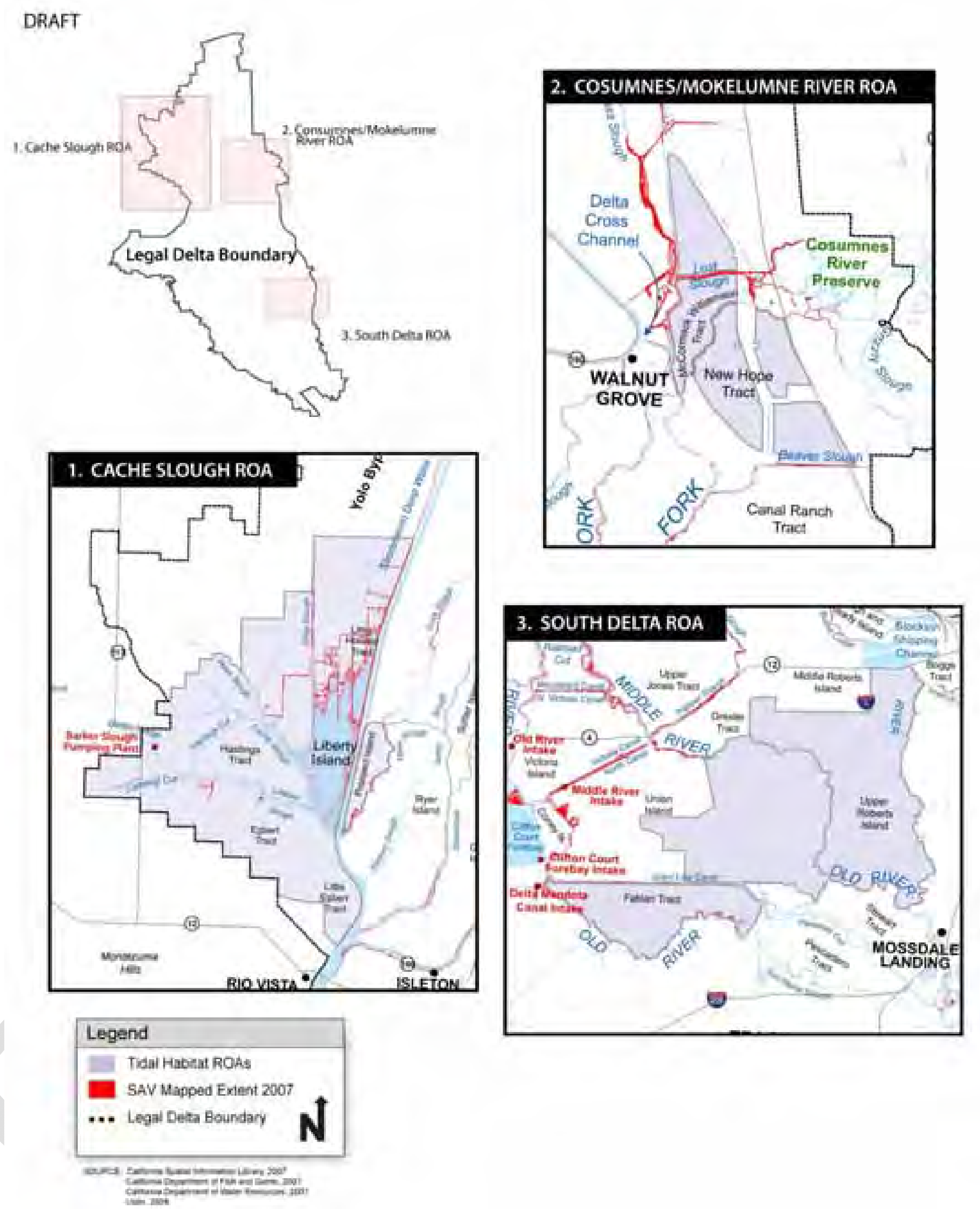

Figure 3-58. Overlap of Submerged Aquatic Vegetation in 2007 and Tidal Habitat Restoration Opportunity Areas (CM13)

Problem Statement

Although the historical extent of native SAV and FAV in the Delta ecosystem is unknown, invasive SAV and FAV species have recently colonized large areas of the Delta (Brown 2003, DFG 2008a, Ustin et al. 2008) and are continuing to expand into a greater proportion of channels and new areas (IEP 2008b). The widest spread nonnative FAV species, water hyacinth, was introduced into the Delta over 100 years ago, and severe infestations were experienced by the 1980s. The majority of the surface cover of SAV detected through the recent use of airborne hyperspectral imagery is Brazilian waterweed, although the SAV vegetation frequently contains a mixture of three invasive nonnative species: Brazilian waterweed, *Potamogeton crispus* (curlyleaf pondweed), and *Myriophyllum spicatum* (Eurasian watermilfoil) (Ustin et al. 2008). Of the 55,000 acres of the Delta surveyed in 2007, SAV cover has been estimated to be between 5,500 and 10,000 acres (Ustin et al. 2008). Nonnative SAV and FAV are thought to cause multiple negative effects on the Delta ecosystem, including providing habitat for nonnative predators of covered fish species (Brown 2003, Nobriga et al. 2005), reducing food abundance and feeding ability of covered fish species by reducing light and turbidity (Brown and Michniuk 2007), and blocking rearing habitat for juvenile salmon and splittail (IEP 2008a).

The DBW Water Hyacinth Control Program, which began in 1982, has been effective in reducing hyacinth from Delta waterways by using chemical and mechanical removal methods. DBW has developed and operated the *Egeria densa* Control Program since 2001 in response to AB 2193, which amended the Harbors and Navigation Code to designate DBW as the lead agency for the control of Brazilian waterweed in the Delta (DBW 2006, 2008). Initially, the program focused control efforts in a number of locations where Brazilian waterweed impeded navigation, tested a range of mechanical and chemical control techniques, and conducted an extensive suite of toxicology and water quality tests and sampling that were required by the terms of its National Pollution Discharge Elimination System permit and under biological opinions issued by USFWS and NOAA Fisheries (DBW 2008). In 2006, DBW concluded that its current approach was not effective at stopping the expansion of SAV in the Delta and proposed expanding the treatment area to sites across most of the legal Delta between 2006-2010 and concentrating on Franks Tract between 2006-2008 (DBW 2006).

Hypothesized Benefits

Removing nonnative SAV and FAV from tidal habitat restoration areas is hypothesized to provide benefits to covered fish species through the following mechanisms:

1. Reducing predation mortality on juvenile salmon, steelhead, and splittail by reducing habitat for nonnative predatory fish (see Appendix F, *DRERIP Evaluation Results*). SAV provides relatively high quality habitat for nonnative piscivores and is spread across large portions of the Delta in or adjacent to significant migration corridors and pelagic and subtidal open water habitat for covered species (Figure 3-59). The interior of SAV stands is good habitat for larval and juvenile centrarchids (Brown and Michniuk 2007), whereas

adult striped bass forage immediately outside of the SAV bed and feed on juvenile Chinook salmon, steelhead, splittail, delta smelt, and longfin smelt (Stevens 1966, Temple et al. 1998, Nobriga and Feyrer 2007b, 2008);

2. Reducing predation mortality of delta smelt by increasing turbidity levels (IEP 2008a, Appendix F, *DRERIP Evaluation Results*). SAV and FAV are thought to reduce local flow rates and cause suspended solids to precipitate out of the water column, resulting in a localized reduction in turbidity levels (Grimaldo and Hymanson 1999). Increased turbidity is hypothesized to improve the predator avoidance abilities of delta and longfin smelt. In addition, improved turbidity may reduce the hunting efficiency of nonnative piscivores (Nobriga et al. 2005);

3. Increasing food consumption by delta and longfin smelt by increasing turbidity levels. SAV and FAV are thought to reduce local flow rates and cause suspended particles to precipitate out of the water column, resulting in a localized reduction in turbidity levels (Grimaldo and Hymanson 1999). A reduction in turbidity is hypothesized to reduce the foraging ability of delta and longfin smelt;

4. Increasing rearing habitat for juvenile salmon (all races), steelhead, and splittail (Appendix F, *DRERIP Evaluation Results*). Dense patches of SAV and FAV physically obstruct covered fish species' access to habitat (IEP 2008a) that would become available with SAV and FAV removal and control; and

5. Increasing food availability for all covered fish species near removal locations by increasing light levels below vegetation. Phytoplankton growth is hypothesized to be light-limited in the Delta (Cole and Cloern 1984). The presence of SAV/FAV is more light-limiting for phytoplankton growth, through shading, than anticipated increases in water turbidity resulting from SAV/FAV removal. The reduction in light levels near nonnative SAV and FAV are thought to reduce local growth of phytoplankton, which can affect the local abundance of zooplankton that forms the food base for covered fish species near patches of SAV and FAV.

Adaptive Management Considerations

Implementation of this conservation measure by the BDCP Implementation Office will be informed through effectiveness monitoring that will be conducted as described in Section 3.6, *Monitoring and Research Program*, and the adaptive management process described in Section 3.7, *Adaptive Management Program*. The Implementation Office will monitor the effectiveness of BDCP-funded elements of the nonnative aquatic vegetation control in successfully controlling SAV and FAV. The Implementation Office will adjust control strategies and funding levels through the BDCP adaptive management process as appropriate based on review of program reports.

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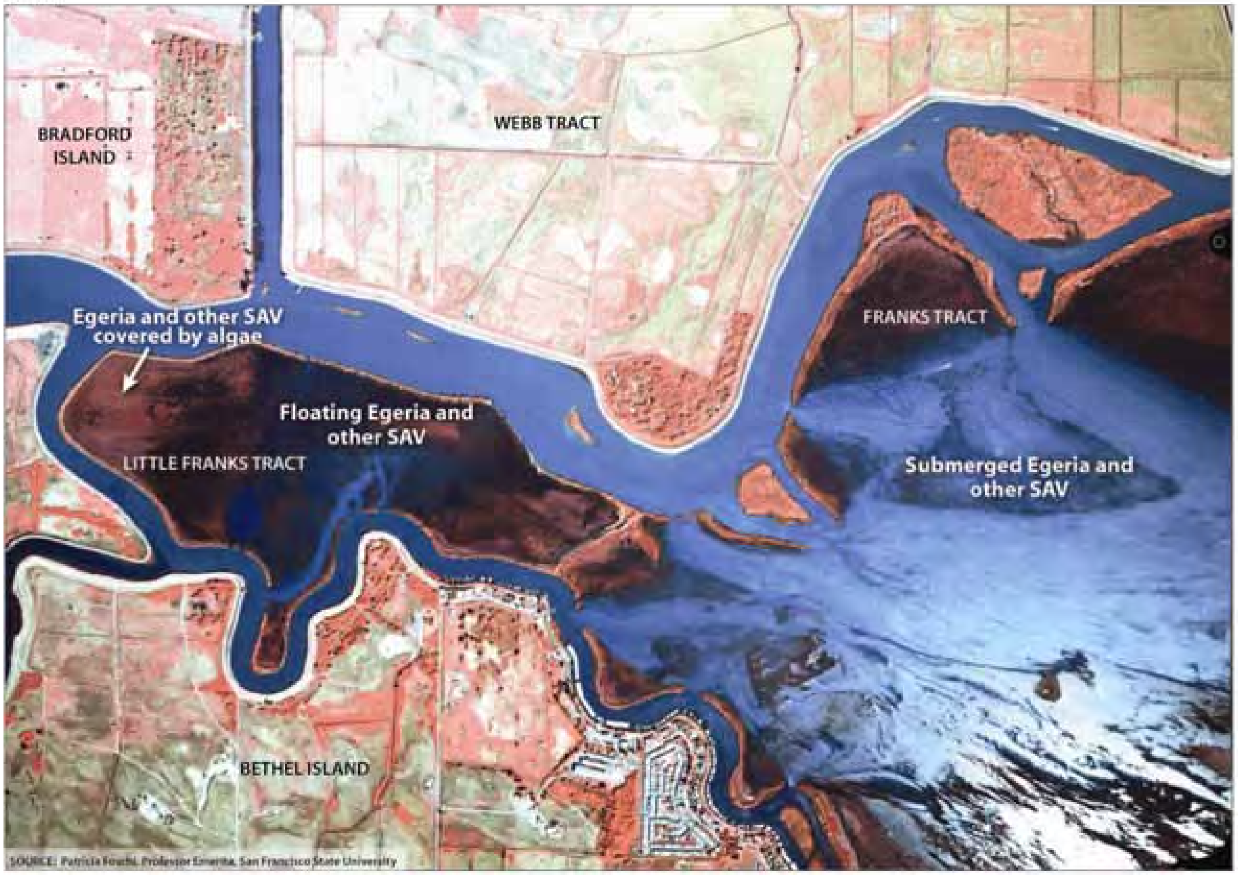

Figure 3-59. Examples of Delta Areas with Submerged Aquatic Vegetation (SAV) Infestations (CM13)

The Implementation Office will use results of effectiveness monitoring to determine if controlling SAV and FAV results in measurable benefits to covered fish species and to identify adjustments to funding levels, control methods, or other related aspects of the program that would improve the biological effectiveness of the program. Such changes, once approved through the adaptive management decision-making process, will be effected through subsequent annual work plans.

If results of monitoring indicate that removing and controlling SAV and FAV does not substantially and cost-effectively benefit covered fish species, the Implementation Office, in coordination with Fishery Agencies, may terminate this conservation measure. If terminated, remaining funding would be deobligated from this conservation measure and reallocated to augment funding for other more effective conservation measures identified in coordination with the Fishery Agencies through the BDCP adaptive management

3.4.4.3 CM14 Stockton Deep Water Ship Channel Dissolved Oxygen Levels

The purpose of this conservation measure is to maintain dissolved oxygen concentrations above levels that impair covered fish species in the Stockton Deep Water Ship Channel during periods when covered fish species are present. The BDCP Implementation Office will operate and maintain an oxygen aeration facility in the Stockton Deep Water Ship Channel to increase dissolved oxygen concentrations between Turner Cut and Stockton to meet Total Maximum Daily Load (TMDL) objectives established by the Central Valley Regional Water Quality Control Board (CVRWQCB) (2005) (above 6.0 mg/L from September 1 through November 30 and above 5.0 mg/L at all times). The existing aeration facility will be modified as necessary and, if necessary, additional aerators and associated infrastructure would be added to optimize oxygen delivery to the river, contingent upon results of an ongoing demonstration project conducted by DWR and effectiveness monitoring during implementation.

The Implementation Office will be responsible for developing annual work plans in coordination with Fishery Agencies that specify the extent of dissolved oxygen improvements to be implemented and will be responsible for monitoring the effectiveness of dissolved oxygen enhancement measures in improving dissolved oxygen levels.

Problem Statement

The Stockton Deep Water Ship Channel has been identified as an impaired waterway by the State Water Resources Control Board because of low dissolved oxygen concentrations during late summer and early fall (CVRWQCB 2005). The combination of low flows, high loads of oxygen-demanding substances (algae from upstream, effluent from the City of Stockton Regional Wastewater Control Facility, and other unknown sources), and channel geometry contribute to low oxygen levels in the Stockton Deep Water Ship Channel (CVRWQCB 2005). The Stockton Deep Water Ship Channel often fails to meet water quality objectives established by the Regional Board for dissolved oxygen (CVRWQCB 2007). The 7.5-mile low dissolved oxygen area of the ship channel creates a barrier for upstream migration of adult fall-run

Chinook salmon and Central Valley steelhead on the mainstem of the San Joaquin River (Hallock et al. 1970). Further, low dissolved oxygen levels can cause physiological stress on and mortality of fish, including Chinook salmon and steelhead (Jassby and Van Nieuwenhuyse 2005), and other aquatic organisms (CVRWQCB 2007). Once spring-run Chinook salmon are re-established in the San Joaquin River under the San Joaquin River Litigation Settlement, dissolved oxygen sags in the Deep Water Ship Channel will likely have similar effects on this run if sags were to occur during their adult migration period (expected to be approximately March-September). In addition, juvenile white sturgeon, which rear in the San Joaquin River, exhibit reduced foraging and growth rates at dissolved oxygen levels below 58 percent saturation (5.8 mg/l at 15 °C) (Cech and Crocker 2002).

One potential solution to dissolved oxygen sags in the Stockton Deep Water Ship Channel, a dissolved oxygen aeration system, has been installed and is currently undergoing field testing by DWR. Results suggest that the aeration facility is effective at raising dissolved oxygen levels in much of the channel. Long-term funding for operations and maintenance has not yet been secured and there are currently no mandates by the CVRWQCB that require contributors to the sag to fund the project. Under this conservation measure, the BDCP would share in funding the long term operation and maintenance costs associated with the project.

Hypothesized Benefits

Increasing dissolved oxygen concentrations in the Stockton Deep Water Ship Channel in accordance with TMDL objectives is hypothesized to result in:

- Reduced delay and inhibition of upstream and downstream migration of fall-run Chinook salmon, steelhead, white sturgeon, river and Pacific lamprey, and, once they are re-established in the San Joaquin River, spring-run Chinook salmon (Hallock et al. 1970); and
- Reduced physical stress and mortality of fall-run Chinook salmon, steelhead, white sturgeon, river and Pacific lamprey, and, once they are re-established in the San Joaquin River, spring-run Chinook salmon.

Adaptive Management Considerations

Implementation of this conservation measure by the BDCP Implementation Office will be informed through effectiveness monitoring that will be conducted as described in Section 3.6, *Monitoring and Research Program*, and the adaptive management process described in Section 3.7, *Adaptive Management Program*. Results from monitoring of dissolved oxygen levels at various distances from the diffuser(s) will be used to assess the performance of the facilities operations at achieving the water quality objective. The Implementation Office will use effectiveness monitoring results to determine whether aeration facility operations result in measurable benefits to covered fish species.

Based on review of performance and effectiveness monitoring results, the Implementation Office will adjust funding levels, oxygen diffuser methods, or other related aspects that will improve the performance and/or biological effectiveness of the project through the BDCP adaptive management process as appropriate. Such changes will be effected through the BDCP adaptive management process and would be included in the subsequent annual work plans.

If results indicate that the aeration facility does not substantially and cost-effectively benefit covered fish species, the BDCP Implementation Office, in coordination with Fishery Agencies, may terminate this conservation measure. If terminated, remaining funding will be deobligated from this conservation measure and reallocated to augment funding for other more effective conservation measures identified in coordination with the Fishery Agencies through the BDCP adaptive management process.

3.4.4.4 CM15 Predator Control

The purpose of this conservation measure is to reduce local effects of predators on covered fish species by conducting focused predator control in high predator density locations. The BDCP Implementation Office will reduce the local effects of predators on covered fish species by conducting focused predator control using a variety of methods in locations in the Delta that are known to have high densities of predators ("hot spots").

The Implementation Office will examine existing fish monitoring data, bathymetry data, and radio and acoustic tagging study results to determine the locations and causes of predator hot spots throughout the Delta (Figure 3-X [to come]). Locations of hot spots in which focused predator control will occur include:

1. Old structures in or hanging over Delta waterways, such as pier pilings or other man-made structures, that are no longer functional or have been abandoned but affect flow fields or provide shade (target: 10-20 structures removed per year);
2. Boats that have been abandoned throughout the Delta (target: 5-10 boats removed per year);
3. New intake structures of the North Delta Diversions (target: daily focused removal when sensitive lifestages of covered fish species are present);
4. The deep hole just downstream of the Head of Old River in the San Joaquin River (target: daily focused removal when sensitive lifestages of covered fish species are present. Additional control efforts may be needed in conjunction with operation of non-physical barriers, as described in CM16);
5. Specific locations in Georgiana Slough, as identified by Fishery Agencies (target: daily focused removal in up to 3 specific locations when sensitive lifestages of covered fish species are present);

6. Specific locations in Sutter and Steamboat sloughs, as identified by Fishery Agencies (target: daily focused removal of predators in up to 2 specific locations per slough when sensitive lifestages of covered fish species are present); and
7. Release sites of salvaged fish from CVP/SWP facilities (target: weekly focused removal at each salvage release site when sensitive lifestages of covered fish species are being salvaged).

The Implementation Office will use a variety of methods to control predator populations in hot spots, including removal of predator hiding spots, modification of channel geometry, targeted removal of predators, and/or other focused methods as dictated by site-specific conditions and the intended outcome or goal. Preference for which hot spots to address will be given to areas of high overlap with covered fish species, such as major migratory routes or spawning and rearing habitats.

Site-specific control plans will be developed in consultation with the Fishery Agencies, and will include expected benefits, methods, and a monitoring design that will provide information necessary to determine the effectiveness of the action.

<u>*Problem Statement*</u>

Although a natural part of the estuarine ecosystem, predation in the Delta has been identified as a stressor to BDCP covered fish species (Appendix F, *DRERIP Evaluation Results*). Habitat for fish predators generally consists of a specific suite of attributes that allow them to forage more efficiently, such as dark locations adjacent to light locations or deep pools that allow the predator to hide and ambush their prey. There are multiple locations in the Delta that contain these physical attributes and attract predatory fish that prey upon covered fish species.

<u>*Hypothesized Benefits*</u>

Conducting localized predator control at hot spots in the Delta using a variety of control methods is expected to reduce local predator abundance, thus reducing localized predation mortality of Chinook salmon (Temple et al. 1998, Lindley and Mohr 2003), steelhead (Temple et al. 1998), Sacramento splittail (Moyle et al. 2004), and delta smelt (Stevens 1966, Thomas 1967, Moyle 2002); and possibly longfin smelt (Nowak et al. 2004), green sturgeon (J. Israel pers. obs.), and white sturgeon.

Within the Columbia River system, a predator removal program was investigated in the 1980's for the control of juvenile salmonid predators benefiting from the existence of multiple hydropower dams located along this system. The principle predators for juvenile salmonids within the Columbia River are the northern pikeminnow (*Ptychocheilus oregonensis*), and two nonindigenous species: smallmouth bass (*Micropterus dolomieu*) and walleye (*Sander vitreus*). Northern pikeminnow greater than ~10 inches were considered the primary predator of juvenile salmonids in slower moving portions of the Columbia River (i.e., near hydropower facilities).

The program, designed to reduce predation rates in these areas utilizing a bounty program, net fisheries, professional fishers, and fishing areas adjacent to hatcheries, was initiated in 1990. The bounty program targets the removal of 10 to 20 percent of the larger pikeminnow to control size classes that have the greatest juvenile salmonid predation rates, while still maintaining a sustained pikeminnow population. By maintaining a sustained pikeminnow population, the program was designed to avoid compensatory responses of other juvenile salmonid predators in the system (smallmouth bass and walleye) filling the void created by pikeminnow removal. Through the first 16 years of the program there were no indications of compensatory responses. In 2006, however, there were possible indications of localized compensatory responses, although there is insufficient data to determine whether there is a system-wide compensatory response (Takata et al. 2007, Van Dyke 2010).

Prior to the initiation of this program, Beamesderfer et al. (1996) estimated that approximately 16.4 million juvenile salmonids of the estimated 200 million downstream migrants were consumed by northern pikeminnow in the Columbia system. Another study estimated that northern pikeminnow accounted for 10 to 20 percent of juvenile salmonid mortality (as cited in Young 1997). Predation rates are greatest in the vicinity of each of the eight Columbia and Snake River reservoirs ("pools"). Within the John Day pool, it was estimated that a northern pikeminnow exploitation rate of 10 to 20 percent could reduce their predation on juvenile salmonids by 50 percent (as cited in Young 1997). From 1990 through 2008, the Northern Pikeminnow Sports Reward Fishery removed 3.3 million reward-sized (≥9 inches) northern pikeminnow from the Columbia system. From 1991-1998, system-wide exploitation rates of northern pikeminnow averaged 11.7 percent (Hankin and Richards 2000). The removal program estimates northern pikeminnow predation has been reduced by 37 percent (Northern Pikeminnow Sports Reward Fishery 2009). Although the program does not provide an estimated annual number of juvenile salmonids "spared" due to predator removal, model estimates for a reduction of 50 percent predation rate range from 5.2 to 8.2 million juvenile salmonids annually (Hankin and Richards 2000).

Adaptive Management Considerations

Implementation of this conservation measure by the BDCP Implementation Office will be informed through effectiveness monitoring that will be conducted as described in Section 3.6, *Monitoring and Research Program*, and the adaptive management process described in Section 3.7, *Adaptive Management Program*. Monitoring will consist of assessing the abundance, distribution, and size of predator species before and immediately after implementation of predator control actions in each hot spot to determine the performance of the action. In addition, potential changes in survival rate of covered species will be monitored using acoustic tagging studies where possible or similar techniques.

The Implementation Office, in consultation with the Fishery Agencies, will use results of effectiveness monitoring to determine whether the actions result in measurable benefits to covered fish species, and to identify adjustments to funding levels, methods, or other related aspects of the program that would improve its biological effectiveness. Such changes, once approved through the adaptive management decision-making process, will be effected through subsequent annual work plans. If results of monitoring indicate that the action does not substantially and cost-effectively benefit covered fish species, the BDCP Implementation Office, in coordination with Fishery Agencies, may terminate this conservation measure. If terminated, remaining funding will be deobligated from this conservation measure and reallocated to augment funding for other more effective conservation measures identified in coordination with the Fishery Agencies through the BDCP adaptive management process.

3.4.4.5 CM16 Non-Physical Fish Barriers

The purpose of this conservation measure is to improve the survival of outmigrating juvenile salmonids by using non-physical barriers to re-direct them away from channels in which survival is lower (Figure 3-60). The BDCP Implementation Office will install non-physical barriers at the junction of channels with low survival of outmigrating juvenile salmonids to deter fish from entering these channels[37]. Non-physical barrier placement locations will include the Head of Old River, the Delta Cross Channel, Georgiana Slough, and could possibly include Turner Cut, Columbia Cut, the Delta Mendota Canal intake, and Clifton Court Forebay (Figure 3-61). Other locations may be considered in the future by the Implementation Office if, for example, future research demonstrates differential rates of survival in Sutter and Steamboat sloughs relative to the mainstem Sacramento River, or in the Yolo Bypass relative to the mainstem Sacramento River. Non-physical barriers will include a combination of sound, light, and bubbles similar to the three-component non-physical barrier used in the 2009 DWR Head of Old River Test Project (Bowen et al. 2009). Non-physical barriers will be installed and operated during October to June or when Fishery Agencies monitoring determines that salmonid smolts are present in the areas when barriers are to be installed. Non-physical barrier placement may also be accompanied by methods to reduce local predator abundance described in CM15 above if monitoring finds that barriers attract predators. Barriers will be removed and stored off-site while not in operation (M. Holderman pers. comm.).

Problem Statement

Juvenile salmonids experience low survival rates while migrating through the Delta towards the ocean. Survival rates vary among routes taken through the Delta (Brandes and McLain 2001, Perry and Skalski 2008, 2009, Holbrook et al. 2009, Perry et al. 2009) as a result of differential exposure to predation, entrainment mortality at state and federal water export facilities and small agricultural diversions, and other factors (SJRGA 2006, J. Burau pers. comm.).

[37] Previous evidence suggests that, under a non-physical barrier configuration that was effective in deterring salmon smolts, the non-physical barrier was not effective in deterring delta smelt (Bowen et al. 2008). It is currently not known whether this was a result of the configuration (e.g., sound frequency) of the non-physical barrier or the poor swimming ability of delta smelt that was swamped by high flows (Bowen et al. 2008). Reclamation is currently studying whether there are sound frequencies that deter delta smelt (M. Holderman pers. comm.). If demonstrated to be effective in deterring delta smelt and longfin smelt and deemed necessary by the Fishery Agencies, non-physical barriers could also be installed at the mouths of Old and Middle rivers and in Three Mile Slough (if salinity manipulation is not also needed) to deter these species from moving into these channels where survival is thought to be lower when present, as determined by Fishery Agencies monitoring.

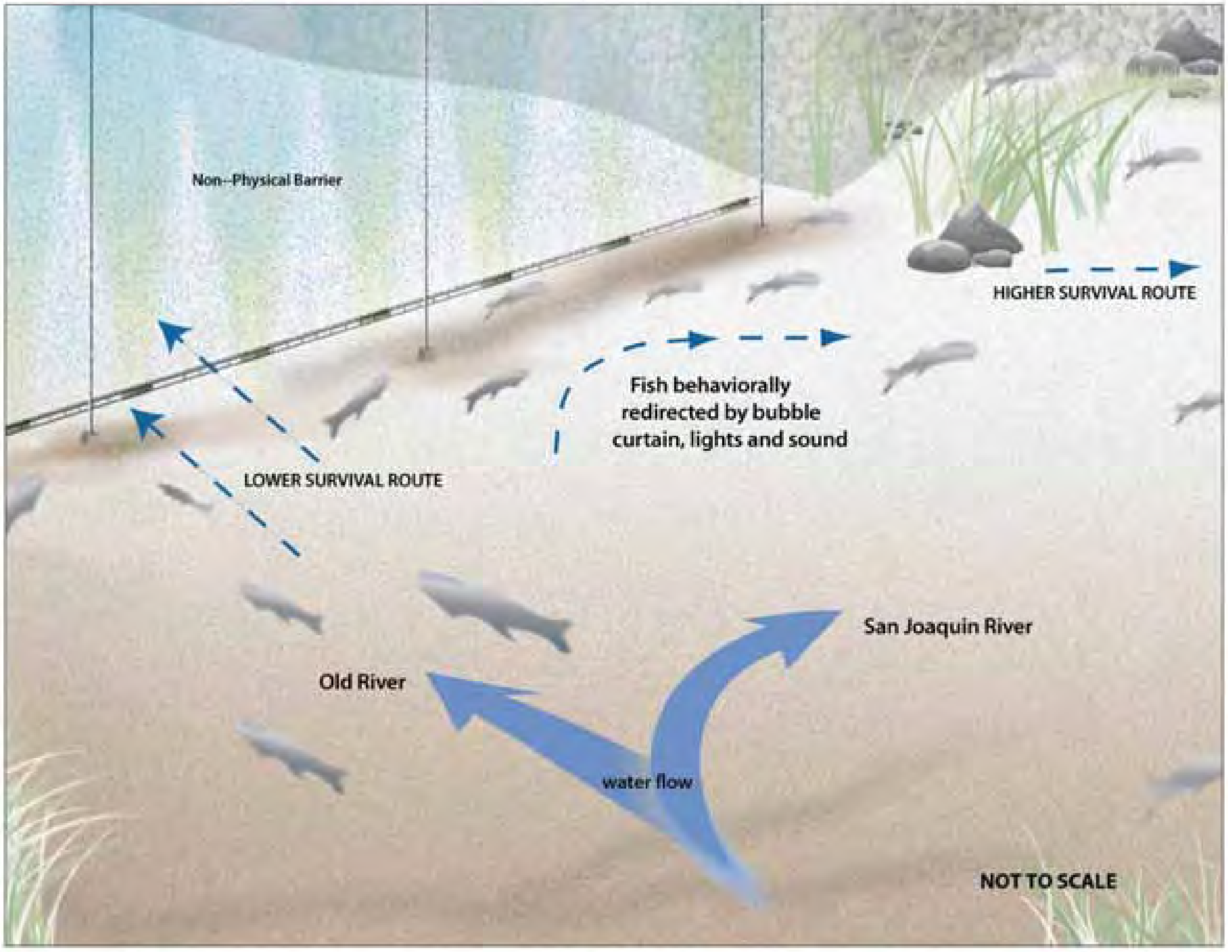

Figure 3-60. Schematic of Non-Physical Fish Barrier (CM16)

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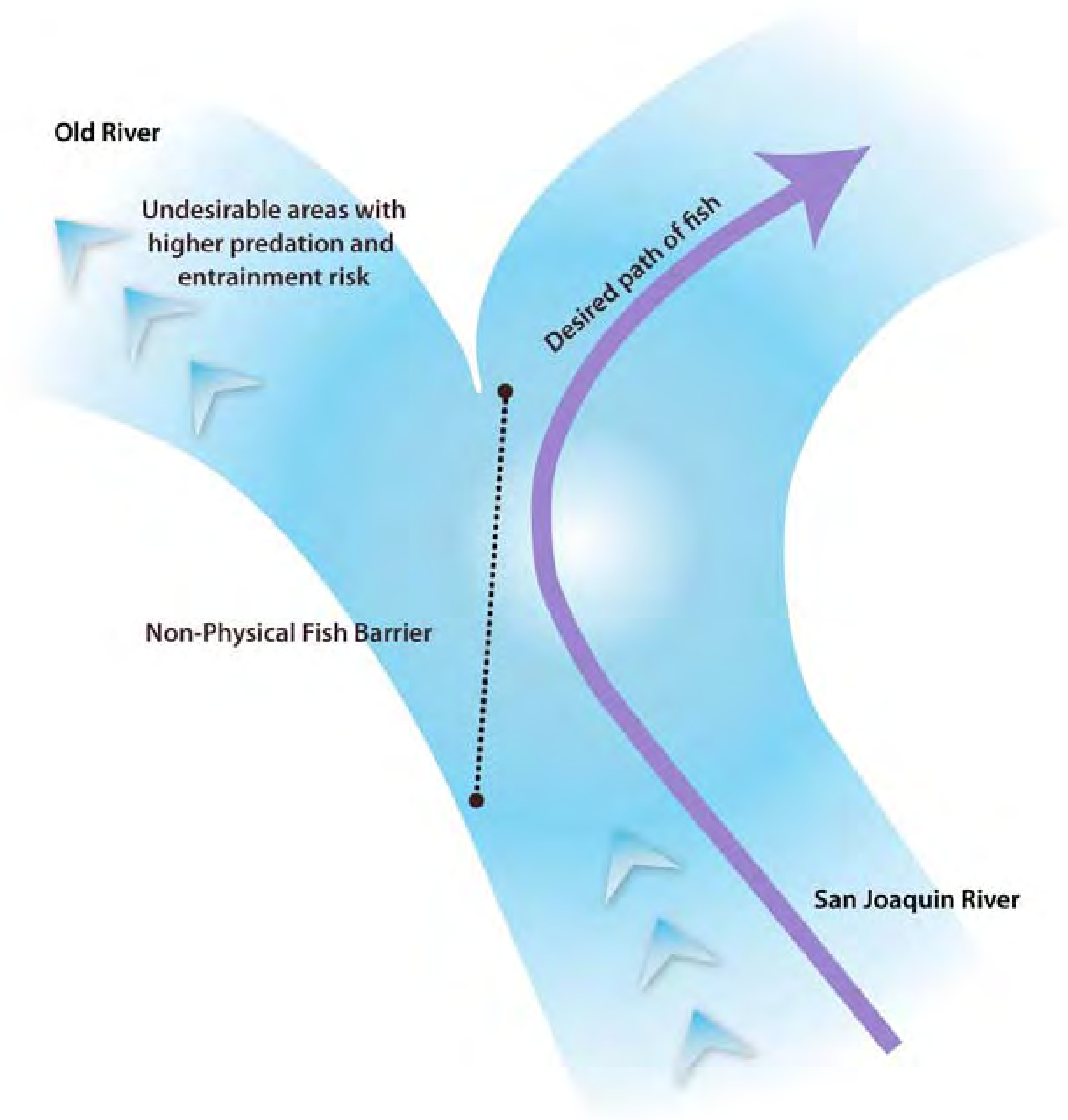

Figure 3-61. Conceptual Location of Non-Physical Fish Barrier (CM16)

Survival for routes through the interior Delta was at most 35 percent that of survival for fish remaining in the Sacramento River (Perry et al. 2010). Such low probability of survival when migrating through the interior Delta indicates that significant population level impacts could result if a sizable portion of the salmon population passed through this area. Perry and Skalski (2009) found that 19.8 to 34.5 percent of tagged salmon used Sutter and Steamboat sloughs during migration, while 26.7 percent to nearly one-third of the population entered the interior area. Low survival probabilities and high proportions of the population migrating through the interior Delta combine to significantly reduce salmon survival through the Delta during migration. Physical barriers have been used in the Delta, such as the Delta Cross Channel gates and the rock barrier at the Head of Old River, to prohibit the entry of fish into channels where survival rates are low. Physical barriers are effective at prohibiting entry of salmonids into channels, but also alter flow dynamics in these channels, likely affecting tidal flows, sediment loads, bathymetry, water supply reliability, potential for noxious algal blooms, toxic concentrations, and other water quality parameters. However, operation of non-physical barriers is predicted to cause smaller changes in the physical configuration of the channel, thus reducing flow-related effects, while improving survival of salmonids by deterring them from entering channels with a higher risk of mortality.

Hypothesized Benefits

Installation and seasonal operation of non-physical barriers is hypothesized to improve survival of juvenile salmonids migrating downstream by guiding fish into channels in which they experience higher survival rates (Welton et al. 2002, Bowen et al. 2009). The three component non-physical barrier has shown promising results in laboratory experiments on Chinook salmon emulating the Sacramento River/Georgiana Slough flow split (Bowen et al. 2008) and a field experiment on Atlantic salmon (*Salmo salar*) smolts in the River Frome, UK (Welton et al. 2002). In addition, preliminary evidence suggests that the three-component barrier was effective in deterring acoustically-tagged Chinook salmon juveniles from entering the head of Old River during a 2009 pilot study (Bowen et al. 2009). Non-physical barriers that utilize only one component, such as sound or light, have demonstrated only limited success in deterring fish during field trials. For example, out of 25 separate single-component sound and light systems placed in 21 different locations in Europe and the United States to affect the behavior of salmonids near water intakes and canals, fewer than 50 percent were effective in altering fish behavior (USBR 2006). The three-component Non-physical Barrier Test Project at the confluence of Old River and the San Joaquin River in the Sacramento-San Joaquin Delta has demonstrated greater success, successfully deterring 81.4 percent of tagged Chinook salmon smolts from entering Old River compared to conditions without the barrier operating that deterred 25.4 percent of tagged salmon smolts (Bowen et al. 2009). Sound is known to affect the behavior of salmonids (Vanderwalker 1967, Knudsen et al. 1992, 1994).

Adaptive Management Considerations

Implementation of this conservation measure by the BDCP Implementation Office will be informed through effectiveness monitoring that will be conducted as described in Section 3.6, *Monitoring and Research Program*, and the adaptive management process described in Section 3.7, *Adaptive Management Program*. The Implementation Office will conduct and review monitoring to assess the effectiveness of using non-physical barriers. The Implementation Office will use results of effectiveness monitoring to determine whether operations of non-physical barriers result in measurable benefits to juvenile salmonids and to identify adjustments to funding levels, methods, or other related aspects of the program that would improve the biological effectiveness of the program. Uncertainty regarding the potential attraction of predators to non-physical barriers and the effectiveness of barriers in higher flow areas must be resolved. Such changes, once approved through the adaptive management decision-making process, will be effected through subsequent annual work plans. If results of monitoring indicate that operations of non-physical barriers do not substantially and cost-effectively benefit covered fish species, the Implementation Office, in coordination with Fishery Agencies, may terminate this conservation measure. If terminated, remaining funding will be deobligated from this conservation measure and reallocated to augment funding for other more effective conservation measures identified in coordination with the Fishery Agencies through the BDCP adaptive management process.

3.4.4.6 CM17 Hatchery and Genetic Management Plans

[*Note to Reviewers*: *SAIC is in discussion with hatchery coordinators to determine the funding needs for this conservation measure. This measure will be updated as new information becomes available via continued coordination.***]**

The purpose of this conservation measure is to develop and implement hatchery and genetic management plans to minimize the potential for genetic and ecological impacts of hatchery-reared salmonids on wild salmonid stocks. The BDCP Implementation Office will minimize potential adverse effects of hatchery-reared salmonids on wild salmonid stocks by supporting the accelerated development and implementation of Hatchery and Genetic Management Plans (HGMPs) for all state Chinook salmon and steelhead hatcheries in the Central Valley. HGMPs would be implemented to reduce adverse ecological and genetic effects of hatcheries on wild fish and to be consistent with conservation and protection for listed fish species.

The Implementation Office will provide funding to:

- Expand and finalize steering groups for each hatchery HGMP process, in part to aid in determining hatchery function;
- Support DFG staff and DFG contractors to prepare HGMPs under DFG and NMFS direction;

- Staff a DFG HGMP Coordinator, a position dedicated to coordinating HGMPs from beginning through implementation. HGMP implementation and adaptive management will be an ongoing task for the life of each hatchery;
- Staff hatcheries sufficiently to carry out changes necessary to meet ESA requirements, including providing regional support for fishery biologists at each hatchery;
- Improve efforts to minimize several categories of hatchery impacts including trucking, inter-basin egg transfers, genetic stock management, monitoring (especially hatchery natural proportions and impacts of hatcheries on natural stocks), and conservation hatcheries; and
- Provide support for staffing and analysis associated with a genetic parental-based tagging system.

Funding of these efforts will be higher during development of the plans and should decline as plans are completed. The BDCP Implementation Office will enter into binding Memoranda of Agreement or similar instruments with DFG as described in Section 3.4.4, *Species Level Other Stressors Conservation Measures*.

Problem Statement

Hatchery-reared Chinook salmon and steelhead are believed to have negative effects on wild Chinook salmon and steelhead, including competition for space and food as juveniles and for spawning habitat as adults. Fish reared in hatcheries can be selected for traits that are different from those in nature, such as those that allow them to survive in an artificial, contained environment (e.g., fast growth, large size). This could result in reduced genetic isolation of hatchery fish from wild fish. It is thought that these hatchery fish outcompete their smaller wild-reared conspecifics (individuals of the same species) for food and space in natural waterways (Williams 2006). Also, as adults, straying by hatchery-reared salmon into natural spawning grounds may lead to competition for spawning habitat and genetic introgression, where offspring of wild salmon are “genetically polluted” with hatchery-selected genes, thereby reducing the fitness of wild population (ISAB 2003, Goodman 2005, Hey et al. 2005).

To address these concerns, hatcheries have begun reforming their management practices to minimize the effects that hatchery fish may have on wild fish. HGMPs serve as the foundation of hatchery management and reform to minimize genetic and ecological impacts to wild fish. HGMPs are developed to devise and evaluate practices of a hatchery to ensure the hatchery contributes to the conservation and recovery of listed salmonids.

Although required, the development of HGMPs in Central Valley hatcheries has been slow to date. The following provides a summary of the status of the progress made toward completion of HGMPs at Central Valley hatcheries (M. Lacy pers. comm.):

- Nimbus Hatchery - Draft HGMPs for both fall Chinook salmon and winter steelhead have been completed. Updates and minor revisions were made during 2008 to initial drafts. Reclamation and DFG staff are currently reviewing subsequent drafts.
- Feather River Hatchery - Draft HGMPs for spring and fall Chinook salmon and Central Valley steelhead were completed in late 2008. DWR is reviewing the spring Chinook salmon draft HGMP; fall Chinook salmon and steelhead HGMPs are both still in development by consultant staff. Updates and DWR comments are being incorporated into all drafts as appropriate.
- Mokelumne River Hatchery - A revised draft HGMP for the steelhead program was completed at the end of 2008 and has been reviewed by hatchery staff. A draft HGMP for the fall Chinook salmon is 50 percent complete.
- Merced River Hatchery - There has been no progress towards beginning work on this HGMP.
- Coleman National Fish Hatchery and Livingston Stone National Fish Hatchery - All of the necessary HGMP information for Coleman and Livingston Stone National Fish Hatcheries are contained in the 2001 Biological Assessment (plus a subsequent addendum for Section 10 coverage for winter Chinook and amendments to respond to operational changes at Coleman National Fish Hatchery) submitted to NMFS. The Biological Opinion, including updates to the BA, is in process.

Hypothesized Benefits

Accelerating the development and implementation of HGMPs at Central Valley hatcheries is hypothesized to:

- Improve the genetics and fitness of wild salmonids (ISAB 2003, Goodman 2005, Hey et al. 2005); and
- Reduce competition for rearing and spawning habitat and food with hatchery-reared salmonids (Flagg et al. 2000, Goodman 2005).

Adaptive Management Considerations

Implementation of this conservation measure by the BDCP Implementation Office will be informed through effectiveness monitoring that will be conducted as described in Section 3.6, *Monitoring and Research Program*, and the adaptive management process described in Section 3.7, *Adaptive Management Program*. The Implementation Office will review annual reports or other relevant reports to assess the performance of the HGMP teams in the accelerated development and implementation of HGMPs. The Implementation Office will coordinate with the individual hatcheries to adjust HGMP strategies and funding levels through the BDCP adaptive management process as appropriate, based on review of performance monitoring results and other relevant reports.

The Implementation Office will use effectiveness monitoring results to determine whether HGMP development and implementation results in measurable benefits to covered fish species and to identify adjustments to funding levels or other related aspects of the program that would improve the biological effectiveness of the program. Such changes will be effected through the BDCP adaptive management process and will be included in the subsequent annual work plans.

If results of review indicate that HGMP development and implementation does not substantially and cost-effectively benefit covered fish species, the Implementation Office, in coordination with Fishery Agencies, may terminate this conservation measure. If terminated, remaining funding will be deobligated from this conservation measure and reallocated to augment funding for other more effective conservation measures identified in coordination with the Fishery Agencies through the BDCP adaptive management process.

3.4.4.7 CM18 Illegal Harvest

The purpose of this conservation measure is to reduce illegal harvest of Chinook salmon, Central Valley steelhead, green sturgeon, and white sturgeon in the Delta, bays, and upstream waterways. The BDCP will provide funding over the term of the BDCP to increase the enforcement of fishing regulations in the Delta and bays to reduce illegal harvest of covered salmonids and sturgeon. The BDCP Implementation Office will provide funds to DFG to hire and equip 17 additional Game Wardens and 5 supervisory and administrative staff in support of the existing field wardens assigned to the Delta-Bay Enhanced Enforcement Program over the term of the BDCP.

The DFG Delta-Bay Enhanced Enforcement Program (DBEEP) is a 10-Warden squad that was formed specifically to increase enforcement on poaching of anadromous fish species in Bay-Delta waterways. The program is funded by water contractors through the Delta Fish Agreement. The BDCP would contribute directly to this existing program by expanding its size to improve enforcement against poaching of covered species.

The BDCP Implementation Office will enter into Memoranda of Agreement or similar binding instruments with DFG as described in Section 3.4.4, *Species Level Other Stressors Conservation Measures*.

Problem Statement

California has the lowest Game Warden to population ratio in the nation with fewer than 200 field wardens for the entire state. The Delta is a particular hot spot for poaching because of the large number of sport fish, particularly gravid female white sturgeon, whose roe are used for caviar (Lt. L. Schwall, pers. comm.). Illegal harvest is thought to have high impacts on sturgeon populations, particularly white sturgeon (Beamsderfer et al. 2007). Illegal harvest of juvenile and adult Chinook salmon and steelhead in the Delta and bays is also common (DBEEP 2007).

Hypothesized Benefits

It is hypothesized that enhanced enforcement on poaching will reduce mortality, and potentially increase population sizes, of green sturgeon (Beamesderfer et al. 2007, DFG unpublished, Boreman 1997, D. Tanner pers. comm., DFG 2007b, Appendix F, *DRERIP Evaluation Results*); white sturgeon (Bay-Delta Oversight Council 1995, Boreman 1997, Schaffter & Kohlhorst 1999, Beamesderfer et al. 2007, DFG 2007b, DFG 2008c, M. Gingras pers. comm., Z. Matica pers. comm., CDFG unpubl. data, Appendix F, *DRERIP Evaluation Results*); Chinook salmon (all races) (Bay-Delta Oversight Council 1995, Williams 2006); and steelhead (DFG 2007b, DFG 2007c, DFG 2008d, Moyle et al. 2008, Appendix F, *DRERIP Evaluation Results*). Spring-run Chinook salmon are hypothesized to experience the greatest benefit because they are more susceptible to poaching than other runs due to over-summer holding and ease of locating them (Appendix F, *DRERIP Evaluation Results*). Due to the recent establishment of daily bag limits for Sacramento splittail by the Fish and Game Commission, it is hypothesized that this conservation measure will also reduce mortality and potentially increase population size of splittail.

Magnitudes of population-level benefits of this measure are expected to vary inversely with the population size of each covered species (Bay-Delta Oversight Council 1995, Begon et al. 1996, Futuyma 1998, Moyle et al. 2008).

Adaptive Management Considerations

Implementation of this conservation measure by the BDCP Implementation Office will be informed through effectiveness monitoring that will be conducted as described in Section 3.6, *Monitoring and Research Program*, and the adaptive management process described in Section 3.7, *Adaptive Management Program*. The Implementation Office will coordinate with DFG to adjust enforcement strategies and funding levels through the BDCP adaptive management process as appropriate based on review of DBEEP annual reports.

3.4.4.8 CM19 Conservation Hatcheries

The purpose of this conservation measure is to establish new and expand existing conservation propagation programs for delta and longfin smelt. The BDCP Implementation Office will support: (1) the development of a delta and longfin smelt conservation hatchery by the USFWS to house a delta smelt refugial population and provide a source of delta and longfin smelt for supplementation or reintroduction, if deemed necessary by Fishery Agencies; and (2) the expansion of the refugial population of delta smelt and establishment of a refugial population of longfin smelt at the University of California, Davis Fish Conservation and Culture Laboratory to serve as a population safeguard in case of a catastrophic event in the wild.

The new facility proposed by the USFWS will house genetically-managed refugial populations of delta and longfin smelt (Clarke 2008). Further, the facility will provide fish to supplement the wild population and provide fish stocks for reintroduction, as necessary and appropriate. State-of-the-art genetic management practices will be implemented to avoid hatchery-produced fish becoming genetically different from wild fish. The facility will be designed with the ability to add other species if necessary in the future. Due to space limitations, the facility as planned will consist of two sites: a science oriented genetic refuge and research facility on the edge of the Sacramento River, and a larger supplementation production facility nearby (B. Clarke pers. comm.) (Figure 3-62). Specific rules will be established to discontinue housing refugial populations of delta and longfin smelt at the hatchery if and when populations of these species are considered recovered by the Fishery Agencies.

In addition, the UC Davis Fish Conservation and Culture Laboratory (FCCL) is in need of additional space and funds to expand the refugial population of delta smelt and establish a refugial population of longfin smelt. The FCCL and the Genomic Variation Laboratory (GVL) at UC Davis are and will be, the primary entities developing and implementing genetic management of the delta smelt refugial population over the period 2009-2015 or longer and may then play a secondary role in keeping a back-up population(s).

At both facilities, genetic management practices will be implemented to maintain wild genetic diversity, minimize genetic adaptation to captivity, minimize mean kinship, and equalize family contributions. Furthermore, genetic monitoring of wild populations will proceed to minimize risks such as genetic swamping from the hatchery population, reduction in effective population size, and changes in the census population-to-breeder population ratio over time.

The BDCP Implementation Office will enter into binding Memoranda of Agreement or similar instruments with the USFWS and University of California, Davis similar to that described in Section 3.4.4, *Species Level Other Stressors Conservation Measures*. In addition, if and when populations of these species are considered recovered by the Fishery Agencies, the Implementation Office will terminate funding for the propagation of the species and either fund propagation of an additional BDCP covered fish species, if necessary and feasible, or deobligate funds to this conservation measure and reallocate them to augment funding other conservation measures identified in coordination with the Fishery Agencies through the BDCP adaptive management process.

Problem Statement

Populations of both delta and longfin smelt have dramatically declined recently (IEP 2008a, b). Although a variety of stressors are suspected, there is not a clear understanding of why these populations have declined (IEP 2008a, b). There is evidence that delta smelt continue to decline and that very low population size could result in an Allee effect causing an even more rapid decline of the species (Mueller-Solger 2007). As a result, the risk of extinction of delta smelt is hypothesized to be increasing. Longfin smelt abundance has followed a similar trend to delta smelt (IEP 2008a, b).

Figure 3-62. Potential USFWS Conservation Hatchery Facility Locations (CM19)

Hypothesized Benefits

Artificial propagation and maintenance of refugial populations of delta and longfin smelt are hypothesized to:

- Provide a safeguard against the possible extinction of delta and/or longfin smelt by maintaining a captive population that is genetically similar to the wild population (Lande 1988, Hedrick et al. 1995, Sveinsson & Hara 1995, Carolsfeld 1997, Sorensen 1998, USFWS 2003, Hedgecock et al. 2000, Kowalski et al. 2006, Turner et al. 2007, Nobriga 2008, Turner & Osborne 2008, B. Clarke, pers. comm., Appendix F, *DRERIP Evaluation Results*);
- Improve the knowledge base regarding threats to and management of delta and longfin smelt by increasing the ability to study the effects of various stressors on these species using hatchery-reared specimens (Appendix F, *DRERIP Evaluation Results*); and
- Contribute to increasing population sizes of delta smelt (Lande 1988, Deblois & Leggett 1991, Sveinsson & Hara 1995, Carolsfeld 1997, Sorensen 1998, USFWS 2003, Flagg et al. 2000, Richards et al. 2004, Kowalski et al. 2006, Purchase et al. 2007, Nobriga 2008, B. Clarke, pers. comm.) and longfin smelt (Sveinsson & Hara 1995, Carolsfeld 1997, Sorensen 1998, USFWS 2003, Flagg et al. 2000, Richards et al. 2004, Kowalski et al. 2006, Nobriga 2008) to self-sustaining levels in the wild when combined with effective habitat restoration and other measures to improve conditions in their natural environment.

Adaptive Management Considerations

Implementation of this conservation measure by the BDCP Implementation Office will be informed through effectiveness monitoring that will be conducted for this conservation measure as described in Section 3.6, *Monitoring and Research Program*, and the adaptive management process described in Section 3.7, *Adaptive Management Program*. Based on review of performance and effectiveness monitoring results in USFWS and UC Davis annual reports, the Implementation Office, in coordination with Fishery Agencies and UC Davis, will adjust funding levels, hatchery operations, or other related aspects that will improve the performance and/or biological effectiveness of the program through the BDCP adaptive management process as appropriate. Such changes will be effected through the BDCP adaptive management process and would be included in the subsequent annual work plans.

3.4.5 Avoidance and Minimization Measures

As required by Section 10 of the ESA, the BDCP includes avoidance and minimization measures that will be implemented by the BDCP Implementation Office to avoid and minimize adverse impacts of covered activities on the covered species. Careful design and implementation of covered activities will help avoid take of covered species, but specific avoidance and minimization measures may be required during implementation to fully meet this requirement. It is the responsibility of the Implementation Office to design and implement projects in compliance with these measures.

Biological surveys are an essential first step that will be used to assess the location, extent, and quality of suitable habitat or occurrences of covered species on BDCP project sites. Three levels of surveys, described in greater detail in the following sections, may be required for implementation of covered activities and conservation measures: planning surveys, preconstruction surveys, and construction-period monitoring.

- **Planning Surveys.** Planning surveys are used to identify the natural communities that are present in a BDCP project site, to determine whether suitable habitat for covered species is present, and to determine whether additional surveys are required to establish occupancy by covered species. Planning survey maps are used in assessing project effects on natural communities by identifying the extent of natural communities in BDCP project sites.
- **Preconstruction Surveys**. Preconstruction surveys are used to determine whether covered species are present in a BDCP project site, and whether species-specific avoidance and minimization measures must be implemented to ensure compliance with the HCP/NCCP. Agency-approved protocols are available for surveying some covered species; survey procedures for other species will be developed in cooperation with USFWS and DFG.
- **Construction Monitoring.** Construction monitoring ensures that necessary avoidance and minimization measures are implemented properly during construction activities.

3.4.5.1 General Avoidance and Minimization Measures

Avoidance and Minimization Measure (AMM) 1. Conduct planning surveys for covered wildlife and plant species. Planning surveys are reconnaissance level surveys that are intended to identify the habitats that are present in BDCP project sites, and what, if any, more intensive survey effort should be made to accurately determine the status of covered species and natural communities on the sites. Planning surveys are required for all covered activities and implementation of conservation measures. Results of planning surveys will inform project design and be used, if avoidance is not possible, to preserve the species and implement relevant conservation measures.

Planning surveys will use existing data on natural community and habitat distribution and covered species occurrences gathered during the development of the BDCP GIS mapping layers and covered species models (Appendix A, *Covered Species Accounts*) and other sources of information to assess the location, quantity, and quality of suitable habitat for covered wildlife and plant species on and near the project site. Results of planning surveys will be used to determine whether more intensive preconstruction and construction monitoring surveys are necessary. For example, if suitable habitat is not present for one of the covered species, the BDCP Implementation Office will not be required to conduct preconstruction surveys or construction monitoring for that species. For covered plant species, it is expected that follow-up floristic surveys (see AMM2) will be needed if the covered species are likely to be present on the project site but cannot be reliably identified to species at the time of the planning survey.

A survey report with the following information for the project site will be included with project application documents for covered activities and implementation of conservation measures:

- Description of the types of natural communities present in the project site, including the extent of each community;
- Description and map of locations of suitable habitat and/or habitat features for covered wildlife species;
- Description and map of potential habitat for covered plant species (e.g., vernal pools) based on soil type and land cover types;
- Map of all reported Covered Species occurrences;
- CNDDB California Native Species Field Survey Forms for all covered plants found on the site; and
- A description of the applicable avoidance and minimization measures required by the HCP/NCCP (e.g., preconstruction surveys).

Results of the planning survey will provide permit applicants with the information necessary to comply with the HCP/NCCP. Applicable avoidance and minimization measures described in this section must be incorporated into the project design and submitted with the application package. The BDCP Implementation Office will review and approve all planning survey reports before approving coverage under the HCP/NCCP. The Implementation Office will enter all relevant information in the survey reports into a database and use these data to monitor plan compliance.

*AMM2: Conduct preconstruction surveys for covered wildlife and plant species***.** If planning surveys for covered species identify suitable habitat and specific habitat elements (e.g. nest sites) described in the species habitat models (Appendix A, *Covered Species Accounts*), and if impacts cannot be avoided by modifying project design or project implementation, preconstruction surveys will be conducted. Preconstruction surveys are intended to determine the presence, status and likely impacts to covered species on the site. Results are used to identify or refine the site-specific measures required to avoid and minimize take. Permit applicants will be responsible for contracting with qualified biologists to conduct preconstruction surveys.

In general, preconstruction surveys will be conducted not less than 30 days or more than 6 months prior to commencement of construction activities on specific proposed construction sites, with the exception that preconstruction surveys may be completed up to one year in advance of construction if the sole period for reliable detection of a covered species is between May 1 and December 31. Detailed survey requirements are available for some covered species in existing

USFWS survey protocols, which will be used for the species listed in Table 3-16 (survey protocols are presented in Appendix I). It is expected that USFWS and DFG will refine these survey protocols and develop new protocols for other listed species in the future. In this case, the latest protocols and guidance from agencies will be followed.

Table 3-16. USFWS Preconstruction Survey Protocols

Covered Species	*Survey Protocol*
San Joaquin kit fox	USFWS San Joaquin Kit Fox Survey Protocol for the Northern Range (1999)
Riparian woodrat	USFWS Draft Habitat Assessment Guidelines and Survey Protocol for the Riparian Brush Rabbit and the Riparian Woodrat
Riparian brush rabbit	USFWS Draft Habitat Assessment. Guidelines and Survey Protocol for the Riparian Brush Rabbit and the Riparian Woodrat
California red-legged frog	USFWS Guidance on Site Assessments and Field Surveys for the California Red-legged Frog (2005)
California tiger salamander	USFWS Interim Guidance on Site Assessment and Field Surveys for Determining Presence or a Negative Finding of the California Tiger Salamander (2003)
Valley elderberry longhorn beetle	Document shrub and habitat conditions according to USFWS conservation guidelines

The BDCP Implementation Office will coordinate with USFWS and DFG to develop preconstruction survey protocols for the remaining covered wildlife and plant species. Components of preconstruction survey protocols for selected wildlife species are presented in Table 3-17.

Table 3-17. Preconstruction Survey Protocol Elements for Selected Wildlife Species

Covered Species	*Survey Protocol Element*
Salt marsh harvest mouse	Identify suitable habitat within 0.25 miles of the project footprint limits. Conduct preconstruction surveys of suitable habitat using USFWS and DFG approved survey protocols.
Townsend's big-eared bat	Identify suitable roost sites within 0.25 miles of the project footprint limits. Conduct preconstruction surveys of hibernation roosts and nursery roosts using USFWS and DFG approved survey protocols.
Suisun shrew	Identify suitable habitat within 0.25 miles of the project footprint limits for projects in the Suisun Marsh ROA and West Delta ROA. Conduct preconstruction surveys of suitable habitat using USFWS and DFG approved survey protocols.
Tricolored blackbird	Conduct preconstruction surveys in breeding habitat within 0.25 miles of BDCP project footprint limits (covered activities and habitat restoration projects). Preconstruction surveys will be conducted during the breeding season (approximately early April through late-August) prior to project activity, and during the construction year.
Suisun song sparrow, yellow-breasted chat, least Bell's vireo, and western yellow-billed cuckoo	Conduct preconstruction surveys of potentially-occupied breeding habitat within 0.25 miles from the project footprint limit (covered activities and habitat restoration projects). Preconstruction surveys will be conducted during the breeding season prior to project activity, and during the construction year.
Western burrowing owl	Conduct preconstruction surveys of breeding and wintering habitat within __ feet of the BDCP project footprint limit (covered activities and habitat restoration projects). Preconstruction surveys will be conducted during the breeding season (approximately March through August) or wintering season (approximately September through February) prior to project activity, and during the construction year.

Table 3-17. Preconstruction Survey Protocol Elements for Selected Wildlife Species (continued)

Covered Species	*Survey Protocol Element*
Greater sandhill crane	Conduct preconstruction surveys within the identified greater sandhill crane winter use area to determine the presence of occupied winter roost sites within 0.5 miles of the project footprint limits during late-October/early-November of each construction year.
California black rail California clapper rail	Identify suitable habitat within 0.25 miles of the project footprint limits. Conduct preconstruction surveys of suitable habitat using USFWS and DFG approved survey protocols.
White-tailed kite	Conduct preconstruction surveys of potentially-occupied breeding habitat within 0.25 miles from the project footprint limits and within 0.25 miles of planned restoration sites to locate active white-tailed kite nest sites. Preconstruction surveys will be conducted early (March-April) during the breeding season (March 1 to September 1), prior to project activity, and during the planned construction year.
Swainson's hawk	Conduct preconstruction surveys of potentially-occupied breeding habitat within 0.5 miles from the project footprint limits (covered activities and habitat restoration projects) to locate active Swainson's hawk nest sites. Preconstruction surveys will be conducted early (March 15 to April 20) during the breeding season (March 15 to September 1), prior to project activity, and during the planned construction year.
Giant garter snake	Identify suitable aquatic habitat (wetlands, ditches, canals) within project footprint limits. Conduct preconstruction surveys during active period (May 1 to September 30) of suitable habitat and 200 feet into adjacent uplands using USFWS and DFG approved survey protocols.
Western pond turtle	Identify suitable aquatic habitat and upland nesting and overwintering habitat within 0.25 miles of the project footprint limits. Conduct preconstruction surveys of suitable aquatic habitat using USFWS and DFG approved survey protocols.
Western spadefoot toad	Identify suitable aquatic habitat (vernal pools, ponds, pools along intermittent streams) for spadefoot toad within 0.25 miles of the project footprint limits. Conduct preconstruction surveys of suitable aquatic habitat during the breeding season (January to May) using USFWS and DFG approved survey protocols.

Additional survey requirements will apply to vernal pool habitats and associated plant and animal species. Surveys will be scheduled as specified in USFWS and DFG guidelines to ensure that vernal pool habitat is present. Vernal pools in BDCP project sites will be described, mapped and characterized in terms of duration, depth of ponding, and source of hydrology. Descriptive information for the site will include topography, drainage patterns and the extent of vegetative cover. Assessments should be made in consideration of "normal or average" conditions, if possible. Wildlife surveys following protocols listed in Tables 3-16 and 3-17 will include giant garter snake, western pond turtle, California red-legged frog, California tiger salamander and western spadefoot toad. The fairy shrimp and tadpole shrimp species surveys will follow USFWS-approved guidelines (USFWS Interim Survey guidelines to Permittees for Recovery Permits under Section 10(a)(1)(A) of the Endangered Species Act for the Listed Vernal Pool Branchiopods (1996)). Vernal pool plant species will be inventoried by floristic surveys following DFG Protocols for Surveying and Evaluating Impacts to Special Status Native Plant Populations and Natural Communities (2009) and USFWS Guidelines for Conducting and

Reporting Botanical Inventories for Federally Listed, Proposed and Candidate Plants (1996). In addition to requirements listed below for survey reports, vernal pool survey reports will include estimates of the size and acreage of direct and indirect impacts (as defined by seasonal inundation and other hydrology indicators, and the presence of hydric soils) on species that occur in the pool/pool complex.

Preconstruction surveys of other covered plant species will be conducted in suitable natural communities, using general habitat distribution models for these species (Appendix A, *Covered Species Accounts*). Surveys will be conducted during the appropriate season for identification of these species (i.e. floristic surveys). If covered plants or populations are found, the location, extent, and condition of all occurrences will be documented in the survey report. Any new records of sensitive plant species will be submitted to the CNDDB.

The BDCP Implementation Office will prepare a report with results of the preconstruction surveys and recommended minimization measures, and submit it to t the USFWS and DFG. The survey report will include the following elements:

- Survey dates, methods, timing and intensity;
- Map of survey area showing proposed BDCP project footprint and locations of covered wildlife and plant species occurrences;
- Description of status of wildlife species in occupied sites, (e.g. breeding);
- Description of special habitat features used by covered species (e.g. nest trees, caves, buildings);
- CNDDB field survey forms and maps for all covered animals and plants encountered on the site;
- A description of the applicable avoidance and minimization measures required by the HCP/NCCP and incorporated into project design or project implementation (e.g., construction timing, buffer width, buffer location); and
- Occurrences of covered species and other listed species will be documented in CNDDB forms.

*AMM3: Conduct Construction Monitoring***.** Construction-period monitoring by qualified biologists focuses on the covered natural communities and species identified during planning and preconstruction surveys, and is intended to ensure proper implementation of specific avoidance and minimization measures that have been integrated into the project design and permit requirements. Construction monitoring is the responsibility of the BDCP Implementation Office.

Before implementing an approved project, the BDCP Implementation Office will prepare a construction monitoring plan. The construction monitoring plan will include the following elements:

- Summaries or copies of planning and preconstruction surveys (if applicable) for covered natural communities and species;
- Description of avoidance and minimization measures to be implemented, including a description of project-specific measures or additional measures not included in the HCP/NCCP;
- Descriptions of monitoring activities, including the specific activities to be monitored (e.g. grading activities), monitoring frequency and duration; and
- Description of the onsite authority of the monitoring biologist to modify construction activity and protocols for consultation with DFG and USFWS, if needed.

*AMM4: Implement construction best management practices***.** Construction activities have the potential to affect covered species by removing natural habitat (i.e. vegetation), disturbing soils, and transporting sediments and pollutants, creating visual and noise disturbance, and introducing invasive and exotic species. In order to avoid and minimize these impacts, best management practices (BMPs) will be used to minimize new disturbances during construction and monitoring. These measures generally apply to all covered natural communities. BMPs include, but are not limited to:

- Construction activities will be staged to avoid, as much as possible, the sensitive time period for covered species that have been determined, through preconstruction surveys, to occur on the site. The sensitive time periods are defined in avoidance and minimization measures for each species in Section 3.4.5.3, *Species-Specific Avoidance and Minimization Measures*.
- Disturbance to existing grades and vegetation will be limited to the project site and necessary access routes. Placement of roads, staging areas, and other facilities will avoid and limit disturbance to stream bank or stream channel habitat as much as possible. When possible, existing egress points will be used and/or work will be performed from the top of stream banks. Upon completion, the contours of stream channels will be restored to pre-construction or better.
- Construction by-products and pollutants such as petroleum products, chemicals, cement, or other harmful materials will not be discharged into aquatic habitats, and will be collected and transported to an authorized disposal area.
- A plan for the emergency clean up of any spills of fuel or other material will be prepared and implemented, as needed.
- Water contained mud or silt from construction activities will be treated by filtration or retention in a settling pond to prevent turbid water from entering live streams.
- Equipment will be refueled and serviced at designated construction staging areas away from aquatic habitats. All construction material and fill will be stored and contained in a designated area that is located away from aquatic habitats. A silt fence will be installed to collect any discharge, and adequate materials for spill cleanup will be maintained on site.

- Construction vehicles and equipment will be maintained to prevent contamination of soil or water from external contaminants (i.e. grease and oil) or from leaking hydraulic, fluid, fuel, oil, and grease.
- Building material storage areas containing hazardous or potentially toxic materials will have an impermeable membrane between the ground and the hazardous materials and will be bermed to prevent the discharge of pollutants to ground water and storm water runoff.
- Project proponents will implement environmentally sound practices, utilize safer alternative products such as biodegradable hydraulic fluids, where feasible, and conduct employee training programs. Employee training will emphasize prevention and reduction of pollutant discharge from construction activities to aquatic habitats, and the appropriate measures to take should a spill occur.
- In-channel work will take place only in dry channels.
- If a work site is to be temporarily de-watered or filled, the de-watering and other required maintenance will be conducted during time frames specified for covered species (i.e. giant garter snake, California red-legged frog, California tiger salamander), see AMMs 20, 21, 22.

*AMM5: Establish setbacks and buffer zones***.** To the extent practicable, buffer zones dominated by native vegetation will be established between construction activities and covered natural communities, and nest, den or roost sites or covered species. Required buffers proposed by this measure are designed to maintain existing habitat value for covered species, reduce disturbance of species that use habitats protected by buffers, and provide wildlife movement corridors. With regard to streams and wetlands, buffer widths must be compatible with standards and requirements of existing regulatory programs, including the Clean Water Act and State regulations. Avoidance and minimization measures specific to buffers for covered riparian and aquatic communities include the following:

- Establish construction buffers for streams, measured horizontally from the top of the bank and extending the entire length of perennial, intermittent, and ephemeral streams (or linear wetland) within the boundaries of the project site.
- Stream buffer widths will be a function of stream order (e.g. first order), duration of flow, and location (i.e., agricultural, natural, or urban locations). Buffers will be determined in consultation with permitting agencies, and may be reduced with the concurrence of the permitting agencies if the reduction will not result in an adverse impact to the covered species or reduction in the biological values of the riparian or aquatic habitat. No setbacks are required on irrigation ditches, underground stream reaches, or on drainages and swales that lack a defined bed and bank or evidence of scour or sediment transport. The buffer must be marked throughout construction with stakes, fencing or other materials that will be visible to construction workers.

- Require appropriate erosion control measures (e.g. hay bales, filter fences, vegetative buffer strips or other equivalents) to reduce siltation and contaminated runoff from project sites. Brush, loose soils, or other debris materials will not be stockpiled within stream channels or on adjacent banks.
- Silt fencing or other sediment trapping method will be installed downgradient from construction activities to minimize the transport of sediment off site.
- Temporary stream diversions, if required, will use sand bags or other approved methods that minimize instream impacts and effects on wildlife.
- Limit removal of native vegetation as much as possible.
- Locate roadways and other facilities perpendicular to waterways wherever practical to reduce the total riparian area disturbed.
- Locate bridge and road footings outside of high water zones and riparian habitats where practical.
- Construction monitoring will be conducted throughout the construction period to ensure that buffers, BMPs, and other restrictions are being implemented properly.

3.4.5.2 Avoidance and Minimization Measures for Covered Natural Communities

*AMM6: Avoid and minimize impacts on vernal pool complex and alkali seasonal wetland complex***.** Natural community goals and objectives of the BDCP Conservation Strategy include the protection of vernal pool complex and alkali seasonal wetland complex and managed wetlands in and adjacent to the Plan Area that support habitat for associated native species. BDCP projects should avoid and minimize the fill of seasonal wetlands, vernal pools, and associated uplands, in particular the high value sites identified through implementation of Conservation Measure CM3 *Natural Communities Protection*. If planning surveys indicate that these communities are present in areas where fill is proposed, areas specified for avoidance will be protected with vegetated buffers that protect the wetland community and provide habitat for covered species and other native species. General buffer criteria are outlined in AMM5. Additional avoidance and minimization measures specific to vernal pool, vernal swale, alkali meadow, and alkali sink habitats, including their watersheds, and managed wetlands are as follows:

- Establish buffers measured horizontally from the edge of hydrophytic vegetation associated with the vernal pool;
- Vegetated buffers will consist of valley floor grassland and/or other natural vegetation communities (i.e, oak savanna/woodland, coastal marsh or riparian habitats);
- Buffer width will be sufficient to prevent significant adverse changes in water quality due to adjacent upland sources, or the inflow of water that could change the timing and duration of inundation of the wetland;

- Buffer width must be adequate to provide upland habitat for pollinators, amphibian species and terrestrial species;
- Buffer width must be adequate to provide connectivity between individual aggregations of vernal pools within a larger complex; and
- Buffer width must be adequate to protect the wetland and associated upland habitat from edge effects associated with surrounding land uses.

Buffer widths of 500 feet or greater will be presumed to meet these criteria. If avoidance is not practicable, the BDCP Implementation Office will provide documentation to USFWS and DFG explaining why avoidance is not practicable and/or would not contribute to the conservation goals and objectives of the BDCP. Smaller proposed buffer distances must be supported by assessments of the project's compliance with water quality/quantity criteria and assessments of habitat-related criteria.

AMM7: Avoid and minimize impacts on riparian communities. Natural community goals and objectives of the BDCP Conservation Strategy include increasing the extent and spatial distribution of riparian forest and scrub within the Planning Area to support habitat and food production for associated native species and increase connectivity among native habitats within and adjacent to the Plan Area. If planning surveys indicate that riparian communities are present in areas affected by BDCP projects, areas specified for enhancement, restoration or other actions under BDCP conservation measures will be protected by avoidance or minimization measures. General avoidance and minimization measures for riparian communities include establishing buffer zones (AMM5), construction period best management practices (AMM4), and construction period monitoring (AMM3). Additional avoidance and minimization measures specific to riparian communities include the following:

- Design project elements including roadways and other facilities perpendicular, rather than parallel to riparian zones and waterways whenever possible; and
- Locate bridge and road footings outside of high water zones and riparian habitats.

Except as noted below for covered wildlife species that inhabit riparian communities, riparian buffer widths will extend at a minimum to the outer dripline of riparian vegetation.

*AMM8: Implement Construction Best Management Practices for Fish Species***.** Construction of the proposed intake facilities in the North Delta have the potential to affect fish species, including covered species, by creating noise levels above ambient conditions during construction activities such as mobilization and demobilization of equipment, development of staging/storage areas and construction zones, creation of temporary detour roads, earthwork, deep excavation, shoring and bracing, levee construction, slurry cut-off walls, and coffer-damming, trenching, and other construction activities. In addition to increased noise, fish species could be affected by increased suspended sediments from pile installation, levee breaching, and dredging by decreasing visibility for foraging activities or impairing oxygen exchange due to clogged gills

(USEPA 1993). Moreover, the greatest effects from suspended sediments are to fish eggs, larvae, and juveniles (USACE 1992).

Best management practices (BMPs) will be used to avoid and minimize these impacts during construction. Although most fishes would likely move out of disturbed areas during construction and could return after these activities are completed, a number of protection measures would be used to further reduce affects to fish species, including:

- Preparing, maintaining, and implementing a Stormwater Pollution Prevention Plan (SWPPP) that contains all of the BMPs that would apply to all aspects of project construction.
- Placing and maintaining silt fences, coir logs, straw bale dikes, silt fences, and other siltation barriers so that silt or other deleterious materials does not enter the river.
- Settling, filtering, or otherwise treating construction-related water before discharge to minimize turbidity and siltation.
- Preventing raw cement and concrete, concrete wash water, bentonite, petroleum products, or other products that could be hazardous to aquatic life from contaminating soils, and/or entering streams, sloughs, or the river.
- Setting work windows during which the most sensitive lifestages of covered fish species are not generally found in the vicinity of the construction area.
- Dredging in front of the intake structure should be performed during a low river flow period, if possible, and a temporary silt screen should be provided to minimize suspended sediment movement into the river. This should coincide with the work windows set in the previous bullet.
- Vegetate or otherwise protect all disturbed surfaces to prevent erosion.

3.4.5.3 Species-Specific Avoidance and Minimization Measures

This section provides descriptions of avoidance and minimization measures for specific covered species. Several covered species are designated as fully protected by the California Fish and Game Code (§3511 and §4700), as DFG cannot issue permits for take of these species. Fully protected species in the Plan Area are: salt marsh harvest mouse, greater sandhill crane, California black rail, California clapper rail, and white-tailed kite.

Many of the avoidance and minimization measures described in this section are designed to provide opportunities for individual wildlife to avoid or escape construction areas.

AMM9: Avoid and minimize impacts on and mortality of San Joaquin kit fox. The BDCP Implementation Office will implement the 1999 USFWS Standardized Recommendations for Protection of the San Joaquin Kit Fox Prior to or During Ground Disturbance (see Appendix I) to avoid and minimize impacts on occupied kit fox sites. If preconstruction surveys (AMM2) identify a kit fox den in the proposed development footprint of a BDCP project site, the den will be monitored for 3 days by an agency-approved biologist using a tracking medium or an infrared beam camera to determine if the den is currently being used. Unoccupied dens should be destroyed to prevent subsequent use. If kit fox activity is observed at a den during the initial monitoring period, the den will be monitored for an additional 5 consecutive days from the time of the first observation. If an active natal or pupping den is found, USFWS and DFG will be notified immediately. The den will be excavated after the pups and adults have vacated and then only after further consultation with USFWS and DFG. For dens other than natal or pupping dens, use of the den can be discouraged by partially plugging the entrance with soil such that any resident animals can easily escape. Once the den is determined to be unoccupied it may be excavated under the direction of the biologist. Alternatively, if the animal is still present after 5 or more consecutive days of plugging and monitoring, the den may have to be excavated when, in the opinion of the biologist, it is temporary vacant (i.e. during the animal's normal foraging activities.).

If dens are identified outside the proposed disturbance footprint of a BDCP project site, exclusion zones around each den entrance or cluster of entrances will be demarcated. No construction-related activities will be allowed within the exclusion zone. Exclusion zone radius for potential or atypical kit fox dens will be at least 50 feet and 250 feet for all known occupied dens. The exclusion zone will be marked with flagged stakes.

*AMM10: Avoid and minimize impacts on and mortality of riparian woodrat and riparian brush rabbit***.** If preconstruction protocol surveys (AMM2) identify occupied riparian woodrat or riparian brush rabbit habitat along BDCP project construction corridors, avoid mortality by 1) reducing the corridor width to avoid occupied habitat, 2) if feasible, consider tunneling beneath the occupied riparian corridor, and 3) if appropriate, coordinate with the USFWS and DFG to develop a trapping and relocation program. All trapped animals will be relocated to approved sites prior to construction activities. If occupied habitat is present within proposed habitat restoration sites, avoid mortality and minimize impacts on individuals by 1) selecting alternative unoccupied restoration sites; or 2) designing the habitat restoration to avoid direct impacts on individuals, minimize impacts on habitat, and include riparian woodrat and riparian brush rabbit habitat in the restoration project design.

Implementation of avoidance and minimization measures for riparian habitat (see AMM7) will be considered sufficient to avoid take of these species in unoccupied potential habitat. Limited take of up to 3 acres of potential habitat (i.e. habitat conversion) for these species may occur under the HCP/NCCP for covered projects under the following conditions: 1) no individuals are encountered in preconstruction surveys, 2) the impact is less than 0.25 acres of habitat on a per-project basis, and 3) actions result in no harm, injury, or harassment of individuals.

*AMM11: Avoid and minimize impacts on Townsend's Big-eared Bat***.** If initial planning surveys, CNDDB search and habitat models (Appendix A, *Covered Species Accounts*) indicate suitable breeding or roosting sites for Townsend's big-eared bat are present on BDCP project sites, an agency-approved wildlife biologist will conduct preconstruction surveys to determine if they are occupied by the species. If the site is occupied, the BDCP permit applicant will avoid impacts to the extent practicable by relocating impacts at least 500 feet away from the occupied breeding or roosting site, and postponing construction activities that could disturb active roost sites while sites are occupied. Construction is allowed either prior to or after the hibernation season (November to March) for hibernation sites and prior to or after the breeding season (April to August 15) for nursery colonies. Avoidance and minimization measures will be incorporated into the project design.

If the project design cannot fully avoid impacts to roost sites, sealing the sites while they are unoccupied will allow bats to reestablish elsewhere. In this case, monitoring surveys will be conducted immediately prior to construction to determine if the sites are occupied or whether they show signs of recent previous occupation. If bats are discovered or if evidence of recent prior occupation is established in these surveys, construction will be scheduled such that it minimizes impacts on the bats. Unoccupied hibernation sites with evidence of prior occupation will be sealed before the hibernation season, and nursery sites will be sealed before the breeding season.

*AMM12: Avoid mortality of salt marsh harvest mouse***.** The salt marsh harvest mouse is a fully protected species under the California Fish and Game Code and direct mortality must be avoided. All construction activities will be done between May 1 and October 15, and locations of activities, such as levee breaches, will be sited to avoid potential salt marsh harvest mouse habitat. Salt marsh harvest mouse surveys using approved protocols will be conducted at the breach locations prior to excavation according the protocol specified by the USFWS. Surveys will be conducted for 7 consecutive days. If salt marsh harvest mouse is present at specific breach locations the captured animals will be relocated to a suitable alternate location on the property and surveys will continue until no mice are captured for 5 consecutive days. Vegetation will then be hand-removed, followed by another trapping sequence. To avoid the loss of individual salt marsh harvest mice from construction activities in suitable habitat, vegetation removal will be limited to the minimum extent necessary to permit the construction activity to occur. A sufficient extent of habitat, as determined by a DFG and USFWS approved biologist, will be allowed to remain adjacent to the construction area to provide refugia for displaced salt marsh harvest mice. Construction can commence after salt marsh harvest mice are not detected for 5 consecutive days following vegetation removal. If salt marsh harvest mice are not present, vegetation will be removed (by hand) from breach locations immediately following surveys. A qualified (with necessary permits from USFWS) biologist will walk in front of the excavator as it moves down the levee towards the breach location to flush any salt marsh harvest mice that may be in the vegetation on the levee crown and shoulders. No pets will be allowed on the work site and all persons will stay within the boundaries of the work site, which is the top of the levees and the water side levee slopes.

*AMM13: Avoid and minimize impacts on and mortality of Suisun shrew***.** Conduct preconstruction surveys to identify occupied habitat for the Suisun shrew within the area that could be impacted by BDCP actions in the Suisun Marsh Restoration Opportunity Area and potentially occupied habitats in the West Delta Restoration Opportunity Area. If Suisun shrews are present on project sites, avoid mortality and minimize impacts on individuals by 1) designing the habitat restoration to avoid the potential for mortality or 2) remove Suisun shrews from locations that could be affected by habitat restoration activities using DFG-approved methods and relocating them to DFG-approved sites. Direct mortality will be avoided by establishing a 200 foot buffer adjacent to suitable tidal marsh habitats, in which no construction activity or disturbance is permitted.

AMM14: Avoid and minimize impacts on tricolored blackbird. Conduct preconstruction surveys within known or suitable nesting habitat no more than 30 days prior to scheduled construction to identify active tricolored blackbird colonies within a BDCP project site. Avoid mortality and minimize impacts by creating a 500-foot no-disturbance buffer around each active colony and allow no entry of any kind into the buffer while the colony site is occupied during the breeding season (approximately mid-March through mid-August). Entry into the buffer may be granted if a qualified biologist, with concurrence from USFWS and DFG, determines through monitoring surveys that healthy young have fledged and nest sites are no longer active, or nesting birds do not exhibit significant adverse reaction to construction activities.

AMM15: Avoid and minimize impacts on Suisun song sparrow and California least tern. Conduct preconstruction surveys of potential breeding habitat for the Suisun song sparrow and California least tern within 0.25 miles from the project footprint limit of habitat restoration projects in the Suisun Marsh Restoration Opportunity Area and potentially occupied habitats in the West Delta Restoration Opportunity Area. Preconstruction surveys will be conducted during the breeding season prior to project activity. If an active Suisun song sparrow nest is present, avoid mortality and minimize impacts by creating a minimum 500-foot no-disturbance buffer around the nest site and allow no entry of any kind into the buffer while the site is occupied during the breeding season (approximately early April through late August). Entry into the buffer may be granted if a qualified biologist, with concurrence from USFWS and DFG, determines through monitoring surveys that healthy young have fledged and nest sites are no longer active, or nesting birds do not exhibit significant adverse reaction to construction activities.

AMM16: Avoid and minimize impacts on yellow-breasted chat, least Bell's vireo, and western yellow-billed cuckoo. Conduct preconstruction surveys of potential breeding habitat for the yellow-breasted chat, least Bell's vireo, and western yellow-billed cuckoo within 0.25 miles from the project footprint limit of habitat restoration. Preconstruction surveys will be conducted during the breeding season prior to project activity. If an active yellow-breasted chat nest site is present, avoid mortality and minimize impacts by creating a 1,300-foot no-disturbance buffer around the nest site and allow no entry of any kind into the buffer while the site is occupied during the breeding season (approximately early April through late-August). Entry into the buffer may be granted if a qualified biologist, with concurrence from USFWS and DFG, determines that healthy young have fledged and nest sites are no longer active, or nesting birds do not exhibit significant adverse reaction to construction activities.

*AMM17: Avoid and minimize impacts on nesting and wintering burrowing owls***.** If preconstruction surveys identify occupied breeding burrows within a BDCP project site, establish a 250-foot no-disturbance buffer around each occupied breeding burrow and allow no entry of any kind into the buffer while the site is occupied during the breeding season (approximately February 1 through August 31). The buffer may be reduced through consultation with a qualified biologist and with concurrence from USFWS and DFG based on line-of-sight, topography, land uses, type of disturbance, and other relevant factors. Entry into the buffer is granted when a qualified biologist, with concurrence from USFWS and DFG, determines that healthy young have fledged, are capable of independent survival, and nest sites are no longer active.

Avoid disturbance to winter burrows by creating a 160-foot no-disturbance buffer around each occupied wintering burrow and allow no entry of any kind into the buffer while the site is occupied during the winter season (approximately September 1 through January 31). The buffer can be reduced through consultation with a qualified biologist and with concurrence from USFWS and DFG based on line-of-sight, topography, land uses, type of disturbance, monitoring of the site to evaluate reaction to disturbances, and other issues. If direct impacts to active winter burrows cannot be avoided and the site is also used for breeding, implement standard DFG guidelines for passive relocation by installing one-way doors on active winter burrows (see Appendix I).

*AMM18: Avoid and minimize impacts on and avoid mortality of greater sandhill cranes***.** The greater sandhill crane is fully protected under the California Fish and Game Code and direct mortality must be avoided. If preconstruction surveys determine that a greater sandhill crane roost site is located within or adjacent to a BDCP project site, a 0.5 mile no-disturbance buffer will be established around each identified roost area. Construction and other work activity in the buffer will be restricted based on crane use patterns of the roost while the site is occupied during the winter season (approximately October 1 through February 28). During the roosting season, construction equipment greater than 50 feet in height will avoid locations that could lead to strikes by greater sandhill crane. When locating permanent facilities that could pose a bird strike hazard for greater sandhill crane, specific site locations will be chosen that minimize bird strike hazard to greater sandhill crane. Bird strike risk to greater sandhill crane will be considered when locating transmission, sub-transmission, and distribution power lines and conductor and ground lines will be fitted with flight diverters in compliance with the best available practices such as those specified in the USFWS Avian Protection Guidelines.

*AMM19: Avoid and minimize impacts on and avoid mortality of California black rail and California clapper rail***.** The California black rail and the California clapper rail are fully protected species under the California Fish and Game Code and direct mortality must be avoided. In areas with habitat for California black rail or the California clapper rail, as determined by planning surveys, work will be conducted outside of the breeding season during the period from September 1 to January 31, and no buffers will be required. To avoid the loss of individual rails, construction or other work activities within or adjacent to rail habitat will not be allowed in the time period within two hours before or two hours after local mean higher high tide to allow fleeing rails to reach cover. This restriction may be modified in consultation with DFG and USFWS if mean higher high tides during work periods are not sufficient to increase the likelihood for affecting individual birds. Activities conducted during the breeding season will implement the specific avoidance and minimization measures. If preconstruction surveys, using agency accepted protocols, determine that California black rail or California clapper rail are nesting within or adjacent to BDCP project sites, a 500-foot buffer will be established within which no activities will be allowed that could disturb the nesting pair or their young. The size of the no-disturbance buffer zone may be reduced if a qualified biologist determines, in consultation with DFG and USFWS, that the birds would be unaffected by project-related activities. An example in which a buffer distance would be reduced is in instances in which a major slough channel or other substantial physical barrier exists between the rail nest site and the activity. Buffers will be maintained until the young have fledged and are capable of flight (typically prior to September 15).

*AMM20: Avoid and minimize impacts on white-tailed kite and Swainson's hawk and avoid mortality of white-tailed kites***.** The white-tailed kite is a fully protected species under the California Fish and Game Code and direct mortality must be avoided. Preconstruction surveys will be conducted for active raptor nest sites (i.e. trees) within and adjacent to (within 0.5 miles) BDCP project sites. For construction scheduled during the breeding season of white-tailed kite and Swainson's hawk (March 15-September 15), surveys will take place no more than 30 days prior to the start of construction. A 1,000-foot radius no-disturbance buffer will be established around each active white-tailed kite nest site and at 0.25 mile radius around each Swainson's hawk nest site. No entry of any kind related to the BDCP construction activity will be allowed in the buffer while a nest site is occupied by white-tailed kite or Swainson's hawk during the breeding season. The buffer size may be reduced on the determination of a qualified biologist and with concurrence from USFWS and DFG based on line-of-sight, topography, land use, type of disturbance, existing ambient noise and disturbance levels, and other relevant factors. Entry into the buffer will be granted when a qualified biologist, with concurrence from USFWS and DFG, determines that the young have fledged and are capable of independent survival and the nest site is no longer active. If nest tree removal is necessary, tree removal will occur only during the non-breeding season (September through February).

*AMM21: Avoid and minimize impacts on giant garter snake***.** To the extent practicable, implement BDCP project site-specific measures approved by USFWS and DFG to avoid and minimize impacts on giant garter snake, as follows: Limit habitat disturbance to the period May 1 to September 30 (the active period for snakes) to minimize direct mortality, and dewater irrigation ditches, canals or other aquatic habitat, if needed, between April 15 and September 30. Dewatered areas must remain dry for at least 15 consecutive days prior to excavation or filling the habitat. If a site cannot be completely dewatered, netting and salvage of prey items may be necessary to discourage use by giant garter snakes.

Impacts to giant garter snakes may be minimized by the following measures: (1) From October to April, construction should be limited to in-channel work below OHWM and channel banks should not be disturbed. (2) During the dormant period, dredged or excavated material should be hauled off-site to discourage use by overwintering snakes. (3) Clearing of vegetation in aquatic habitats and channel banks should be limited to the minimum necessary to facilitate construction. (4) Movement of heavy equipment should be confined to existing roads and tops of channel banks. (5) No erosion control material containing nylon mesh or monofilament may be used within 200 feet of suitable giant garter snake aquatic habitat.

AMM22: Avoid and minimize impacts to western pond turtle and California red-legged frog. Conduct preconstruction USFWS and DFG-approved surveys to determine if suitable aquatic habitat is present for California red-legged frog and western pond turtle within one mile of BDCP project sites. The survey period for red-legged frogs extends from January to September, and surveys should be conducted two weeks prior to the beginning of construction activities during this period. The survey period for western pond turtle will be determined in consultation with the agencies. Guidelines for sampling habitats and site occupancy of western pond turtles are in preparation (Bury 2009, pers. comm.), and may be implemented with agency approval.

If occupied sites consist of isolated pools or ponds, avoid disturbance to these sites within or near the project footprint to the extent feasible and minimize the loss of occupied and potentially occupied aquatic habitat and grassland vegetation through adjustments in project design, as practicable. If occupied sites are along streams or other channels, install temporary aquatic barriers and relocate and exclude animals from the work area. A 500 foot buffer will be established on both sides of creeks and wetlands occupied by red-legged frogs or western pond turtles, and entry will be restricted during the construction period. Buffers may be reduced if a qualified biologist determines, in consultation with DFG and USFWS, that 1) the reduction would not affect habitat (e.g., a stream crossing project is directionally bored under the occupied habitat), or 2) the reduction will not result in an adverse impact to the species or reduction in the biological values of the habitat.

Direct mortality for California red-legged frogs and western pond turtles in irrigation ditches and canals can be minimized by implementing de-watering measures described for giant garter snake (AMM20), screening water intakes, and removing predators such as crayfish, bullfrogs and warm-water fish from aquatic habitats in the project site. Construction activities should avoid creation of perennial ponds in occupied sites that could result in the expansion of predator populations. Permit applicants will coordinate with the USFWS and DFG to develop a trapping and relocation program and to develop appropriate seasonal restrictions to minimize mortality. Individuals found within the construction footprint will be captured and relocated to designated relocation habitat approved by USFWS and DFG.

*AMM23: Avoid and minimize impacts on western spadefoot toad and California tiger **salamander**.* Conduct preconstruction USFWS approved surveys to determine if California tiger salamanders or western spadefoot toads are present in suitable aquatic and upland habitat within

1.24 miles of BDCP project sites. Aquatic larval sampling for California tiger salamanders is conducted in March, April, and May; upland sampling of adults is conducted from October through March. The survey period for western spadefoot toads will be determined in consultation with the agencies.

Avoid disturbance to occupied sites within or near the project footprint to the extent feasible and minimize the loss of occupied and potentially occupied seasonal pool and grassland vegetation through adjustments in project design, as practicable. As needed, permit applicants will coordinate with the USFWS and DFG to develop appropriate seasonal restrictions to minimize mortality. Dewatering of aquatic habitats will take place outside of the breeding season (December to June). Construction activities should avoid creation of perennial ponds in occupied sites that could result in the expansion of predator populations. Permit applicants will coordinate with the USFWS and DFG to develop a trapping and relocation program. Individuals found within the construction footprint will be captured and relocated to designated relocation habitat approved by USFWS and DFG. .

*AMM24: Avoid and minimize impacts on valley elderberry longhorn beetle***.** Avoid disturbance to elderberry shrubs large enough to support beetle habitat within or near the project footprint to the extent practicable through adjustments in project design. For ground-disturbing activities within 100 ft around elderberry shrubs with stems > 1 inch, establish a 20 ft buffer from the dripline of each plant. No harmful chemicals will be applied within 100 ft of the buffer. Protected elderberry bushes may be trimmed during the dormant period (November to mid-February), and grasses may be mowed within the buffer from July to April.

*AMM25: Avoid impacts on covered plant species associated with tidal mudflats, tidal emergent wetlands, and valley/foothill riparian communities***.** If occurrences of side-flowering skullcap slough thistle, Suisun thistle, soft bird's-beak, Delta tule pea, Mason's lilaeopsis, Delta mudwort, or Suisun marsh aster could be affected by BDCP actions, to the extent practicable, implement the proposed BDCP actions to avoid the direct loss of plants. Establish a 100 foot buffer around known populations of covered plants, and place temporary fences around plants to be avoided during construction. Minimization of impacts to side-flowering skullcap, where side-flowering skullcap is present on stumps or other substrate, may occur through the movement and transplantation of the substrate and plants to appropriate sites in the immediate vicinity.

*AMM26: Avoid and minimize impacts on covered plant species associated with alkali seasonal wetland complex, vernal pool complex, other natural seasonal wetlands, and grassland habitats***.** If occurrences of alkali milk-vetch, heartscale, brittlescale, San Joaquin spearscale, slough thistle, Delta button-celery, Boggs Lake hedge-hyssop, Carquinez goldenbush, Legenere, Heckard'pepper-grass, or caper-fruited tropidocarpum are detected within BDCP project sites, design and implement proposed BDCP actions to avoid the direct loss of any of these covered plants. To the extent practicable, implement project site-specific measures approved by the USFWS and DFG to avoid and minimize impacts on these species. Avoidance of impacts may require case-by-case review with DFG and/or USFWS. Impacts to plants that occur in vernal pool habitat may be avoided or minimized by implementing measures provided in AMM6. For plants occurring in other covered communities, establish a 250 foot buffer around covered plant populations, and avoid disturbance to adjacent areas that support the hydrological regime of the plants.

*AMM27: Avoid and minimize impacts on soft bird's-beak and Suisun thistle***.** If occurrences of soft bird's-beak and Suisun thistle are detected within BDCP project sites, design and implement proposed BDCP actions to avoid the direct loss of any of these covered plants. Implement project site-specific measures approved by the USFWS and DFG to avoid and minimize impacts on these species. Avoidance of impacts may require case-by-case review with DFG and/or USFWS. Establish site appropriate buffers with approval of USFWS and DFG around covered plant populations.

3.5 Potential Conservation Measures to Address Other Stressors

*[**Note to Reviewers:** As the BDCP Conservation Strategy is refined over the next several months, the Potential Conservation Measures described in this section will be further evaluated to determine whether they should be included as conservation measures in the initial BDCP or remain as potential actions that may be adopted as conservation measures at a later date, pursuant to the adaptive management program. The Steering Committee believes that the concepts reflected in these potential conservation measures may effectively address a number of other stressors, but that they require further development before they can serve as conservation measures. As such, Potential Conservation Measures will not be used by the fish and wildlife agencies to provide the basis for the issuance of regulatory authorizations for the BDCP.]*

3.5.1 Introduction

The BDCP Conservation Strategy includes a number of conservation measures that address environmental stressors not related to water operations or physical habitat restoration, preservation, or management. Such measures, which are referred to as "other stressor conservation measures," have the potential to improve the quality of Delta's ecological conditions to the benefit of covered fish species. Some other stressor conservation measures are described in Section 3.4.4, *Species Level Other Stressor Conservation Measures*. The Steering Committee indentified additional actions that address other stressors, referred to as "important related actions" (IRAs) that could potentially become conservation measures.

Because of these potential conservation measures could reduce other stressors to benefit ecological conditions in the Delta, the BDCP establishes the requirement that the BDCP Program Manager take the steps necessary, through the adaptive management process, to determine whether these potential conservation measures identified in this section should ultimately be adopted as new conservation measures. The following are potential conservation measures to address other stressors:

- Ammonia Load Reduction;
- Endocrine Disrupting Compounds Load Reduction;
- Agricultural Pesticides and Herbicides Runoff Reduction;
- Stormwater and Urban Runoff Toxic Contaminants Reduction;
- Nonnative Aquatic Organisms Introduction Risk Reduction;
- Nonnative Species Introduction Detection and Response Improvement;
- Nonnative Predatory Fish Harvest Increase;
- Mark-Selective Fishery Implementation; and
- Non-Project Diversions Entrainment Reduction.

The approach to the implementation of these potential conservation measures under the BDCP is described in Section 3.5.2, *Implementation of Potential Conservation Measures to Address Other Stressors*. Descriptions of these additional other stressor conservation measures are provided in Section 3.5.3, *Descriptions of Potential Conservation Measures to Address Other Stressors*.

3.5.2 Implementation of Potential Conservation Measures to Address Other Stressors

The potential conservation measures described in Section 3.5.3, below, may be enacted during the course of Plan implementation through the BDCP adaptive management program (Section 3.7 *Adaptive Management Program*). As monitoring and research improve scientific knowledge about the effects of other stressors on covered fish species, the level of uncertainty will diminish regarding the importance of such stressors for the fish and the effectiveness of actions to reduce such stressors. Through the adaptive management process, measures to address other stressors that are proven to be effective in the conservation of covered fish species will be more fully developed and implemented by the BDCP Program Manager or the Program Manager will seek to have the measures implemented by other entities that has the authority to do so.

In certain instances, the Program Manager may identify mechanisms to create intergovernmental partnerships between BDCP authorized entities and the agencies that have jurisdiction over the environmental effects that the other stressor measures would address. These interagency partnerships may be used to advance studies, actions, and enforcement to reduce the adverse effects of the stressors on fish. The Program Manager, through the BDCP Science Manager, may work with the Delta Independent Science Board, Delta Science Program, State Water Resources Control Board, Regional Water Quality Control Boards, and others to support research necessary to clarify the science and assure implementation of corrective actions related to other stressors.

The Program Manager, BDCP Implementation Board, and BDCP Stakeholder Committee members will work to encourage all state and federal agencies, boards, and commissions that have regulatory authority in the Plan Area to exercise that authority to reduce the impact of other stressors on the covered species and will encourage those entities to provide funding to support those activities in their annual budgets. The Program Manager, Implementation Board, and Stakeholder Committee members will encourage state and federal agencies to seek opportunities to take or support actions that implement BDCP conservation measures that address other stressors. The Program Manager and Implementation Board may consider incorporating new other stressors measures into the BDCP, through the adaptive management process, as they are identified by the state and federal agencies.

The Program Manager, through the Science Manager, will advocate and pursue research to continue evaluation of other stressors and engage the regulatory agencies to take actions based upon improved scientific understanding to reduce the effects of these stressors on the health of at risk fish species in the Delta. The Program Manager will initially focus on ammonia effects on covered fish species and regulatory actions to eliminate those effects.

3.5.3 Descriptions of Potential Conservation Measures to address Other Stressors

*[**Note to Reviewers:** This section will include descriptions of potential conservation measures to address other stressors, i.e., all the Important Related Actions (IRAs).]*

3.5.3.1 Ammonia Load Reduction

3.5.3.2 Endocrine Disrupting Compounds Load Reduction

3.5.3.3 Agricultural Pesticides and Herbicides Runoff Reduction

3.5.3.4 Stormwater and Urban Runoff Toxic Contaminants Reduction

3.5.3.5 Nonnative Aquatic Organisms Introduction Risk Reduction

3.5.3.7 Nonnative Species Introduction Detection and Response Improvement

3.5.3.8 Nonnative Predatory Fish Harvest Increase

3.5.3.9 Mark-Selective Fishery Implementation

3.5.3.11 Non-Project Diversions Entrainment Reduction

3.6 MONITORING AND RESEARCH PROGRAM

*[**Note to Reviewers:** This draft of the Monitoring and Research Program is revised from the July 27, 2009 draft. The two large monitoring actions tables included in this section are initial drafts that will be revised and refined, as described in the Note to Reviewers in Section 3.3. It is expected that a section will be added in future drafts, specifying in more detail the issues to be addressed by the research program and focus for additional research needs.]*

The BDCP Conservation Strategy provides flexibility for adjustments to be made over time as additional information becomes available about the ecological systems and processes of the Delta and the effect of the BDCP conservation measures on those systems and processes. Monitoring and research are critical elements of adaptive management, providing the data and analysis needed to inform decision-making. Information gained through monitoring and research also provides the basis for determining the effectiveness of the Conservation Strategy over time. A well-designed monitoring and research program is essential for the success of BDCP.

Monitoring will play four crucial roles in the implementation of the BDCP. First, it will provide basic information necessary to track Plan commitments and compliance with the terms and conditions of regulatory authorizations. Second, it will provide information about the current state of the system against which change can be assessed. Third, it will provide information about the changing state of the system as conservation actions are implemented that can be used to assess system response and progress toward achieving the Plan's goals and objectives over time. Finally, monitoring provides important information about implementation of conservation measures that can be used to increase their effectiveness.

Program evaluation involves compiling and synthesizing monitoring data to evaluate program success and support adjustments over time, including revising program objectives and actions. Program evaluation will also be used to support the Implementation Office's efforts to communicate information to the public about the status of the BDCP (Section 3.7, *Adaptive Management Program*, discusses the program evaluation).

Information derived from research efforts will provide the basis for addressing key uncertainties and testing hypotheses that underpin various conservation measures. Research supports learning, a better understanding of the processes driving the system, and an improved knowledge base upon which informed decisions can be made regarding management interventions. Given the complexities of the Delta ecosystem, and the uncertainties regarding the outcomes that will result from the implementation of certain conservation measures, research and other information-gathering efforts will help ensure the success of the Plan.

This section describes key elements of the BDCP monitoring and research program, including: the parties responsible for implementing the monitoring program; the framework for integrating monitoring data to support program evaluation and reporting; the manner in which the BDCP monitoring program will interface with other monitoring programs; the types of monitoring that will be conducted; the process that will be used to develop site-specific monitoring plans; and the process that will be used to develop a research program. For more information on the Adaptive Management Program, including the role of monitoring and research in the adaptive management process, see Section 3.7, *Adaptive Management Program*.

Site-specific monitoring plans for each conservation measure, as well as a specific research agenda, will be prepared as part of the BDCP implementation process. These plans will be reviewed on a regular basis and adjustments made in response to new information and/or identified research needs. Plan implementation, monitoring, analysis and research, are all part of an overall adaptive management process. This process is not intended to be a stand-alone process, but rather one that integrates information to facilitate decision making, including decisions to adjust the design and implementation of conservation measures, and the type and extent of monitoring associated with those measures, as the Plan is implemented.

Because the Delta reflects a highly altered ecosystem, with limited reference sites for historical conditions, the monitoring program and the evaluation framework will rely heavily on Before/After and Control/Impact (BACI) design approaches to assess ecosystem change (Green 1979, Underwood 1992, Underwood 1994). Although the BACI approach is typically presented as a means for testing whether an impact to the system has occurred, it is technically a model that tests for changes in conditions. The model may also be used to evaluate conservation and restoration projects (Michener 1997 and Lincoln-Smith et al 2006) and test if conditions are improving. These types of monitoring approaches are commonly used in restoration ecology, particularly where numerous natural and anthropogenic disturbances represent unplanned, uncontrollable events that cannot be replicated or studied using traditional experimental approaches and statistical analyses. Ultimately, experience in restoration ecology suggests using a broad mix of appropriate research approaches (e.g., long-term studies, large-scale comparative studies, space-for-time substitution, modeling, manipulative experiments, and focused experimentation) and analytical tools (e.g., observational, spatial, and temporal statistics) (Michener 1997).

Evaluating discernable changes in environmental conditions is often difficult, due to the multitude of interacting factors. It is often not clear which environmental component will be affected by a stressor reduction and what type of change will result. A changing environment is natural and variation due to natural effects may be great (Smith 2002). To account for this, BDCP monitoring designs will be informed by the location and timing of effects expected to occur (both spatially and temporally), what organisms are expected to be affected (fish, wildlife, plants, aquatic invertebrates, etc.), what the expected benefits are (magnitude, duration), potential mitigating factors (including distribution and exposure), and how various factors may alter exposure and effect.

The BDCP monitoring program will be conducting sufficient baseline monitoring to establish the "before" condition against which change can be compared. This will entail both assessing existing data bases and determining what new measurements will be useful prior to the implementation of a conservation measure.

The monitoring program outlined in this chapter is consistent with the guidance provided by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service in the "Five-Point Policy" for Habitat Conservation Plans (HCP)[38] and provisions of the Natural Community Conservation Planning Act (NCCPA)[39] . As described in the Five-Point Policy, the monitoring

[38] 65 FR 106, June 1, 2000

[39] Fish and Game Code Sections 2810(a)(7)

program of a conservation plan should generate information sufficient to guide plan implementation, particularly with respect to the following matters:

> *"(1) assess the implementation and effectiveness of the HCP terms and conditions (e.g., financial responsibilities and obligations, management responsibilities, and other aspects of the incidental take permit, HCP, and the IA, if applicable); (2) determine the level of incidental take of the covered species; (3) determine the biological conditions resulting from the operating conservation program (e.g., change in the species' status or a change in the habitat conditions); and (4) provide any information needed to implement an adaptive management strategy, if utilized. An effective monitoring program is flexible enough to allow modifications, if necessary, to obtain the appropriate information."*[40]

The BDCP research program will be implemented to address specific scientific questions regarding: (1) covered species; (2) natural communities; and (3) ecosystem processes to increase the base of knowledge about these resources such that conservation measures can be adaptively implemented to advance biological goals and objectives. Specifically, the BDCP monitoring and research program will be conducted primarily to:

- Document compliance with terms and conditions of BDCP regulatory authorizations, including limits established for the incidental take of covered species;
- Increase and refine scientific understanding of the effects of the covered activities (Chapter 4, *Description of Covered Activities*) on covered species and natural communities;
- Collect data necessary to effectively implement conservation measures;
- Document and evaluate the effectiveness of conservation measures in achieving BDCP biological goals and objectives;
- Test the scientific hypotheses on which the assessment of effects and effectiveness are based; and
- Assess progress towards achieving the biological goals and objectives both specific to conservation actions and Delta-wide.

3.6.1 Responsibility for the Monitoring and Research Program

The Implementation Office (IO) Science Manager, under the direction of the BDCP Program Manager, will be responsible for the overall management and oversight of the BDCP monitoring and research programs, including the implementation of monitoring-related activities (see Section 7.3.4, *Management of Biological Monitoring, Scientific Research, and Reporting Programs*). The Science Manager, with the support of the Interagency Ecological Program (IEP), will be responsible for developing and overseeing the implementation of the monitoring

[40] 65 FR 106, June 1, 2000; 35254

and research program activities. The Science Manager may further utilize the Delta Science Program and Independent Science Board to review and provide input on aspects of the monitoring and research program. The IO may look to the Authorized Entities and Supporting Entities (see Chapter 7, *Implementation Structure*) to conduct monitoring activities on specific conservation actions, as appropriate.

The BDCP Science Manager will be responsible for ensuring that the BDCP science activities, reporting, and reviews are coordinated with other science activities being conducted in the Delta. The Science Manager will seek the assistance of the Lead Scientist of the IEP and the Chief Scientist for the Delta Science Program to ensure that BDCP science activities, reporting, and reviews are coordinated with other science activities being conducted in the Delta.

3.6.2 Monitoring Framework

The following outlines a framework for integrating monitoring data to support program evaluation and reporting. The BDCP Evaluation Framework is described in Section 3.7, *Adaptive Management Program*. Specific types of monitoring (baseline, compliance, effectiveness, and system-wide) that will feed the evaluation framework (as well as other plan reporting requirements) are described in more detail in Section 3.6.4, *Types of Monitoring*.

The BDCP monitoring framework as presented herein is modeled after the successful Ecosystem Health Monitoring Program used as part of the Healthy Waterways Initiative in South East Queensland, Australia (South East Queensland Healthy Waterways Partnership 2007). The framework tracks indicators for five basic ecological conditions that collectively reflect the overall health of the ecosystem. For the BDCP, the monitoring and evaluation framework is divided into five ecological categories: (1) ecological processes; (2) physical and chemical conditions (including nutrients); (3) food webs; (4) natural communities; and (5) fish, wildlife, and plants. A select set of key indicators for these five characteristics will be measured for the appropriate geographic area to assess status and trends. Specific indicators, metrics and sampling designs will vary depending on the regional area.

Table 3-18 illustrates how the BDCP monitoring and evaluation framework could be structured. An example of all likely possible monitoring elements was developed for the implementation of a project at Suisun Marsh under the CM4, *Tidal Habitat Restoration*. It is expected that frameworks for other conservation measures will be developed and refined during plan implementation using this as an example of the types of elements that could be included.

Table 3-18. Example Framework For Southern Suisun Marsh Monitoring and Metrics

*[**Note to Reviewers:** Table in development. To come]*

3.6.3 Integration of Monitoring and Research with Other Programs

Monitoring of covered species and many ecosystem conditions that are relevant to BDCP implementation is currently undertaken by a number of entities, including IEP, Delta Science Program, California State University Endangered Species Recovery Program, USGS, DFG, DWR, USFWS, Reclamation, NOAA Fisheries Science Center, and UC Davis. As an example of the types of monitoring data that are currently being collected, Table 3-19 lists some of the fisheries monitoring data that is coordinated by the IEP.[41]

In addition to fish monitoring, there is a considerable amount of water quality monitoring that is currently being conducted in the Delta. The Environmental Monitoring Program (which also monitors lower trophic levels) is part of the IEP, while programs tracking environmental contaminants currently are not. The new Delta Regional Monitoring Program is intended to coordinate these programs.[42] [43]

Most of the existing Delta monitoring efforts are being implemented as conditions of existing regulatory authorizations and many are coordinated under the IEP umbrella. The IEP has been instrumental in coordinating Delta monitoring and research activities conducted by State and federal agencies and other science partners for 40 years. IEP monitoring activities are generally carried out in compliance with Water Right Decision and Endangered Species Act permit conditions. Most of the existing IEP-coordinated monitoring focuses on open water areas and the major Delta waterways conveying water to the SWP and CVP facilities in the south Delta. A new regional monitoring program intended to coordinate Delta water quality monitoring in compliance with Clean Water Act permit conditions is currently under development by the Central Valley Regional Water Quality Control Board. A similar regional monitoring program already exists for San Francisco Bay and is carried out by the San Francisco Estuary Institute, a non-profit research organization.

Due to their permit-driven nature, none of the existing long-term monitoring programs focus explicitly on monitoring ecological processes and habitats. Perhaps as a result, there has never been an integrative "Ecosystem Health" assessment similar to the Australian example mentioned in Section 3.6.2, Monitoring Framework. The "Are Our Aquatic Ecosystems Healthy?" portal[44] currently under development by the California Water Quality Monitoring Council (WQMC) may provide an opportunity to better organize, integrate, evaluate, and communicate data and information about the health of the Delta relative to other aquatic ecosystems in California and changes in Delta ecosystem health associated with the BDCP and other programs. The WQMC is based on an interagency MOU mandated by California Senate Bill 1070 (Kehoe, 2006) and

[41] A more complete summary of the IEP fish monitoring programs can be found at: http://www.water.ca.gov/iep/docs/IEP_FishMonitoring_final.pdf.

[42] For information on this new Delta Regional Monitoring Program see http://www.swrcb.ca.gov/rwqcb5/water_issues/delta_water_quality/comprehensive_monitoring_program/index.shtml).

[43] A recent summary of existing water quality monitoring programs can be found at http://www.swrcb.ca.gov/rwqcb5/water_issues/delta_water_quality/comprehensive_monitoring_program/draftfinal_deltamon_25nov09.pdf

[44] See the portal at http://www.waterboards.ca.gov/mywaterquality/

requires the boards, departments and offices within the California Environmental Protection Agency (Cal/EPA) and the California Natural Resources Agency to integrate and coordinate their water quality and related ecosystem monitoring, assessment, and reporting.

The Science Manager will coordinate with the IEP and other entities involved in monitoring programs and will use data collected through these programs, as appropriate, to support evaluation of the effectiveness of the BDCP Conservation Strategy in achieving biological goals and objectives and to assess the long-term status and trends of covered species populations and ecosystem conditions.

Table 3-19. Sample Listing of Existing Bay-Delta Fish Monitoring Programs Coordinated through the Interagency Ecological Program (IEP)

Monitoring Program	*Agency*	*Primary Purpose*	*Available Data for BDCP*
Spring Kodiak trawl	DFG	Monitors spawning adult delta smelt distribution, relative abundance, and reproductive status, January-May, 2002-present	Spawning abundance index, distribution, sex ratios, reproductive status (e.g., pre-spawn, mature, or spent)
20 mm tow net survey	DFG	Monitors post larval-juvenile delta smelt distribution and relative abundance, March-June, 1995-present	Post larval and juvenile abundance index, distribution, length frequency
Summer tow net survey	DFG	Monitors striped bass and delta smelt abundance indices, July-August, 1959-present	Delta smelt: juvenile delta smelt abundance index, distribution, and length frequency. Longfin smelt: post larval juvenile longfin smelt abundance index, distribution, and length frequency. Sacramento splittail: YOY splittail, distribution, and length frequency
Fall midwinter trawl	DFG	Monitors striped bass and delta smelt abundance indices, September-December, 1967-present	Delta smelt: Pre-adult delta smelt abundance index. Longfin smelt: Pre-adult longfin smelt abundance index. Sacramento splittail: Abundance of all size classes
Smelt larval study	DFG	Monitors longfin smelt larvae distribution and relative abundance, January 2009-present	Larval abundance index and distribution
Bay Study	DFG	Monitors abundance indices for a variety of species in South San Francisco and Suisun Bays, Year-round, 1980-present	Delta smelt: Juveniles-adult delta smelt abundance index. Longfin smelt: Juveniles-adult longfin smelt abundance index. Sacramento splittail: Young of year and older splittail abundance.
Suisun Marsh fisheries monitoring program	UC Davis	Monitors abundance of all fish species in Suisun Marsh, Year-round, 1979-present	Delta smelt: Juveniles-adult delta smelt abundance, distribution within Suisun Marsh. Longfin smelt: Juveniles-adult longfin smelt abundance, distribution within Suisun Marsh. Sacramento splittail: Abundance of all size classes, distribution within Suisun Marsh.
Fish salvage monitoring	DWR, DFG, USBR	Monitors entrainment and salvage of all fish species, Year-round, 1979-present	Delta and longfin smelt: 20 mm post larvae-adult smelt abundance. Sacramento splittail: Abundance of all size classes >20 mm and length frequency. Almonds: >20 mm larvae-adults abundance. Sturgeon: >20 mm juvenile sturgeon abundance.

Table 3-19. Sample Listing of Existing Bay-Delta Fish Monitoring Programs Coordinated through the Interagency Ecological Program (IEP) (continued)

Monitoring Program	*Agency*	*Primary Purpose*	*Available Data for BDCP*
Chips Island, Mossdale, and Sacramento trawls	USFWS	Monitors fish abundance and distribution in mid-channel at surface at Chips Island, Moss dale (RM 54), and Sacramento (RM 55), and survival through the Delta, targets Chinook salmon, Year-round, 1976-present	Almonds: juvenile abundance, distribution, length frequency, survival indices (of hatchery tagged fish) to Chips Island Delta smelt: >25 mm abundance, distribution, and length frequency. Longfin smelt: >25 mm abundance and distribution, and length frequency. Sacramento splittail: >25 mm abundance and distribution, and length frequency.
Beach seines	USFWS	Monitors fish abundance and distribution throughout the Delta, upstream Sacramento River, northern San Francisco and San Pablo Bays, targets Chinook salmon, Year-round, 1976-present	Sacramento splittail: >25 mm young of year splittail abundance, distribution, and size frequency. Almonds: juvenile almonds, abundance, distribution, and size frequency.
Chinook salmon escapement estimates (Grand tab database)	DFG, DWR	Grand tab collects all races of Chinook salmon escapement	Almonds: adult returns to spawning grounds by race and location
Suisun March otter trawl	UC Davis	Monitors abundance of all fish species in Suisun Marsh, Year-round, 1979-present	Chinook salmon: juvenile abundance and distribution within Suisun Marsh
Adult sturgeon tagging study	DFG	Tag-recapture (via creel surveys) of green (prior to being listed) and white sturgeon for abundance and population dynamics	White and green sturgeon: abundance, distribution, population dynamics, length frequency, annual harvest rates, and migration rates.

3.6.4 Types of Monitoring

The Implementation Office will conduct and/or coordinate several types of monitoring to ensure the success of the Conservation Strategy. The general types of monitoring required are described in this section.

3.6.4.1 Preconstruction Surveys

As specified in Section 3.4.5, *Avoidance and Minimization Measures*, preconstruction surveys are required for specifically identified covered species, prior to the implementation of certain covered activities and conservation measures (e.g., water facilities construction or tidal habitat restoration actions that would remove existing terrestrial habitat) that may affect covered species or their habitats.

The potentially affected area will be surveyed to determine if covered species are present and likely to be affected by the activity. Survey results will be used by the Implementation Office to determine the need to implement measures described in Section 3.4.5 to avoid and minimize impacts on covered species and natural communities related to the covered activity or conservation measure. Preconstruction surveys may also be used in measure and record the level of take for a specific action as part of compliance monitoring, discussed below.

Preconstruction surveys may be coupled with baseline surveys, discussed below, as appropriate.

3.6.4.2 Construction Monitoring

Monitoring of construction activities will be conducted during the construction of various proposed facilities (both covered activities and conservation measures), including habitat restoration projects. Construction monitoring is required to ensure that avoidance and minimization measures are properly carried out where specific sensitive occurrences of covered species (e.g., an active nesting site for a covered bird species or a population of a highly restricted covered plant species) have been identified at or adjacent to a construction site. The Implementation Office will: (1) monitor implementation of covered activities to ensure that any applicable avoidance and/or minimization measure is properly and effectively implemented, and (2) ensure that conservation measures are implemented in accordance with specifications and plans.

3.6.4.3 Compliance Monitoring

The purpose of compliance monitoring is to: (1) track progress of BDCP implementation in accordance with established timetables, and (2) ensure compliance with terms and conditions of the BDCP and its associated permits. Compliance monitoring will be undertaken for all conservation measures, whether implemented directly by the BDCP Implementation Office or by other supporting entities through contracts, memoranda of agreement, or other agreements with the BDCP Implementation Office. Compliance monitoring will be conducted to ensure that conservation measures are meeting specified permit terms.

3.6.4.4 Baseline Surveys

Surveys to establish existing baseline conditions are critical to conducting a "before" and "after" comparison of biological and physical conditions related to the implementation of conservation actions and to the evaluation of the effectiveness of those conservation actions (refer to Section 3.6.4.5, *Effectiveness Monitoring*, below). Appropriate statistical designs for baseline surveys and effectiveness monitoring will be established as part of development of action-specific monitoring plans (Section 3.6.6, *Development of Specific Monitoring Plans*). Baseline surveys will be performed prior to implementation of conservation actions with sufficient lead time to allow future detection of changes in trajectories for the expected outcomes after implementation. For example, zooplankton sampling would be conducted in channels adjacent to tidal restoration sites in all seasons for multiple years prior to levee breaching to set the baseline condition. Monitoring sampling of zooplankton would be conducted at the same channel locations immediately following the levee breaching and throughout the natural development period of the restored tidal habitat, to quantify changes in the zooplankton community related to increased food availability.

Baseline and monitoring survey results will be used as the basis for BACI designs intended to evaluate program effectiveness. In some cases baseline monitoring may involve monitoring at reference (control) sites inside or outside the BDCP area (e.g., habitat use in unaffected habitat areas). BACI design approaches may be used where reference sites are limited.

3.6.4.5 Effectiveness Monitoring

Effectiveness monitoring assesses ecosystem, natural community, and covered species responses to the implementation of conservation measures and monitors progress made toward achieving biological goals and objectives. Effectiveness monitoring will occur at two scales: (1) a local scale focused on evaluating the effectiveness of specific individual conservation measures; and (2) a system-wide scale focused on the status and trends in species populations, natural communities, and ecosystem processes within the Plan Area. Each of these effectiveness monitoring scales are described in more detail below.

Effectiveness monitoring will be closely coordinated with baseline monitoring and the BDCP research program to support adaptive management. It is anticipated that the extent of effectiveness monitoring will be reduced over time as causal relationships between the implementation of conservation measures and the responses of covered species and ecosystems to those measures are better understood (as a result of knowledge gained under the BDCP monitoring and research program and other research programs). For example, if relationships between restoration of tidal marsh and zooplankton production are established through monitoring and research on initially restored tidal marshes, then effectiveness monitoring for assessing the production of zooplankton associated with subsequent restoration of tidal marsh may be reduced or no longer required. Effectiveness monitoring will also be spatially stratified to establish the effectiveness of the conservation measures in each Conservation Zone or ecologically relevant portions of the Plan Area.

Conservation Measure Monitoring. Monitoring focused on specific conservation measures will be undertaken for water operations, physical habitat restoration and enhancement, and other stressors conservation measures implemented by the BDCP Implementation Office and Supporting Entities. BDCP covered species will be monitored to assess individual, population, and community responses directly associated with specific conservation measures. Specific attributes of the aquatic ecosystem that are necessary for the survival and recovery of covered fish species will also be monitored as they relate to specific conservation measures. Monitoring at the local scale will also be used to determine whether any desirable or undesirable consequences are occurring in association with the implementation of specific conservation measures.

System-Wide Monitoring. Together with the BDCP research program, system-wide monitoring is intended to complement conservation measure monitoring by evaluating the status of ecological processes, natural communities, and covered species across the Plan Area, and in some cases outside of the Plan Area. Information within the scope of system-wide monitoring includes overall status, distribution of organisms, and trends related to covered species populations. Together with the conservation measure monitoring, system-wide monitoring is intended to help determine causality when examining a potential biological response, or lack thereof, to BDCP actions. System-wide monitoring allows for the evaluation of the collective effects of multiple conservation measures through time and provides information specific to the measuring metrics and the achievement of biological goals.

Consistent with the BDCP goals and objectives, system-wide monitoring will focus on three levels of ecological scale: (1) ecosystem processes (ecological processes, physical and chemical conditions, and food webs), (2) natural communities (including the ecological functions they provide for covered species), and (3) covered species. Each of these is described below.

Ecosystem Processes. Within the BDCP conservation lands and the Plan Area, the Implementation Office will monitor the structure and function of the aquatic ecosystems and the processes that influence these attributes at appropriate time intervals and at appropriate locations, over the term of the BDCP. Monitoring of aquatic ecosystem processes and conditions will provide the BDCP Implementation Office with information necessary to track long-term changes affecting the aquatic ecosystem (e.g., covered activities, climate viability and change, activities of others) and to document the contribution of the BDCP toward maintaining and improving aquatic ecosystem attributes in support of the covered fish species.

The BDCP Implementation Office will use the best available scientific understanding and datasets associated with the Delta aquatic ecosystem to establish markers from which to assess future changes in ecosystem processes, structure and function. Depending on the type and extent of data gaps, the BDCP Implementation Office will at the outset of Plan implementation collect necessary additional information to better understand existing conditions. If strong relationships between the response of specific ecosystem functions and conservation measures are established, the frequency of system monitoring for those monitoring elements of the Plan may be modified by the BDCP Implementation Office.

Natural Communities. The BDCP Implementation Office will monitor the extent and distribution of natural communities within the BDCP conservation lands and within the Plan Area at appropriate intervals over the term of the BDCP, depending on the type of community. Monitoring of covered natural communities will provide the BDCP Implementation Office with information sufficient to track long-term changes in the distribution and extent of covered natural communities attributable to any of a number of factors that may affect the communities (e.g., covered activities, climate variability and change, and activities of others). The results of these monitoring efforts will also provide documentation of the contribution of the BDCP towards maintaining and improving the extent, distribution, and continuity of natural communities. The baseline conditions from which changes in the range and distribution of natural communities will be assessed are the conditions described in Chapter 2, *Existing Ecological Conditions* and Appendix A, *Covered Species Accounts* and in baseline data collected by the Implementation Office early in the implementation period.

Covered Species. The status, distribution, and trends in populations of covered fish, wildlife, and plant species will be monitored within the BDCP Plan Area over the term of the BDCP. This level of monitoring will provide the BDCP Implementation Office with information sufficient to track long-term changes attributable to factors such as covered activities, physical and chemical changes, and climate variability and change that may affect covered species. The results of these monitoring efforts will document the contribution of the BDCP toward the conservation of covered species and inform system-level assessments of status, trends, and distribution. The baseline conditions from which changes in the range and distribution of covered species will be assessed are the conditions described in Chapter 2, *Existing Ecological Conditions* and Appendix A, *Covered Species Accounts* and in baseline data collected by the Implementation Office early in the implementation period.

As part of the covered species monitoring, the BDCP Implementation Office will also review relevant scientific data collected for covered species whose range and life stage distribution extends beyond the BDCP Plan Area as this information becomes available. Review of information gathered outside of the BDCP Plan Area will be sought to further inform assessments of the status and trends relating to covered species within the BDCP Plan Area and for making adjustments to BDCP implementation through the adaptive management process.

Species monitoring will be particularly important for covered fish and wildlife species that are migratory, nomadic, or otherwise highly mobile (i.e., dispersing readily in and out of the Plan Area). For these species, factors external to the Plan Area can readily obscure the type and extent of response to the implementation of the BDCP. For example, it may be that a conservation measure intended to restore habitat for a covered species is not followed by use of that habitat. The apparent lack of response, however, may be due to a population decline of the covered species caused by increased mortality outside the Plan Area. To establish causality, a number of monitoring metrics are needed, making use of cross-system comparisons.

3.6.5 Potential BDCP Monitoring Actions and Metrics

Potential monitoring actions and metrics to be implemented by the BDCP Implementation Office are divided into the same ecological hierarchy as the biological goals and objectives and conservation measures. Potential effectiveness monitoring actions and metrics for conservation measures are presented in Table 3-20 and potential monitoring actions and metrics for system-wide monitoring are presented in Table 3-21. Each potential monitoring action includes a description of existing programs that are currently implementing a portion or all of the monitoring action and how the monitoring information is expected to inform adaptive management decision making. All types of monitoring identified in Section 3.6.4, *Types of Monitoring*, are addressed in these tables. Tables 3-20 and 3-21 illustrate the types of monitoring actions and metrics that could be implemented, however, the Implementation Office will have the flexibility to determine the specific methods for gathering monitoring information and to change monitoring actions and metrics through the adaptive management process (see Section 3.6.6, *Development of Specific Monitoring Plans*, and Section 3.7, *Adaptive Management Program*).

3.6.6 Development of Specific Monitoring Plans

The BDCP Implementation Office will prepare detailed monitoring plans tailored to specific conservation measures and to system-wide monitoring needs based on the monitoring actions and metrics in Tables 3-20 and 3-21. These monitoring plans will be developed prior to implementation of the applicable conservation measures and the plans will include specific experimental and statistical designs to allow analysis of the status and trends of the selected metrics using approaches such as BACI analyses (see the discussion of target research in Section 3.7.5, *Adaptive Management Experiments)*. The monitoring plans will include survey protocols for efforts related to preconstruction, construction, compliance, effectiveness, and system-wide monitoring. In most instances, existing and generally accepted monitoring protocols (e.g., USFWS survey protocols for listed species, and protocols for monitoring status and trends in abundance and distribution of covered fish species) will be adopted by the BDCP Implementation Office, as appropriate. In some cases, however, the Implementation Office will need to develop specific monitoring protocols to assess a conservation measure.

The specific contents of each specific monitoring plan may vary depending on its purpose. The monitoring plans, however, will generally include the following types of information:

- Description of the purpose and objectives of the monitoring (e.g., assessing progress towards achieving a biological objective);
- Description of monitoring protocols, including sampling design and justification supporting the validity of monitoring methods and sampling design;
- Analytical methods for assessing monitoring results;
- Procedures for validating monitoring data and methods;
- Monitoring schedule, duration, and rationale;
- Spatial sampling scheme;
- Content requirements and submission schedule for monitoring reports;
- Monitoring data storage and management procedures;
- Analytical methods for the assessment of data and presentation of results;
- References, including printed references and personal communications;
- Provisions for documenting subsequent revisions to the monitoring plan; and
- Other information pertinent to specific monitoring plans.

Monitoring provides the necessary information to make adjustments in the implementation of the Plan and to measure progress toward achieving the BDCP biological goals and objectives; therefore, monitoring plans must be based on the best available information and subject to rigorous standards, including statistically sound sampling designs. To ensure defensibility of the

BDCP monitoring plans, protocols, and sampling designs, the Implementation Office will provide for internal science-based review of these monitoring elements as a routine matter and the overall plans will be examined by external science review as necessary and appropriate.

3.6.7 Research Program

While habitat conservation plans and natural community conservation plans are not specifically required to include research programs, the ecological complexity of the Delta and the level of uncertainty regarding the level of anticipated beneficial outcomes for covered species resulting from some of the conservation measures highlight the need for targeted research to better inform BDCP implementation and monitoring and adaptive management decision making. Existing research programs (particularly those funded under the IEP and Delta Science Program) have produced a broad range of valuable information. The BDCP Science Manager will identify research priorities to address specific uncertainties and provide funding for research to support more effective implementation of the Conservation Strategy. The Science Manager will coordinate with other entities, including IEP and the Delta Science Program to identify research needs and priorities. Many of the uncertainties and research needs are stated within the BDCP conservation measures in Section 3.4, *Conservation Measures*.

The following provides a preliminary description of how the BDCP will approach its research program. Additional details regarding the research program will be developed as proposed conservation measures are further refined and site-specific designs are developed, including the development of experimental designs to be incorporated with program implementation to support the adaptive management process.

BDCP Implementation Office may undertake or contract focused research to develop information necessary to better inform BDCP implementation. The types of research that may be conducted include those related to resolving BDCP-specific questions and needs related to:

- Key ecological processes and controls on these processes;
- Technologies and methods for effectively implementing and measuring the outcome of conservation measures;
- Development of new and more sensitive indicators and metrics;
- Improving understanding of the ecological requirements of covered species as they relate to effective implementation of conservation measures;
- Modeling and assessing responses of covered species to conservation measures;
- Determining causal relationships between ecological stressors and drivers and changes in natural communities and covered species; and
- Identify and evaluate tradeoffs among conservation measures.

Each conservation measure in Section 3.4, *Conservation Measures*, include discussions of hypothesized benefits of the measures that are testable under the either the monitoring program or the research program. Results of research would also be used to help direct and prioritize subsequent implementation of conservation measures through the adaptive management process.

The BDCP Implementation Office will use and maintain existing analytical tools (e.g., the DRERIP conceptual models and hydrologic models such as CALSIM, DSM2, and RMA), as appropriate, may also develop or participate in the development of models and other analytical tools to help inform BDCP implementation and support the adaptive management process. These analytical tools include current models and development or improvement of relevant deterministic, statistical, and conceptual models and exploring correlations and the cause and effect relationships between various components of the Delta ecosystem. To develop these modeling and analytical tools, the BDCP Implementation Office may conduct studies to collect information necessary for development of the tools. Additionally, it is anticipated that the BDCP Implementation Office will also participate in revising and improving existing tools (e.g., hydrologic and hydrodynamic models, DRERIP conceptual models) as new capabilities become available over the term of the BDCP.

3.6.8 Database Development and Maintenance

The BDCP Implementation Office will develop and maintain a comprehensive spatially-linked database to track implementation of all aspects of the BDCP. The database would be structured to be "user friendly" and to allow for future expansion and integration with external databases (e.g., linkage to databases of the Delta Science Program, and California Water Quality Monitoring Council). The database would look to other well recognized database management examples such as the Consortium of Universities for the Advancement of Hydrologic Science and the U.S. Long Term Ecological Research Network, which are leaders in multiple facets of data management in the environmental sciences. Functions that the BDCP database would be expected to support include:

- Data documentation such that future users can determine why, how, and where data were collected (i.e., metadata);
- Quality assurance and control of the data and data entry;
- Access to and use of the most current information for analysis and decision making; and
- Evaluation of data by all users, as appropriate, and incorporation of corrections and improvements in the data.

Major types of information expected to be maintained within the database include:

- Monitoring, research, and adaptive management experiment data and results;
- Modeling inputs, outputs, and results;

- Status of covered activities, including implementation and impacts;
- Implementation status of conservation measures;
- Implementation status of research and adaptive management experiments;
- Adopted changes to BDCP implementation through the adaptive management process; and
- All reports and documents generated by the Implementation Office and relevant data and reports generated by other entities.

The BDCP Implementation Office may choose to develop a web-linked database to facilitate controlled transference of information into and out of the database by other entities. If the BDCP Implementation Office chooses to allow access to the database by others, the database will incorporate strict controls and monitoring to ensure the integrity of the database is maintained.

The BDCP Implementation Office will ensure quality control of all monitoring data and will adopt procedures to maintain high standards of quality. Steps will be instituted to maintain the accuracy and functionality of gages, meters, and other devices, and protocols will be established to govern the collection, transcription, and storage of data. All monitoring data will be entered into database software and will be made readily available online once quality control analyses have been conducted.

The BDCP Implementation Office will use standard analytical procedures where such procedures exist. Particular analyses would be specific to individual monitoring parameters and would consist of classical parametric or non-parametric hypothesis testing and statistical models (e.g., t-tests, ANOVAs, correlations, regressions, etc.) to the extent practicable. If advanced statistical methods are necessary (e.g., multivariate ANOVAs, principal components analysis, Bayesian statistics, etc.), the BDCP Implementation Office would consult with experts to ensure proper analyses are being conducted. For many parameters, due to high environmental variability, time series analyses will be necessary to assess with confidence whether a trend in a parameter depicts a change that has occurred as a result of a BDCP action. Results of the analysis of monitoring data will feed back into the BDCP adaptive management process to modify and refine conservation measures to maximize benefits to and minimize unanticipated adverse effects on covered species and other components of the aquatic community.

3.6.9 Monitoring and Research Schedule

Following the signing of the Implementing Agreement and authorization of the BDCP, the Implementation Office will develop detailed monitoring plans and schedules for compliance and effectiveness monitoring. In addition, site-specific monitoring schedules will be developed for each BDCP conservation area as they are protected, enhanced, and restored.

3.6.10 Reporting and Science Communication

Requirements for the Reporting of monitoring results are provided in Chapter 6, *Plan Implementation.* The BDCP Implementation Office will regularly prepare implementation reports that describe survey, monitoring, research, and experimental activities and results over the term of the BDCP. Regular reporting requirements are described in Section 6.2, *Compliance and Progress Reporting*. The Implementation Office will also support peer-reviewed publications, seminars, and conferences like the Delta Science Conference and State of the Estuary Conference as additional mechanisms for communicating information and results. These approaches tend to foster the level of synthesis and integration needed to support an adaptive management approach.

*[**Note to Reviewers:** This table presents in-progress draft potential effectiveness monitoring actions for each BDCP conservation measure. This table will continue to be refined and populated to ensure that all of the effectiveness monitoring, including incorporation of metrics from the logic chain, are addressed.]*

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Ecosystem-Level Conservation Measures				
CM1: Water Facilities and Operation				
Monitoring Action CM1-1. Document the operation of the new water diversion facility in the north Delta with multiple intakes and fish screens and an isolated conveyance facility while maintaining sufficient bypass flows for covered fish species.				
Base condition: As-built construction drawings. **Approach**: Record amounts and timing of water diversion and conveyance, record bypass flows at automated monitoring stations downstream of the last intake. **Schedule:** real-time data compiled for daily summaries.	**Existing Programs:** 1. Continuous Multi-parameter Monitoring, Discrete Physical /Chemical Water Quality Sampling (Environmental Monitoring program; IEP) 2.Continuous Recorder Sites (DWR, USBR) 3. National Pollutant Discharge Elimination System (NPDES) Self Monitoring Program (Central Valley Water Board) 4. Delta Flows Network and National Water Quality Assessment Program (USGS) 5. other (DWR, SRCSD, SWAMP, Central Valley Water Board, State Water Board, SFEI, etc) **Potential Program Additions:** add automatic water monitoring stations at each intake as needed.	1. Hourly Intake (cfs) 2. Bypass flow (cfs) downstream of last intake	This monitoring action will provide real-time data on the amount of water diverted by the north Delta diversion facility, and the amount of water that bypasses the facility. This information will be used by the Implementing Office to determine of water operations adhere to existing target levels. The monitoring schedule may be adjusted to better estimate diversion and bypass flows.	ECSY2.1 ECSY2.2 ECSY2.3 ECSY2.4 ECSY2.5 CHSA1.5 GRST1.1 RILA1.4 PALA1.4

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM 1-2: Record and quantify the number of fish impinged at intakes of the new water diversion facility in the north Delta.				
Base condition: As-built construction drawings. **Approach**: Time stratified sampling; record number, size, species and life stage, reproductive status of impinged fish at intake screens; Install underwater monitoring cameras at fish screens to examine fish behavior at intake screens **Schedule:** Daily	**Existing Programs:** Protocols, equipment and skilled personnel working at CVP and SWP facilities (south Delta) **Potential Program Additions:** Equipment and staff to monitor north Delta diversion facility using identical protocols; protocols for analyzing video sequences of underwater cameras	1.Number of fish 2. Species 3. Life stage 4. Reproductive status	This monitoring action will provide data on impingement of covered fish species at the North Delta facilities. This information will be used by the Implementing Office to determine if the existing fish screens perform to meet target thresholds. It will also provide insights in fish behavior at intakes and will be used to evaluate and redesign fish screens if necessary. The monitoring schedule may be intensified if large numbers of fish are impinged at any given time/season.	CHSA1.6 STEE1.5 SASP1.4 GRST1.4 WHST1.4
Monitoring Action CM 1-3: Record and quantify the number of fish entrained at the south Delta SWP and CVP pumping facilities.				
Base Condition: Current levels of entrainment **Approach:** Use existing protocols and sampling procedures, continue to collect entrainment and salvage data at CVP and SWM pumping stations. **Schedule:** ongoing, daily	**Existing Programs:** Ongoing fish sampling at pumping facilities, IEP Monitoring (Fishery Improvements) coordinated with DWR, DFG, USBR, UCD, and other federal, state, and local agencies. **Potential Program Additions:** None	1. Monthly salvage density (fish/cubic foot per second [cfs] 2. Estimated entrainment (numbers) 3. Estimated impingement (numbers) 4. Species composition 5. Size distribution of individual species	This monitoring provides information about the seasonal distribution and amount of fish losses due to entrainment at pumping facilities The Implementation Office will use this information as input in population and life-cycle models of covered fish, and to determine if fish salvage and screening perform at expected target levels. This monitoring activity is already adaptively scheduled by adjusting sampling according to the number of fish entrained and by flow. Modification of this sampling is not expected.	CHSA1.6 GRST1.4 SASP1.4 STEE1.5 WHST1.4

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM1-4: Document diversion operations to ensure target flows in Old and Middle Rivers.				
Base Condition: Pre-implementation flows of Old and Middle Rivers. **Approach:** Use existing network of fixed-site sampling stations to collect time-histories of water quality variables. Derive flux between regions in the Delta through these key channels. **Schedule:** Within 1 year of initiation of the South Delta Diversion Operational Limits, operate monitoring sites and track flow on a daily basis.	**Existing Programs:** 1. Continuous Multi-parameter Monitoring, Discrete Physical /Chemical Water Quality Sampling (Environmental Monitoring program; IEP) 2.Continuous Recorder Sites (DWR, USBR) 3. National Pollutant Discharge Elimination System (NPDES) Self Monitoring Program (Central Valley Water Board) 4. Delta Flows Network and National Water Quality Assessment Program (USGS) 5. other (DWR, SRCSD, SWAMP, Central Valley Water Board, State Water Board, SFEI, etc) **Potential Program Additions:** **1.** If needed, add complementary stations to track water flows within Old and Middle River. see also Monitoring Action CM4-4 and Monitoring Action CM4-6.	1. Flow dynamics (velocity and volume of flows, direction) in Old and Middle River	This monitoring action will provide information regarding the effectiveness of adaptive operational changes of Old and Middle River flows (by modifications in export rates and reverse flows). The Implementing Office will use this information to determine if flow rates are within adaptive range limits. The schedule for monitoring may be changed if flow dynamics are found not to be within not adaptive range limits.	ECSY2.1 ECSY2.2 ECSY2.3 ECSY2.4 ECSY2.5 CHSA1.5 STEE1.3 PALA1.4 RILA1.4

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM1-5: Document fish migration and hydrodynamics (including hydraulic residence time) resulting from Delta Cross Channel operations (increasing the duration of Delta Cross Channel closure).				
Baseline Condition: Current knowledge of migration routes of covered fish species; if necessary determine proportion of covered juvenile fish (salmonids and sturgeon) migrating through the interior Delta and the mainstem of the Sacramento River. **Approach**: Conduct tracking (e.g., radio-telemetry, acoustic tracking, or other appropriate methods) of juvenile winter-run Chinook salmon, green and white sturgeon, and other species as appropriate to determine the proportion of fish migrating through the mainstem Sacramento River and tributaries and the interior of the delta and their survival. Compare water quality and organic food indices among migration routes and under different flow regimes and Cross Channel gate operation. **Schedule**: During migration track marked fish daily. Aggregate data by month and derive mortality estimates for fish in each migration route (mainstem vs interior).	**Existing Programs:** 1. Previous salmon survival and migration studies (e.g., USFWS, Perry et al. 2010), ultrasonic recorder stations (USGS & California Bay-Delta Authority). 2. Water quality monitoring sites within the Delta (see CM1-1). **Potential Program Additions:** Implement a routine juvenile fish migration and survival tracking program by experimentally releasing tagged fish to determine the effects of Cross Channel Closure on survival.	1. Migration routes (% individuals moving through the mainstem) by juvenile salmon and sturgeon 2. route- and species-specific survival estimates 3. Hydraulic residence time 4. Flows and downstream transport of fish eggs, larvae, juveniles, organic material, phytoplankton, and zooplankton, within the Sacramento River into the Delta.	This monitoring will provide information on the effectiveness of Delta Cross Channel closure to increase covered fish survival and by improving downstream transport of fish eggs, larvae, juveniles and organic food resources. Results of this monitoring will be used within the BDCP adaptive management framework to refine and modify seasonal operations of Delta Cross Channel gates. The schedule of monitoring may be adaptively altered if data resolution requirements are not met or when a clear relationship between Delta Cross channel operation, covered species survival and transport, and tidal flows is established and can be predicted robustly and with low uncertainty.	CHSA1.5 STEE1.3 RILA1.4 PALA1.4

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM1-6: Document achievement of minimum flow requirements at Rio Vista to support fishery and aquatic habitat in the reach of the Sacramento River between Sacramento and Rio Vista.				
Base Condition: Existing data and modeling results for flow statistics of the Sacramento river between Sacramento and Rio Vista **Approach:** Using the existing network of fixed-site sampling stations, collect time-histories of water quality variables. Derive flow rates. **Schedule:** Operate monitoring sites and track flow on a continuous basis for at least 5 years or until a robust predictive model can be derived from the monitoring data that allows forecasting of flow rates as a product of operational and other variables.	**Existing Programs:** 1. Continuous Multi-parameter Monitoring, Discrete Physical /Chemical Water Quality Sampling (Environmental Monitoring program; IEP) 2.Continuous Recorder Sites (DWR, USBR) 3. National Pollutant Discharge Elimination System (NPDES) Self Monitoring Program (Central Valley Water Board) 4. Delta Flows Network and National Water Quality Assessment Program (USGS) 5. other (DWR, SRCSD, SWAMP, Central Valley Water Board, State Water Board, SFEI, etc) **Potential Program Additions:** 1. If needed, add complementary stations to track water flows within The Sacramento River between Sacramento and Rio Vista. see also Monitoring Action CM4-4 and Monitoring Action CM4-6.	1. Flow dynamics (cfs) of the Sacramento River reach between Sacramento and Rio Vista.	This monitoring action will provide information regarding the effectiveness of adaptive operational changes to ensure minimum flows at Rio Vista to support fishery and aquatic habitat in the reach of the Sacramento River between Sacramento and Rio Vista. The Implementing Office will use this information to determine if flow rates are within adaptive range limits. The schedule for monitoring may be changed if flow dynamics are found not to be within not adaptive range limits.	ECSY2.1 ECSY2.2 ECSY2.3 ECSY2.4 ECSY2.5 CHSA1.5 STEE1.3 GRST1.1 RILA1.4 PALA1.4

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM1-7: Monitor Delta outflows during the near-term implementation period for environmental benefits.				
Base Condition: Current Delta Outflows; seasonal position of 350 µS/cm EC isohaline (X2). **Approach**: Continue monitoring salinity via the fixed water quality stations throughout the Delta. Obtain Daily and seasonal dynamics to determine if and when Delta outflows are below target levels. **Schedule:** Daily monitoring via fixed station network.	**Existing Programs:** 1. IEP Monitoring Data– daily average surface salinity at fixed stations along the Sacramento River interpolated to determine the location of 350 µS/cm EC isohaline. 2. DSM2 Simulations – daily average, depth-averaged salinity at fixed locations (every DSM2 node) along the Sacramento River is interpolated to determine the location of 350 µS/cm EC isohaline. **Potential Program Additions:** none	1. Daily average surface salinity at fixed stations. 2. Interpolated position of the isohaline (X2), expressed in miles from the Golden Gate Bridge. 3. Net Delta Outflow Index	This monitoring action will provide information on the magnitude of Delta outflow and related parameters (salinity intrusion). It will track the position of the isohaline Based on results and analysis of monitoring data, adaptive modifications to management of Delta outflow under the BDCP adaptive management framework could occur by modifying operational criteria by season or water-year type (hydrology). The schedule of monitoring actions may be altered to improve precision and accuracy of estimating the position of the isohyaline.	ECSY2.1 ECSY2.2 ECSY2.3 ECSY2.4 ECSY2.5 CHSA1.5 STEE1.3 GRST1.1 RILA1.4 PALA1.4
Monitoring Action CM1-8: Record in-Delta agricultural, municipal, and industrial water quality.				
Base condition: Current water quality monitoring **Approach**: Continue current water quality monitoring as mandated by existing D-1641 North and Western Delta agricultural and municipal and industrial (M&I) standards and all water quality requirements contained in the North Delta Water Agency/DWR Contract and other DWR contractual obligations. **Schedule:** as currently implemented.	**Existing Programs:** 1. Continuous Multi-parameter Monitoring, Discrete Physical /Chemical Water Quality Sampling (Environmental Monitoring program; IEP) 2.Continuous Recorder Sites (DWR, USBR) 3. National Pollutant Discharge Elimination System (NPDES) Self Monitoring Program (Central Valley Water Board) 4. Delta Flows Network and National Water Quality Assessment Program (USGS) 5. other (DWR, SRCSD, SWAMP, Central Valley Water Board, State Water Board, SFEI, etc)	1. EC (salinity) 2. Water temperature (°C) 3. mg/L dissolved oxygen 4. Turbidity (NTUs) 5. Concentration (µg/L) of ammonia, pyrethroids, copper, organophosphates 6. pH 7. mg methylmercury/L	This monitoring action is intended to collect data necessary to determine if salinity conditions are meeting contractual and legal requirements. This information will be used to address deviations from salinity target conditions, and design modifications and/ research studies to address uncertainty in salinity control. The monitoring schedule may be adjusted in response to monitoring results to better understand causal relationships between water management and salinity.	CHSA1.3

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM 1-9: Document and quantify effects of modified/reduced operations the Montezuma Slough Salinity Control Gate for covered fish species passage and salinity				
Base Condition: current operation and flows (local current patterns and tidal hydrodynamics). **Approach**: continue to monitor and calculate water quality and flow parameters through Suisun March and at Chipps Island (Delta Net outflow index), continue IEP Suisun Marsh fish monitoring (otter trawls and beach seines) **Schedule**: instantaneous automatic 15 min interval recording of salinity data, Seasonal fish abundance as currently conducted by IEP.	**Existing Programs:** IEP coordinated programs: 1. Suisun Marsh Water Quality Monitoring and Compliance (five compliance stations); 2. Aquatic Monitoring by University of California Davis (UCD) and DFG in Suisun Marsh (otter trawls and beach seine) **Potential Program Additions:** none	1. Catch per unit effort (CPUE) and % change (over baseline conditions) of outmigrating juvenile salmonids and sturgeon in Suisun Marsh; 2. Catch per unit effort (CPUE) and % change (over baseline conditions) of splittail, salmonids, and sturgeon in existing and future restored intertidal marsh habitats in Suisun Marsh (see also CM 4-5). 3. Salinity levels within Suisun marsh and in adjacent Delta channels 4. Flow (cfs) in Montezuma Slough	This monitoring action provides information on the effects of changing or eliminating salinity control gate operations in Montezuma Slough on covered fish species and salinity levels within the Delta. In the event that the control structure remains in place and the gates are opened, results of monitoring could be used in the future to adaptively manage the control gates (resume gate operations) if unexpected undesirable consequences are detected. If the control structure is removed, adaptive management of salinity regimes will require modifications of Delta outflow to manage salinity within the marsh. The monitoring schedule may be adjusted to better inform management decisions if deemed necessary.	CHSA1.1 STEE1.1 STEE1.3 RILA1.4 PALA1.4

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
CM2: Yolo Bypass Fisheries Enhancements				
Monitoring Action CM2-1: Document the operation of the modified Fremont Weir (i.e., elevation reduction)				
Base Condition: As-built construction drawings. **Approach**: Document flow over the weir. Document the operation of inundation gates and deep channel fish passage gates. **Schedule:** real-time recording, during flooding of the weir.	**Existing Programs:** CA Dept of Water Resources/NCRO river stage monitoring gages **Potential Program Additions:** real-time recording of gate operations (open/closed)	1. River stage at Fremont weir 2. Flow (cfs) 3. Gate status (open/closed)	This monitoring action will provide information on the operation of the modified Fremont weir, particularly on the number of days and the amount of water that flows over the weir into Yolo bypass and the operation of the fish passage gates at below flood stage of the Sacramento River (11.5 – 17.5 ft) This information will be used by the Implementing Office to refine operation of the gates to provide for the inundation of the Yolo bypass according to target levels. The monitoring schedule may be adjusted if deemed necessary to provide higher resolution information for gate operations.	ECSY2.2 ECSY5.1 CHSA1.1 CHSA1.5 STEE1.1 STEE1.2 STEE1.3 SASP1.1 SASP1.2 GRST1.3 WHST1.3 RILA1.3

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM2-2: Document the effects of the fish passage gates at Fremont Weir (replacing fish ladder)				
Base conditions: As-built construction drawings. **Approach:** Install and operate underwater high resolution cameras and or automatic fish counters (using resistivity, infrared scanning technology or other appropriate methods) to characterize and quantify covered fish species passing through fish passage gates within the inundation channel during flooding of the Yolo Bypass. Compile and analyze fish passage data daily during operation of the passage gates. **Schedule:** real-time instantaneous fish counting when fish passage gates are open.	**Existing Programs:** none **Potential Program Additions:** Automated fish counting technology (automatic counter sensors, computer system and software to scan, recognize and measure fish); skilled personnel to manage and analyze fish counter data; See Monitoring Action CM2-7, CM2-10, CM2-11	1. Number of fish passing through the gates 2. Species 3. Size class 4. Origin (wild or hatchery for fin-clipped fish)	This monitoring action will provide information to quantify adult fish passage from the up- and downstream between the Sacramento River and the Yolo Bypass. This information will be used by the Implementing Office to estimate the population size of adult covered fish species using the Yolo bypass during inundation. The monitoring schedule will be adjusted during inundation events and status of fish passage gates.	CHSA1.1 CHSA1.5 STEE1.1 STEE1.2 STEE1.3 SASP1.1 SASP1.2 GRST1.3 WHST1.3 RILA1.3

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM2-3: Document the effects of the Yolo Bypass modifications to improve distribution (e.g., wetted area) and hydrodynamic characteristics (e.g., residence times, flow ramping, and recession) of water moving through the Yolo Bypass.				
Base conditions: as-built construction drawings; current extent of Yolo bypass inundation and hydroperiod **Approach:** Document and quantify grading, removal of existing berms, levees, and water control structures, construction of berms or levees, re-working of agricultural delivery channels, and earthwork or structures by remote sensing data and field observations entered into GIS. Record and quantify the hydrodynamic characteristics of the Yolo basin by flood and spill gages and satellite imagery LANDSAT or similar to estimate extent of wetted area). Develop correlation between the extent wetted, hydrodynamic indicators and flood gage measurements. Update GIS database if lands are acquired in fee-title or through conservation or flood easements. **Schedule:** Daily monitoring of flood gauges, weekly acquisition of remote sensing data, until a correlation can be established between stage at various flood gauges and hydrodynamic measures.	**Existing Programs:** Yolo bypass inundation gauging stations at Fremont weir (USGS), Sacramento Weir (USGS) and Lisbon (DWR). Potential GIS capability with DWR IISS section within DWR-DES **Potential Program Additions:** Development of spatial databases and mapping capabilities including photo-interpretation (GIS lab)	1. Yolo bypass wetted area 2. Residence times 3. Flow ramping rate (change of water flow cmps/hr hour) 4. Recession timelines	This monitoring action will provide information on the relationships between the hydrological conditions within the Yolo bypass as they pertain to fish habitat, and flood gage information provided throughout the basin. This information will be used to determine the operational constraints and effectiveness of gate and spill operations of the Fremont weir and flow obstruction removals within the floodplain. It will also be used to assess if additional floodplain modifications are necessary to reduce flow and inundation impediments, and to address erosion and other issues. The monitoring schedule may modified once robust, statistically significant and precise correlations have been verified.	ECSY5.1 CHSA1.1 CHSA1.5 STEE1.1 STEE1.2 STEE1.3 SASP1.1 SASP1.2 GRST1.3 WHST1.3 RILA1.3

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM2-4: Document and quantify the effectiveness of Experimental Sturgeon Ramps for the upstream migration of sturgeon from the Yolo bypass to the Sacramento River.				
Base condition: as-built construction drawings **Approach**: Install and operate underwater high resolution cameras and automatic fish counters (using infrared scanning technology, resistivity sensors or other appropriate methods) to characterize and quantify covered fish species passing through sturgeon ramps when weir spills exceed 2 feet. **Schedule**: instantaneously count and record fish using ramps. Compile counts daily.	**Existing Programs:** none **Potential Program Additions:** Automated fish counting technology (automatic counter sensors, computer system and software to scan, recognize and measure fish); skilled personnel to manage and analyze fish counter data; live video feed to web-based application See CM 2-2	1. Number of fish passing 2. Species 3. Size class	This monitoring action will provide information on the effectiveness of experimental Sturgeon Ramps at the Fremont Weir to allow passage of adult sturgeon and lamprey from the Yolo Bypass over the Fremont Weir and into the Sacramento River. This information will be used by the Implementing Office within the adaptive management experiment framework to estimate passage rates, refine design features or formulate alternative designs. The monitoring schedule may be adjusted to data needs or may be reduced when effectiveness of the sturgeon rams has been documented with low uncertainty.	GRST1.3 WHST1.3

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM2-5: Document Stilling Basin Modification and assess risk of covered fish stranding.				
Base conditions: As-built construction drawings **Approach**: Document the physical changes in stilling basin topography. Estimate the number of fish stranding in the stilling basin as flows are receding by electro-fishing, beach seining or other appropriate method. **Schedule:** Sample if standing water remains within the basin after weir spills have ceased and floodplain drainage has begun.	**Existing Programs:** Intermittent and historical IEP and USFWS beach seine and trawling methods within the Yolo and Sutter bypasses **Potential Program Additions:** Fish sampling of stilling basin to verify stranding. See CM5-2	Number of fish Size species	This monitoring action will provide information to assess if the basin drains sufficiently into the deep fish passage channel and thus will prevent stranding of juvenile and adult fish. Information from this monitoring action will be used by the Implementing Office to assess the risk of stranding at the stilling basin, and to guide the redesign if necessary, if significant numbers of fish are found to be stranded in the basin after re-contouring. The monitoring schedule will be reduced to annual visits at the end of the inundation period once fish escape of from the basin has been verified with low uncertainty.	CHSA1.1 CHSA1.5 STEE1.1 STEE1.2 STEE1.3 SASP1.1 SASP1.2 GRST1.3 WHST1.3 RILA1.3 PALA1.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM2-6: Document and evaluate Sacramento Weir improvements for fish passage and minimization of standing risk.				
Base condition: As-built construction drawings. **Approach:** Document modifications to the weir. Using fish sampling (seining, electro-fishing, traps), determine the number and species of juvenile and adult fish using the stilling basin and (if implemented) fish ladders. Install automatic fish scanners and underwater high-resolution cameras to assess passage of adult fish over the weir into the Sacramento River. **Schedule**: Weekly sampling of fish until a minimal stranding risk has been estimated and verified precisely. Instantaneous video monitoring of fish passing through fish ladder.	**Existing Programs:** none **Potential Program Additions:** Intermittent fish sampling during and after weir spills in Sacramento weir stilling basin; automated fish counting technology (computer system and software to scan, recognize and measure fish); skilled personnel to manage and analyze fish counter data; See Monitoring Action CM2-2	Number, size and species of fish passing over fish ladder Number, species and life stage of juvenile fish sampled in the stilling basin	This monitoring action will provide information on the effectiveness of modifications of the Sacramento weir and its stilling basin to allow passage of adult and juvenile fish from the Yolo Bypass into the Sacramento River or downstream the Tule Canal/Toe Drain to escape stranding. This information will be used by the Implementing Office within the adaptive management experiment framework to estimate passage rates, refine design features or formulate alternative designs. The monitoring schedule may be adjusted to data needs or may be reduced when effectiveness of the implemented modifications has been documented with low uncertainty.	CHSA1.3 CHSA1.1 CHSA1.5 STEE1.1 STEE1.2 STEE1.3 SASP1.1 SASP1.2 GRST1.3 WHST1.3 RILA1.3 PALA1.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM2-7: Document the Tule Canal/Toe Drain Improvements to increase hydrologic connectivity.				
Base condition: As-built construction drawings. **Approach:** Document modifications to the Tule Canal /Toe drain. Measure flow within the channel with automatic gages. **Schedule**: Real-time continuous automatic flow measurements.	**Existing Programs:** none **Potential Program Additions:** Install automatic flow gage within the Tule Canal /Toe drain	1. flow (cfs)	This monitoring action will provide information on the effectiveness of modifications of the Tule Canal /Toe drain to allow passage of adult and juvenile fish downstream the Tule Canal/Toe Drain to escape stranding. This information will be used by the Implementing Office within the adaptive management experiment framework refine design features or formulate alternative designs. The monitoring schedule may be adjusted to data needs or may be reduced when effectiveness of the implemented modifications has been documented with low uncertainty.	CHSA1.5 STEE1.3 GRST1.1 GRST1.3 WHST1.3 RILA1.3 RILA1.4 PALA1.4

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM 2-8: Determine the effectiveness of Lower Putah Creek realignments to improve upstream and downstream passage of Chinook salmon and steelhead in Putah Creek and floodplain habitat restoration.				
Base condition: As-built construction drawings. **Approach:** Document modifications to Lower Putah Creek. Using automatic resistivity-based fish counters to detect and enumerate adult fish returning. **Schedule**: Continuous operation of the fish counter during spawning season.	**Existing Programs:** none **Potential Program Additions:** Install automatic fish counter within Lower Putah Creek. See Monitoring Action CM2-7	1. Number of fish returning 2. Species	This monitoring action will provide information on the effectiveness of modifications of Lower Putah Creek to allow passage of adult and juvenile covered fish along Lower Putah Creek. This information will be used by the Implementing Office within the adaptive management experiment framework refine design features or formulate alternative designs. The monitoring schedule may be adjusted to data needs or may be reduced when effectiveness of the implemented modifications has been documented with low uncertainty.	CHSA1.3 STEE1.3 GRST1.3 WHST1.3 RILA1.3

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM 2-9: Determine upstream migration success of salmonids, sturgeon, and lamprey through the Yolo Bypass.				
Base condition: existing knowledge of upstream migration and its correlation with flow (DFG data) Approach: Using a combination of mark-recapture and automatic resistivity-based fish counters and high-resolution underwater camera systems at Fremont weir, detect and enumerate adult fish returning (see Monitoring Action CM2-7). Schedule: Continuous operation of the fish monitoring system during migration season	**Existing Programs:** DFG fish tagging program **Potential Program Additions:** automated fish counting technology (computer system and software to scan, recognize and measure fish); skilled personnel to manage and analyze fish counter data; See Monitoring Action CM2-2, CM2-6, CM2-10.	1. Number of fish passing 2. Species 3. Size class	This monitoring action will provide information on the effectiveness of adult covered fish species migrating from the Yolo Bypass over the Fremont Weir and into the Sacramento River. This information will be used by the Implementing Office within the adaptive management experiment framework to estimate passage rates, refine design features or formulate alternative designs. The monitoring schedule may be adjusted to data needs or may be reduced when effectiveness of permeability of the Yolo Bypass for upstream migration of adult fish has been documented with low uncertainty.	CHSA1.3 STEE1.3 GRST1.3 WHST1.3 RILA1.3

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM 2-10: Determine passage rates of covered salmonids, sturgeon, Sacramento splittail, and lamprey from the Sacramento River into the Yolo Bypass during periods of Fremont Weir operation.				
Base condition: As-built construction drawings. **Approach:** Using a mark-recapture approach, determine the number and species of juvenile and fish out migrating over the Fremont weir. Install automatic fish scanners and underwater high-resolution cameras to assess passage of adult fish over the weir into the Sacramento River. **Schedule**: Weekly sampling of fish for the period of inundation. Instantaneous video monitoring of fish passing through fish ladder.	**Existing Programs:** none **Potential Program Additions:** Intermittent fish sampling during and after weir spills; automated fish counting technology (computer system and software to scan, recognize and measure fish); skilled personnel to manage and analyze fish counter data; See Monitoring Action CM2-2, CM2-7, CM2-10	Number, size and species of fish passing over fish ladder Number, species and life stage of juvenile fish sampled in the stilling basin	This monitoring action will provide information on the effectiveness of modifications of the Sacramento weir and its stilling basin to allow passage of adult and juvenile fish from the Yolo Bypass into the Sacramento River or downstream the Tule Canal/Toe Drain to escape stranding. This information will be used by the Implementing Office within the adaptive management experiment framework to estimate passage rates, refine design features or formulate alternative designs. The monitoring schedule may be adjusted to data needs or may be reduced when effectiveness of the implemented modifications has been documented with low uncertainty.	ECSY5.1 CHSA1.2 STEE1.2 SASP1.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM 2-11: Determine zooplankton and invertebrate production rates during periods the Fremont Weir is operated.				
Base Condition: existing data on Yolo Bypass zooplankton productivity **Approach:** Establish monitoring stations at inflow and outflow locations and within the inundated floodplain of the Yolo bypass. Take weekly grab samples and measurements of chlorophyll a and zooplankton. **Schedule:** Conduct sampling for the first 5 years following reestablishment of tidal flow and every 5 years thereafter.	**Existing Programs:** Environmental Monitoring Program (EMP, under IEP) **Potential Program Additions:** **1.** Additional sampling stations in the Yolo Bypass floodplains t reflect the before-after-control-impact design. Locations of some added stations will be fixed during the duration of the plan (systemwide monitoring to detect increase on food availability in delta waterways), others are added to account for different flow rates and inundation depth in dry vs wet years to track how food production develops over time. Sampling stations will also provide water quality data (e.g., temperature, turbidity, pH for ammonia conversion, amount of organic carbon) Invertebrate sampling should be adaptively adjusted to changes in fish diets – see also: Monitoring Action CM4-4, CM4-6, and CM16-5	1. Phytoplankton species composition/relative abundance 2. Phytoplankton density (mg/L chlorophyll a) 3. Zooplankton species composition/relative abundance 4. Zooplankton density (number/1,000 m^3)	This monitoring action is intended to collect data necessary to determine and quantify the degree to which the Yolo bypass is producing and exporting phytoplankton and zooplankton into the Delta. This information, in combination with evaluation of other foodweb-related monitoring and research data, will provide the basis for : 1. Identifying sources of uncertainty and the design of management experiments and/ research studies, to address uncertainty. 2. evaluating underlying conceptual models and hypotheses (source-sink dynamics, variability and uncertainty in primary production response) 3. evaluating restoration design options to increase the production and export of primary production inundated floodplains 4. Implementing additional management actions to improve production and export of primary production from the floodplain. The monitoring schedule will be modified if uncertainty or variances do not support a clear causal relationship between floodplain inundation and food production and - exports.	ECSY5.1 ECSY5.2 CHSA1.2 STEE1.2 SASP1.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM 2-12: Determine growth rates of juvenile salmonids entering the Yolo Bypass during periods of Fremont Weir operation.				
Base condition: Current studies and knowledge about salmon growth and survival in the Delta and the Yolo bypass. **Approach**: Conduct routine mark-recapture and radio-telemetry tagging experiments by marking juvenile salmon within the Yolo bypass and measuring survival and growth rates at Chipps Island **Schedule**: annually mark and radio-tag individual Chinook for at least 5 years. Repeat mark-recapture monitoring every 5th year	**Existing Programs:** IEP mid-water trawl at Chipps Island, previous salmon survival studies (Perry et al 2009) **Potential Program Additions:** 1. routine radio-tracking and mark recapture program	1. survival rates 2. growth rates (mm/d)	This monitoring action provides information on the effectiveness of modifying the Fremont weir to benefit survival and growth rates of juvenile outmigrating Chinook salmon. The implementing Office will use this information to determine if operation of the Fremont weir is achieving target levels of survival and growth. The information will also ser as a basis to determine f additional research should be conducted, and if initial models and hypotheses are supported by monitoring data. The monitoring schedule may be extended if survival and growth data are inconclusive to determine that survival and growth has achieved target levels or of substantial environmental variability has increased the level of uncertainty associated with predicted outcomes.	CHSA1.2 STEE1.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM 2-13: Determine escapement success of juvenile covered salmonids, sturgeon, Sacramento splittail, and lamprey from the Yolo Bypass during periods of Fremont Weir operation.				
Base condition: Current studies and knowledge about survival of juvenile covered fish in the Delta and the Yolo bypass. **Approach**: Conduct routine mark-recapture and/ or radio-telemetry tagging experiments by marking juvenile covered species near the Fremont Weir within the Yolo bypass and measuring survival and growth rates at Chipps Island **Schedule**: annually mark and radio-tag individual covered species for at least 5 years. Repeat mark-recapture monitoring every 5th year	**Existing Programs:** IEP mid-water trawl at Chipps Island, previous salmon survival studies (Perry et al 2009) **Potential Program Additions:** 1. routine radio-tracking and/or mark recapture program	1. Survival rates 2. Species	This monitoring action provides information on the effectiveness of modifying the operations of Fremont weir to benefit survival and growth rates of juvenile outmigrating covered species. The implementing Office will use this information to determine if operation of the Fremont weir is achieving target levels of survival and growth. The information will also serve as a basis to determine if additional research should be conducted, and if initial models and hypotheses are supported by monitoring data. The monitoring schedule may be extended if survival and growth data are inconclusive to determine that survival and growth has achieved target levels or of substantial environmental variability has increased the level of uncertainty associated with predicted outcomes.	CHSA1.1 STEE1.1 GRST1.1 PALA1.2
Monitoring Action CM 2-15: Document Sacramento splittail spawning and spawning success in the Yolo Bypass during periods of Fremont Weir operation.				
	[Text to come.]	[Text to come.]	[Text to come.]	SASP1.1 SASP1.2 SASP1.3

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM 2-16: Determine the distribution and abundance of giant garter snake in the Yolo Bypass.				
Base Condition: none **Approach**: Using accepted survey protocols, conduct randomized, stratified surveys to detect presence of GGS in the Yolo Bypass, especially using known or historical locations as starting points and radiating outwards from there. **Schedule**: Annual surveys during periods of GGS activity. Continue for at least 5 inundation years. Repeat every 5 years, focusing on verifying presence in previously established occurrences.	**Existing Programs:** historical surveys, research projects, approved sampling protocols. **Potential Program Additions:** 1. Standardized surveys for Giants Garter Snake 3. Establishment of new sampling points/grids/stations as habitat patches are restored and populations expand See Monitoring Action CM4-8 , 4-14	1. Presence and sex/age distribution of Giant Garter Snake 2. Estimated population trend Giant Garter Snakes in restored habitats (source or sink?)	This monitoring action is intended to collect data on the distribution and population trend of giant garter snake in the Yolo Bypass. Monitoring results will be used to determine if habitat restoration has a source or sink effect on the abundance of giant garter snake in the Yolo Bypass This information is necessary to determine if adaptive changes to the implementation schedule or additional measures may be necessary to increase the abundance and viability of giant garter snake populations in the Yolo Bypass	TANC1.1 FMNC1.1 FMNC2.1 NANC2.1 NWNC2.1 ALNC1.2 ALNC1.5 ALNC1.7 ALNC1.8 GGSN1.1 GGSN2.1
Monitoring Action CM 2-17: Determine abundance of wintering waterfowl and shorebirds in the Yolo Bypass during years the Fremont Weir is operated.				
Base Condition: Current waterfowl monitoring as conducted by USFWS, CDFG and CWA **Approach**: Continue USFWS and CDFG special fall and midwinter aerial surveys. The midwinter survey, the longest running population assessment, focuses on all ducks, geese, swans, and coots. **Schedule**: Annual mid-winter surveys as currently implemented by USFWS.	**Existing Programs:** USFWS midwinter waterfowl surveys **Potential Program Additions:** none	1. Number 2. Species 3. sex/age composition (if possible)	This monitoring action provides information on the abundance of wintering waterfowl. The Implementation office will use this information to determine the effectiveness of inundation of the Yolo bypass ion providing wintering habitat for waterfowl. The Monitoring schedule may be changed if necessary to improve accuracy and/or precision of waterfowl estimates.	MWNC1.1 MWNC1.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
CM3: Protect Natural Communities				
Action CM3-1 Record the acquisition or protection of parcels by conservation zone, natural community, and covered species habitat.				
Base Condition: Pre-acquisition parcel information. **Approach**: Document and record in a suitable database the characteristics of protected land as they are added to the conservation lands system **Schedule:** Update maps and database of conservation lands annually to reflect status of each parcel as they are added to the conservation land system.	**Existing Programs:** DWR IISS section within DWR-DES (potentially) **Potential Program Additions:** 1. Development of spatial databases and mapping capabilities including photo-interpretation (GIS lab)	Acres of land protected by Conservation Zone / ROA and natural community Linear miles of edge within tidal mudflat habitats as habitat for tidal-mudflat associated species (e.g., Delta tule pea, Suisun marsh aster)	This monitoring action will provide the means to track how the Implementing Office is adding conservation lands in each Conservation Acquisition zone. This information will be used to assess progress and determine if conservation targets in each CAZ and natural community have been met.	ECSY1.1 ECSY1.2 GRNC1.1 VPNC1.1 ALNC1.1-1.6
Monitoring Action CM 3-2: Record, quantify and delineate occurrences of covered plant species.				
Base Condition: Pre-acquisition parcel information. Baseline survey of parcels at acquisition **Approach**: Document and record in a suitable database the characteristics of rare species occurrences on BDCP protected lands **Schedule**: Survey once every 5 years to document presence and condition/abundance of special status plants	**Existing Programs:** DWR IISS section within DWR-DES (potentially) **Potential Program Additions:** 1. Development of spatial databases and mapping capabilities including photo-interpretation (GIS lab) 2. Special status surveys and species verifications by a qualified botanist	Species occurrences: 1. Location 2. Species 3. Habitat 4. Number of individuals 5. Land use 6. Threats	This monitoring action will provide information on the presence and status of special-status plants on conservation lands within the BDCP Plan Area. This information will be used in the development of specific management plans for each parcel to ensure that management and protection activities are compatible with special-status plants and these plants are protected and maintained. The monitoring schedule will be altered for species that are dependent on specific climatic events or conditions (i.e. vernal pool plans require "wet" years to emerge)	ALMV1.1 AWNC1.1 CAGB1.1 CFTR1.1 DEBC1.1 HART/ BRIT1.1 HEPE1.1 SOBB1.1 SUTH1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM 3-3: Document habitat connectivity among the various BDCP conservation land units in the conservation land system.				
Base Condition: Pre-acquisition parcel information. Baseline documentation **Approach**: Document and record in a suitable database evidence of connectivity and movement of animals and plants across conservation land habitats. **Schedule**: Update maps and database of conservation lands annually to reflect the conservation status of adjacent lands and the location of newly arriving species of interest.	**Existing Programs:** DWR IISS section within DWR-DES (potentially) **Potential Program Additions:** 1. Development of spatial databases and mapping capabilities including photo-interpretation (GIS lab)	Land status and changes in natural communities on adjacent parcels Species occurrence of newly arriving species Observed shifts in species distribution and use of the parcel.	This monitoring action will identify how well the protected lands are connected with adjacent habitats to enable species to move across the landscape. This information will be used to determine where uncertainties and knowledge gaps exists regarding the connectivity of habitats within the BDCP Plan Area, and where corridors for covered and invasive species exist. This information will be used to determine appropriate management strategies to support covered species and reduce the likelihood of dispersal of non-native invasive species. The monitoring schedule may be reduced to every 5 or even 10 years once conservation targets have been met within a Conservation Zone.	ECSY3.1 ECSY7.1 ALNC1.7 VRNC2.3

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Natural Community-Level Conservation Measures				
CM4: Tidal Habitat Restoration				
Monitoring Action CM4-1. Document the extent of tidal habitat restored.				
Base Condition: As-built construction drawings. **Approach:** Delineate the extent of subtidal aquatic, unvegetated mudflat, vegetated marsh plain by vegetation type, and transitional upland by vegetation type. **Schedule:** Annually delineate habitat components for the first 5 years following reestablishment of tidal flow and every 5 years thereafter.	**Existing Programs:** DWR IISS section within DWR-DES (potentially) **Potential Program Additions:** 1. Development of spatial databases and mapping capabilities including photo-interpretation (GIS lab) 2. Vegetation sampling (on-the ground) for field verification to increase mapping accuracy (aquatic botanist) See Monitoring Action CM4-2, CM16-1	1. Extent, distribution, and channel order of tidal perennial aquatic natural community on restoration sites. 2. Percentage of subtidal aquatic habitat in areas of subsidence 3. Extent, distribution and persistence of high-functioning tidal mudflat community	This monitoring action provides information regarding the development of restored habitat components over time. Results will be used to evaluate if targets and objectives have been met, parameterize and evaluate conceptual models and other analytical tools, and to prioritize potential actions according to certainty, magnitude and timeliness of benefit. This information will also provide the basis for determining if there is a need to modify subsequent restoration designs to improve their ecosystem and habitat functions, or if it is necessary to alter management actions to support the development of desired habitat functions (e.g., control of non-native vegetation, planting of native emergent vegetation to improve development of marsh functions). The monitoring schedule may be adjusted for a particular project in response to monitoring results and the intensity of monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established.	TANC1.1 BMNC1.1 FMNC1.1 MFNC1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM4-2. Document the progress of vegetation community establishment and the extent of covered species habitat provided by restored tidal habitats.				
Base Condition: As-built construction drawings. **Approach:** For the first 5 years following completion of tidal marsh restoration projects, annually conduct aerial and/or field surveys in October to map the extent of tidal vegetation establishment. Evaluate and quantify the extent of each covered species habitat based on evaluation of data collected under Monitoring Action CM4-1. **Schedule:** Annually quantify the extent of restored covered, species habitats for the first 5 years following reestablishment of tidal flow and every 5 years thereafter.	**Existing Programs:** DWR IISS section within DWR-DES (potentially) **Potential Program Additions:** 1. Development of spatial databases and mapping capabilities including photo-interpretation (GIS lab) 2. Vegetation sampling (on-the ground) for field verification to increase mapping accuracy (aquatic botanist/ field personnel; see Monitoring Action CM4-1, CM16-1)	1. Extent, distribution and persistence of high-functioning tidal mudflat community 2. Linear extent of restored or created tidal mudflat substrate as part of the restored brackish and freshwater tidal habitat and channel margin enhancement. 3. Acres of covered species habitat 4. presence of key habitat correlates and requisites/attributes for covered species 5. Percent absolute and relative cover 6. Extent, distribution, cover, and species composition of non-native invasive species within establishing tidal mudflats on restoration sites	This monitoring action is intended to provide information regarding the development of habitat covered species in restored tidal habitats over time. This information will provide the basis for determining if there is a need to modify subsequent restoration designs to improve the development of habitat functions for target covered species. The monitoring schedule may be adjusted for a particular project in response to monitoring results and the intensity of monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established.	BMNC1.1 FMNC1.1 MFNC1.1 SOBB1.1 SUTH1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM4-3. Quantify the primary production exported from restored tidal marsh plain into adjacent restored subtidal aquatic habitat areas.				
Base Condition: Seasonal abundances of phytoplankton and zooplankton in channels adjacent to restoration sites. Sample restored subtidal prior to breaching of levees, measured for at least one year prior to restoring tidal habitat. **Approach:** Establish monitoring stations at inflow and outflow locations and within restored subtidal habitat. Take weekly grab samples and measurements of chlorophyll a and zooplankton. **Schedule:** Conduct sampling for the first 5 years following reestablishment of tidal flow and every 5 years thereafter.	**Existing Programs:** Environmental Monitoring Program (EMP, under IEP) **Potential Program Additions:** **1.** Additional sampling stations in connection with restored tidal marsh plains to reflect the before-after-control-impact design. Locations of some added stations will be fixed during the duration of the plan (systemwide monitoring to detect increase on food availability in delta waterways), others are added as levees are breached and sites are flooded to track how food production in individual wetlands develops over time (i.e., flux from wetland restoration sites) Sampling stations will also provide water quality data (e.g., temperature, turbidity, pH for ammonia conversion, amount of organic carbon) Invertebrate sampling should be adaptively adjusted to changes in fish diets – see also: Monitoring Action CM4-4, CM4-6, and CM16-5	1. Phytoplankton species composition/relative abundance 2. Phytoplankton density (mg/L chlorophyll a) 3. Zooplankton species composition/relative abundance 4. Zooplankton density (number/1,000 m^3)	This monitoring action is intended to collect data necessary to determine and quantify the degree to which restored tidal habitats are producing and exporting phytoplankton and zooplankton into restored subtidal habitats. This information, in combination with evaluation of other foodweb-related monitoring and research data, will provide the basis for : 1. Identifying sources of uncertainty and the design of management experiments and/ research studies, to address uncertainty. 2. evaluating underlying conceptual models and hypotheses (source-sink dynamics, variability and uncertainty in primary production response) 3. evaluating restoration design options to increase the production and export of primary production from restored tidal marsh plains 4. Implementing additional management actions to improve production and export of primary production from restored tidal marsh plains The monitoring schedule will be modified if uncertainty or variances do not support a clear causal relationship between tidal marsh restoration and food production and exports. The intensity of monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established.	ECSY5.1 ECSY5.2 TANC1.1 BMNC1.1 FMNC1.1 SASP1.2 CHIN1.1 STEE1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM4-4. Document the export of organic carbon produced in restored tidal marsh plain into existing Plan Area channels.				
Base Condition: Not applicable. **Approach:** Determine the extent of organic carbon produced in restored tidal marsh plains that is exported from restored tidal habitats to downstream locations either through modeling (e.g., particle tracking modeling) or direct observation (e.g., isotope marking). **Schedule:** To be determined based on an assessment of the sufficiency of phytoplankton and zooplankton production levels determined under CM4-3. Conduct once to establish the extent of organic carbon that is exported and repeat as needed if hydrodynamic conditions change sufficiently in the future such that export rates might be affected.	**Existing Programs:** Environmental Monitoring program (EMP, under IEP) **Potential Program Additions:** See Monitoring Action CM4-3. 1.Possible adaptive expansion of the monitoring program to include isotope particle marking and tracking to determine organic carbon exports downstream locations	1. Amount of organic carbon produced in restored tidal marsh 2. Proportion of total organic carbon produced in restored tidal marsh plain that is exported to specified downstream locations.	This monitoring action is intended to collect complimentary and additional data necessary to determine if and how much restored tidal habitats are producing and exporting phytoplankton and zooplankton to downstream locations. This monitoring is an adaptive contingency monitoring action in case actions under CM-4 suggest a high degree of uncertainty or suggest inadequacy of conceptual models. This monitoring action will be implemented as targeted research project to address uncertainty in food production pathways and the magnitude and dynamics of exports into Delta water ways. It will be adaptively applied to sites, seasons and identified portions of the Delta.	ECSY5.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM4-5. Determine the extent of covered fish species habitat restored by life stage.				
Base Condition: Not applicable. **Approach:** Based on the current understanding of life stage requirements of each covered fish species and key environmental correlates, delineate the extent of habitat restored for each covered species life stage based on bathymetry (determined from as-build drawings), substrate (assessed before levee breaching), and water quality parameters determined through CM-11. **Schedule:** Annually for the first 10 years and every 5 years thereafter.	**Existing Programs:** Current knowledge on life history and biology of covered fishes in the Delta, life history models. **Potential Program Additions:** 1. Development of spatial databases and mapping capabilities including photo-interpretation (GIS lab)	1. Extent of restored habitat 2. extent of spawning habitat 3. extent of rearing habitat 4. portion of restored habitat within migration routes/corridors	This monitoring action will provide information on the amount of habitat that is being restored through BDCP conservation measures and how it pertains to requirements for stage-specific life history events of covered species. The implementing Office will use this information to determine if restored habitat effectively addresses habitat limitations. The monitoring action will be intensified of modeling or field observations suggest that certain habitats are in short supply and that restoration and protection targets should be modified through the adaptive decision making process.	CHSA1.1 STEE1.1 SASP1.1 GRST1.2 WHST1.1 RILA1.1 PALA1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM4-6. Determine covered fish species use of restored subtidal aquatic habitat.				
Base Condition: Estimated existing seasonal abundances of relevant life stages of covered fish species in channels adjacent to restoration sites based on existing information (IEP fish sampling). **Approach:** Conduct surveys for each covered fish species using standardized existing or improved methods. **Schedule:** Conduct sampling for the first 5 years following reestablishment of tidal flow and at least every 5 years thereafter.	**Existing Programs:** IEP –coordinated fish surveys: 1. CDFG 20 mm Survey 2. CDFG Delta smelt larva study 3. USFWS Spring Kodiak Trawl and "Supplemental Surveys", Mossdale trawl 4. USFWS Midwater trawl 5. USFWS beach seine 6. CDFG Summer townet survey 7. UCD/IEP Suisun Marsh otter trawl **Potential Program Additions:** 1. Expanded sampling location array to reflect changed food availability, diversion and flow regimes (e.g., North delta and Ship Channel); additional sampling areas should be located near restored subtidal habitat to determine fish response to restored habitats. Stratify sampling by project and systemwide variables.	1. Seasonal distribution of covered fish species 2. Type of use (e.g., rearing, spawning) 3. Duration of use 4. species, age composition and sizes of covered fish species 5. CPUE	This monitoring action will provide information to determine and quantify use of restored subtidal aquatic habitat by covered fish species. This information in combination with evaluation of other covered fish species-related monitoring and research data, will be used to evaluate underlying models and hypotheses about the predicted benefits of restored subtidal aquatic habitat to covered fish species. This information will aid in identifying sources of uncertainty and will guide the design of further management experiments and/ research studies to address uncertainty. The Implementing Office will use this information to evaluate restoration design options and additional management actions to increase the benefits of restored tidal marsh plains to covered species. The monitoring schedule and methods may be adjusted for a particular project in response to monitoring results and the intensity of monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established.	CHSA1.1 STEE1.1 SASP1.1 GRST1.2 WHST1.1 RILA1.1 PALA1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM4-7. Determine nonnative fish species use of restored subtidal aquatic habitat.				
Base Condition: Estimated existing seasonal abundances of relevant life stages of nonnative fish species in channels adjacent to restoration sites based on existing information (IEP fish sampling). **Approach:** Conduct surveys for nonnative fish species using standardized existing or improved methods. **Schedule:** Conduct sampling for the first 5 years following reestablishment of tidal flow and at least every 5 years thereafter.	**Existing Programs:** IEP –coordinated fish surveys: 1. CDFG 20 mm Survey 2. CDFG Delta smelt larva study 3. USFWS Spring Kodiak Trawl and "Supplemental Surveys", Mossdale trawl 4. USFWS Midwater trawl 5. USFWS beach seine 6. CDFG Summer townet survey 7. UCD/IEP Suisun Marsh otter trawl **Potential Program Additions:** 1. Expanded sampling location array to reflect changed food availability, diversion and flow regimes (e.g., North delta and Ship Channel); additional sampling areas should be located near restored subtidal habitat to determine fish response to restored habitats. Stratify sampling by project and systemwide variables.	1. Seasonal distribution of covered fish species 2. Type of use (e.g., rearing, spawning) 3. Duration of use 4. species, age composition and sizes of covered fish species 5. CPUE	This monitoring action will provide information to determine and quantify use of restored subtidal aquatic habitat by nonnative fish species. This information in combination with evaluation of other non-native fish species-related monitoring and research data, will be used to evaluate underlying models and hypotheses about the predicted use of restored subtidal aquatic habitat by nonnative fish species. This information will aid in identifying sources of uncertainty and will guide the design of further management experiments and/ research studies to address uncertainty. The Implementing Office will use this information to evaluate restoration design options and additional management actions to minimize the use of restored tidal marsh plains to nonnative species. The monitoring schedule and methods may be adjusted for a particular project in response to monitoring results and the intensity of monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established.	ECSY6.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM4-8. Determine the extent of nonnative submerged (SAV) and floating aquatic vegetation (FAV) in subtidal aquatic habitats.				
Implemented through Monitoring Action CM13-1. *Also see Monitoring Action SY 5-2. Determine the abundance and species composition of non-native, submerged and floating aquatic vegetation (Table 3-20)*				ECSY6.1
Monitoring Action CM4-9. Determine the extent and patterns of establishment of nonnative clams in restored subtidal aquatic habitats.				
Base conditions: ongoing benthic monitoring by IEP throughout the Estuary. **Approach**: Benthic monitoring will be conducted at up to 20 sites within the estuary, with four benthic samples and one sediment sample taken at each site. Samples are analyzed by a contracting lab. Samples will be collected using a hydraulic winch and Ponar dredge or other appropriate grab sampler. **Schedule**: Quarterly	**Existing Programs:** Benthic monitoring component of IEP's Environmental Monitoring Program (EMP) **Potential Program Additions:** Increase the number of benthic sampling stations to up to 20 sites as a representatively sample of the entire BDCP plan area. Database to track observation and incidental records of non-native bivalves to estimate their habitat use and range expansion in the Delta	1. Species of non-native bivalves 2. Total number of individuals counted 3. Size distribution of clams	This monitoring activity provides information on the non-native clams of the estuary, changes in their presence, abundance and distribution. Data collected from the benthic monitoring program is also used to detect newly introduced species in the estuary. The Implementing Office will use this information to determine the status and change of benthic communities over the term of the BDCP and to evaluate possible causal relationships between physical factors and benthic invertebrate communities. This information will also provide important indicators of invasive species progress, impacts of toxics and water operations, and other changes within the Delta. The monitoring schedule may be adjusted to provide data at a higher temporal or spatial resolution of deemed necessary.	ECSY6.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM4-10. Determine the extent and patterns of establishment of Microcystis in restored subtidal aquatic habitats				
Base Condition: existing data on Delta microcystis abundance, productivity and correlations with water quality parameters **Approach:** Establish additional fixed monitoring stations as needed in areas where microcystis blooms are observed or likely to occur given water conditions. Take weekly grab samples and measurements of chlorophyll a. **Schedule:** Conduct sampling for the first 5 years following first detection and every 5 years thereafter.	**Existing Programs:** Environmental Monitoring Program (EMP, under IEP) **Potential Program Additions:** **1.** Locations of added stations will be fixed during the duration of the plan to detect increase on microcystis abundance and blooming activity in delta waterways Sampling stations will also provide water quality data (e.g., temperature, turbidity, pH for ammonia conversion, amount of organic carbon) *See Monitoring Actions CM 4-3, CM4-4 , CM4-6, and CM16-5* *See Monitoring Actions SY5-3 (Table 3-21)*	1. Phytoplankton species composition/relative abundance 2. Phytoplankton density (mg/L chlorophyll a) 3. microcystis colony structure 4. Water temperature 5. $NH4^{+}$ concentration 6. EC 7. presence of non-native clams (see SY5-3)	This monitoring action is intended to collect data necessary to determine and quantify the degree of microcystis spread and toxic blooms in the Delta. This information, in combination with evaluation of other foodweb-related monitoring and research data, will provide the basis for : 1. Identifying sources of uncertainty and the design of management experiments and/ research studies, to address uncertainty. 2. evaluating underlying conceptual models and hypotheses (e.g., excessive N loading . grazing effects by clams, salinity and temperature limiting factors) 3. evaluating restoration design options to increase the production and export of primary production inundated floodplains 4. Implementing additional management actions to improve production and export of primary production from the floodplain.	ECSY6.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM4-11. Determine water quality conditions for covered fish species in restored subtidal aquatic habitats.				
Base Condition: Existing seasonal water quality conditions in channels adjacent to restoration sites based on existing information (see Applicable IEP and other Resources). Upon breaching, establish base conditions by paired sampling within restored habitat and at outflow channel locations. **Approach:** Establish water quality sampling stations in restored subtidal habitat area. Monthly, collect and analyze water grab samples at representative depths for: 1) water temperature, 2) dissolved oxygen, 3) turbidity, 4) salinity, 5) ammonia and 6) methylmercury. **Schedule:** Sample monthly for 1) the first 2 years following reestablishment of tidal flow, 2) quarterly for the following 10 years, 3) and quarterly every 5 years thereafter.	**Existing Programs:** 1. Continuous Multiparameter Monitoring, Discrete Physical /Chemical Water Quality Sampling (Environmental Monitoring program; IEP) 2.Continuous Recorder Sites (DWR, USBR) 3. National Pollutant Discharge Elimination System (NPDES) Self Monitoring Program (Central Valley Water Board) 4. Delta Flows Network and National Water Quality Assessment Program (USGS) 5. other (DWR, SRCSD, SWAMP, Central Valley Water Board, State Water Board, SFEI, etc) **Potential Program Additions:** **1.** There are over 100 water quality sampling sites within the Delta providing a baseline of water quality data. If needed, additional localized sampling stations may be added to reflect the before-after-control-impact design (grab samples in project locations). Locations of some stations will be added as levees are breached and sites are flooded to track water quality changes at restoration sites.	1. Water temperature (^{o}C) 2. mg/L dissolved oxygen 3. Turbidity (NTUs) 4. Salinity (EC) 5. pH 6. mg methylmercury/L	This monitoring action is intended to collect data necessary to determine if water quality conditions in restored tidal marshes are suitable for supporting covered fish species. It will also be used to determine the possible impact on water quality in adjacent channels and habitats. This information will be used to evaluate underlying models and hypotheses of water quality responses to tidal marsh restoration. This information will aid in identifying sources of uncertainty and will guide the design of further management experiments, design modifications and/ research studies to address uncertainty. The monitoring schedule may be adjusted for a particular project in response to monitoring results and the intensity of monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established.	CHSA1.3

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM4-12. Determine the response and status of salt marsh harvest mouse, Suisun shrew, Suisun song sparrow, and California clapper rail, California black rail to loss of existing Suisun Marsh habitats that are restored as tidal habitat.				
Base Condition: The existing distribution and abundance of Suisun Marsh covered mammal and bird species based on existing information and additional surveys if needed. **Approach:** Conduct surveys, transects, mark-recapture or other methods to evaluate the response and status of Suisun Marsh populations of covered mammal and bird species following the conversion of existing species habitat areas to tidal habitat. Map upland refugia during high tide events, survey for presence/use of salt marsh harvest mouse during high tide **Schedule:** Conduct at least annual sampling of covered species distribution and abundance for 5 years following each tidal habitat restoration project until use of restored tidal habitats by covered mammal and bird species is established.	**Existing Programs:** IEP's Suisun marsh program (triennial vegetation surveys, GIS map identifying 103 vegetation classifications, change detection analysis, Salt Marsh Harvest Mouse Monitoring program on Conservation Areas), Point Reyes Bird Observatory (PRBO) San Francisco Bay Tidal Marsh Project, some historical surveys, research projects, approved sampling protocols. **Potential Program Additions:** 1. Regular mark-recapture program for SMHM and Suisun shrew (trapping grids) in Suisun marsh 2. Standardized surveys for Clapper rail, Suisun song sparrow and black rail (using PRBO San Francisco Bay Tidal Marsh Project protocols as appropriate) 3. Establishment of new sampling points/grids/stations as habitat patches are restored See Monitoring Action CM4-9	1. Abundance (N) of each species in Suisun Marsh 2. Population trend (λ) of each species in Suisun Marsh 3. Distribution and range of each species in Suisun Marsh 4. Extent and distribution of upland refugia for salt marsh harvest mouse during high tide.	This monitoring action is intended to test the hypothesis that restoring tidal marshes will have no effect on the status and population size of covered species in Suisun Marsh. Monitoring results will be used to determine how much habitat restoration has affected the distribution and abundance of Suisun Marsh covered mammal and bird species. This information is necessary to determine if adaptive changes to the implementation schedule (i.e., timing and extent of tidal habitat restoration projects in Suisun Marsh) are necessary to maintain viability of covered species populations in Suisun Marsh. Monitoring frequency and intensity may be adjusted to provide monitoring that addresses uncertainties effectively.	TANC1.1 BMNC1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM4-13. Determine covered wildlife species use of restored tidal habitats in Suisun Marsh.				
Base Condition: The existing distribution and abundance of covered marsh-associated wildlife species in Suisun Marsh based on existing information and additional surveys if needed. Not applicable to restoration sites in the Delta. **Approach:** Conduct standardized surveys using established methods to determine the abundance and type of use (e.g., foraging, nesting) of marsh plain and transitional upland habitats by covered wildlife species. Conduct standard vegetation transects and monitoring of incidental reports of newly established clones of covered plants, tracking of growth, survival and cover of covered plant species. **Schedule:** Conduct surveys for each species during each species' active period for 5 years following the development of habitat functions for each species as determined through data collected under CM4-2 and every 5 years thereafter.	**Existing Programs:** IEP's Suisun marsh program, some historical surveys, research projects, approved sampling protocols. **Potential Program Additions:** 1. Intensive mark-recapture program for SMHM and Suisun shrew in Suisun marsh 2. Standardized surveys (breeding, winter) for Clapper rail, Suisun song sparrow and black rail 3. standard surveys of covered plant species 3. Establishment of new sampling points/grids/stations as habitat patches are restored and populations expand See Monitoring Action CM4-8	1. Estimated abundance of each species in using restored habitat 2. estimated populations trend in restored habitats (source or sink?) 3. Presence and population size of covered plant species (e.g., bird's beak, Mason's lilaeopsis, Delta mudwort, Delta tule pea Slough thistle,and Suisun Marsh aster)	This monitoring action is intended to collect data on the distribution and population trend of covered species in Suisun Marsh restored habitats. Monitoring results will be used to determine if habitat restoration has a source or sink effect on the abundance of Suisun Marsh covered mammal and bird species This information is necessary to determine if adaptive changes to the implementation schedule (i.e., timing and extent of tidal habitat restoration projects in Suisun Marsh) are necessary to maintain populations of these covered species in Suisun Marsh and to increase the utility of restored habitats to covered species	ECSY1.5 TANC1.1 MFNC1.1 MFNC1.2 BMNC1.1 BMNC2.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM4-14. Determine covered wildlife species use of restored tidal habitats in the Delta.				
Base Condition: The existing distribution and abundance of covered marsh-associated wildlife species, specifically giant garter snake (Conservation Zone 4 and 5), western pond turtles, and California least tern foraging sites. **Approach:** Conduct standardized surveys using established methods to determine the abundance and type of use (e.g., foraging, nesting) of marsh plain and transitional upland habitats by covered wildlife species. Conduct standardized surveys using established methods to determine the abundance and type of use (e.g., foraging, nesting) of Giant Garter snake (Conservation Zone 4 and 5), western pond turtles, and California least tern sites. **Schedule:** Conduct surveys for each species during each species' active period for 5 years following the development of habitat functions for each species as determined through data collected under CM4-2 and every 5 years thereafter.	**Existing Programs:** historical surveys, research projects, approved sampling protocols. **Potential Program Additions:** 1. Standardized surveys for Giants Garter Snake, western pond turtles and California least tern 3. Establishment of new sampling points/grids/stations as habitat patches are restored and populations expand See Monitoring Action CM4-8	1. Presence and sex/age distribution of Giant Garter Snake 2. Presence and sex/age distribution of western pond turtles 3. Estimated populations trend of covered species in restored habitats (source or sink?)	This monitoring action is intended to collect data on the distribution and population trend of covered species in restored habitats. Monitoring results will be used to determine if habitat restoration has a source or sink effect on the abundance of covered mammal and bird species. This information is necessary to determine if adaptive changes to the implementation schedule (i.e., timing and extent of tidal habitat restoration projects) are necessary to maintain populations of these covered species and to increase the utility of restored habitats to covered species.	ECSY1.5 TANC1.1 MFNC1.1 MFNC1.2 BMNC1.1 BMNC2.1 FMNC1.1 FMNC2.1 GGSN1.1 GGSN2.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
CM5: Seasonally Inundated Floodplain Restoration				
Monitoring Action CM 5-1: Develop inundation rating curves to quantify the relationship between discharge and inundation dynamics of floodplain habitat for covered species.				
Base condition: As-built restored habitat elevations and river stage elevations**.** **Approach:** The Implementing Office will develop inundation rating curves for inundation depth and extent of restored inundated floodplain habitat area and will record floodplain inundation events and period of inundation by automatic water depth monitoring gages and other appropriate methods. **Schedule**: monitoring of inundation depth and extent of inundated area will continue until a sufficient inundation rating curve can be established with reasonable uncertainty.	**Existing Programs:** California Bay Delta Authority Science Program - Integrated Regional Wetlands Monitoring (historical pilot program) **Potential Program Additions:** 1. Installation and monitoring of automated monitoring devices or other appropriate measures to determine inundation depth, stage and frequency.	1. Inundation frequency 2. Inundation duration	This monitoring element will provide information on the relationship between inundation depth and inundation period and extent to guide the design of floodplain projects and/or operation of flood control structures. This information will be used to guide and if necessary, change the design of floodplain restoration projects and if applicable, the operation of flood control structures to effectively control the period of inundation in seasonal floodplains under an variable flow regimes. The monitoring schedule may be adjusted in response to uncertainty of the established ratings curve.	CHSA1.1 STEE1.1 SASP1.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM5-2: Record and quantify incidences and locations of stranded covered fish species at the end of the inundation period in restored floodplains.				
Base Condition: none **Approach**: Visual and other surveys (e.g., beach seining) immediately following inundation periods in restored floodplain habitats as flows are receding from the floodplain to document stranding locations and magnitude. **Schedule**: Annual surveys for the first five years after restoration. Once documented, monitoring will be discontinued and a more limited monitoring effort to be determined by the Implementing Office would be conducted every 5th year that restored floodplains are inundated to document any changes in stranding location and magnitude that may result from changes in floodplain topography (e.g., formation of scour holes or sedimentation that create isolated pools).	**Existing Programs:** Intermittent and historical IEP and USFWS beach seine and trawling methods within the Yolo and Sutter bypasses **Potential Program Additions:** **1.** Weekly surveys of restored floodplains to identify areas suddenly dewatered by lower river conditions which may contain stranded fish. 2. Follow-up on the ground, dip netting, beach seining or electro-shocking of remnant puddles to verify stranding. On-the-ground mapping of standing locations to guide re-contouring.	1. locations of covered fish species stranding 2. number, species, length, and age/sex distribution of stranded fish 3. type of stranding pool (i.e., erosion, topography, man-made, etc.)	This monitoring action will provide information on the extent and magnitude of fish strandings at the end of the inundation period in restored floodplains. This information will be used to determine the severity of fish stranding and their locations within the restored floodplain. Results of monitoring will be used to determine if modifications to floodplain surfaces are needed to reduce stranding risk (e.g., grading). The schedule of the monitoring action may be adjusted to reflect changes in management. In locations where floodplain topography was altered to reduce fish stranding, monitoring will continue for at least 3 years to document reduction in stranding incidences.	CHIN1.1 STEE1.1 SASP1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM5-3. Quantify presence and abundance of juvenile salmonids in restored floodplain habitats during inundation periods.				
Base Condition: Concurrent presence and abundance of juvenile salmonids in adjacent Delta waterways **Approach**: Visual and non-lethal fish sampling (e.g., beach seining, electrofishing) of representative, randomly selected sections of restored floodplain habitats during the inundation period and in adjacent Delta waterways. **Schedule**: During the first 5 floodplain inundation events that coincide with rearing/outmigration periods of juvenile salmonids, conduct biweekly sampling of the inundated floodplain as long as the floodplain is inundated. Subsequently monitor every fifth flood event over the term of the BDCP.	**Existing Programs:** Historical sampling, USFWS weekly beach seining survey of juvenile salmonids (49 permanent locations Delta wide) **Potential Program Additions:** 1. Add sampling locations to include restored floodplain and adjacent channel habitats to ensure statistical representative sampling effort	1. Abundance, size, and race of salmonid species in the inundated restored floodplain habitat and in adjacent Delta waterways.	This monitoring action will provide information on the presence and abundance and relative use of restored floodplains compared to adjacent delta waterways. Results of monitoring will be assessed to determine if floodplain habitats attract more salmonids than adjacent waterways and if fish abundance, age and size distributions differ among restored floodplains and adjacent waterways of the Delta. Results will be used to determine if subsequent design or locations of restored floodplains need to be adjusted to improve their function as juvenile salmonid habitat. The schedule of the monitoring action may be adjusted to reflect changes in management or research results on fish presence in inundated floodplains.	CHSA1.1 CHSA1.2 STEE1.1 STEE1.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM5-4: Delineate and quantify Sacramento splittail spawning and rearing in relationship to restored seasonally inundated floodplain habitat.				
Base condition: Conduct surveys of splittail adults, larvae, and eggs in slow-moving sections of rivers and sloughs and dead-end sloughs adjacent to projected floodplains to determine the abundance of splittail larvae and early juveniles present during the reproductive period. **Approach:** Conduct fish sampling surveys in restored floodplain habitats and adjacent slow-moving sections of rivers and sloughs and dead-end sloughs during inundation periods to determine the change in densities of larvae and juveniles relative to base conditions and in-channel spawning. **Schedule:** Weekly fish sampling will be conducted in spawning habitat within restored habitats and in adjacent channel habitats during the first 5 floodplain inundation periods during the splittail spawning season. Subsequently monitor every fifth flood event over the term of the BDCP.	**Existing Programs:** USFWS rotary screw traps USFWS beach seine **Potential Program Additions:** 1. Add sampling locations to include restored floodplain and adjacent channel habitats to ensure statistical representative sampling effort	1. Production of Sacramento splittail (number of larval and early juvenile splittail/10,000 m^3) during floodplain inundation periods	This monitoring action will provide information on productivity of Sacramento splittail populations and the contribution of inundated restored floodplains on spawning and rearing of splittail. This information will be used by the Implementing Office to decide if the production of splittail during floodplain inundation periods has increased significantly from base conditions. If monitoring results do not support conceptual models and hypotheses predicting increasing splittail spawning, the Implementing Office will conduct additional studies to determine 1. uncertainties and competing hypotheses 2. other factors/stressors that affect splittail spawning and rearing in restored habitats, and 3. restoration design modifications to increase splittail productivity. If causes are related to inundation duration, experimental management of flood control structures and floodplain topography may used to address uncertainties. The monitoring schedule may be extended or intensified if uncertainties of causal relationships persist.	SASP1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM5-5: Quantify abundance of nonnative fish species in restored floodplain habitats during inundation periods.				
Base Condition: Concurrent abundance of nonnative fish species in adjacent Delta waterways **Approach**: Visual and non-lethal fish sampling (e.g., beach seining, electrofishing) of representative, randomly selected sections of restored floodplain habitats during the inundation period and in adjacent Delta waterways. **Schedule**: During the first 5 floodplain inundation events that coincide with rearing/outmigration periods of juvenile salmonids, conduct biweekly sampling of the inundated floodplain as long as the floodplain is inundated. Subsequently monitor every fifth flood event over the term of the BDCP.	**Existing Programs:** Historical sampling, USFWS weekly beach seining (49 locations Delta wide) **Potential Program Additions:** 1. Add sampling locations to include restored floodplain and adjacent channel habitats to ensure statistical representative sampling effort	1. Abundance, size, and race of salmonid species in the inundated restored floodplain habitat and in adjacent Delta waterways.	This monitoring action will provide information on the presence, abundance, and relative use of restored floodplains compared to adjacent delta waterways. Results of monitoring will be assessed to determine if floodplain habitats attract more salmonids than adjacent waterways and if fish abundance, age and size distributions differ among restored floodplains and adjacent waterways of the Delta. Results will be used to determine if subsequent design or locations of restored floodplains need to be adjusted to improve their function as juvenile salmonid habitat. The schedule of the monitoring action may be adjusted to reflect changes in management or research results on fish presence in inundated floodplains.	ECSY6.1 CHSA1.8 STEE1.7 SASP1.5

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM5-6: Identify types and quantities of aquatic food production for covered fish species.				
Base Condition: Aquatic food production in adjacent channel habitat prior to restoration activities. Take weekly samples and measurements during inundation period for zooplankton and pelagic macroinvertebrates in Delta waterways adjacent to floodplain restoration sites for a least one year before habitat is restored to establish base conditions. **Approach:** Sample and measure zooplankton and pelagic macroinvertebrates abundance weekly at inflow, outflow and interior sampling points/transects within restored floodplains during inundation periods, and compare these with in-channel samples of zooplankton and pelagic macroinvertebrates taken in adjacent waterways. Assess measurements of zooplankton and pelagic macroinvertebrates to establish relationships between restored floodplain habitat during inundation periods and production of zooplankton and and pelagic macroinvertebrate forage species for covered fish. **Schedule** : Once these relationships have been established, annual monitoring of aquatic food production may be discontinued and a more limited monitoring effort to be determined by the Implementing Office may be conducted every 5th year to document any changes in zooplankton and macroinvertebrates production during floodplain inundation periods over the term of the BDCP.	**Existing Programs:** Zooplankton monitoring conducted by Environmental Monitoring Program (EMP under IEP umbrella) also includes monitoring of water quality, benthos, phytoplankton and exotic species **Potential Program Additions:** 1. Additional sampling stations to reflect the before-after-control-impact design. Locations of some added stations will be fixed during the duration of the plan (systemwide monitoring to detect increase on food availability in delta waterways), others are added as levees are breached and sites are flooded to track how food production in individual wetlands develops over time (i.e., flux from wetland restoration sites) Sampling stations will also provide water quality data (e.g., temperature, turbidity, pH for ammonia conversion, amount of organic carbon) Invertebrate sampling should be adaptively adjusted to changes in fish diets – see also Monitoring Action CM4-4 and Monitoring Action CM4-6.	1. Zooplankton species composition/relative abundance 2. Zooplankton density (number/1,000 m^3) 3. Pelagic macroinvertebrate species composition / relative abundance 4. Pelagic macroinvertebrate density (number/1,000 m^3)	The monitoring action will provide information to test hypotheses on the role that the restored floodplain plays in providing additional aquatic food resources for covered fish in and outside the restoration areas. The monitoring will provide quantitative assessments to determine how much of this food enters the aquatic system through outflows from the floodplain. This information will be used by the Implementing Office to determine if and how much restored floodplains contribute to increased food availability for covered fish species. This information will be used to guide the development of alternative models, hypotheses, management strategies and additional research studies to resolve uncertainties about hypotheses or models. For example, if production of zooplankton and macroinvertebrates does not exceed production relative to base conditions or is not trending towards achieving those production levels, the Implementing Office may conduct investigations to determine causes for insufficient production of zooplankton and macroinvertebrates. Depending on the causes, potential actions could include the experimental modification of floodplain surfaces to increase inundation duration or vegetation structure, or installing water control structures at inflow and outflow locations.	ECSY5.1 ECSY5.2 CHSA1.2 STEE1.2 SASP1.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM5-7: Document occurrences and abundances of delta button-celery and slough thistle.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	MFNC1.1 MFNC1.2
CM6: Channel Margin Habitat Restoration				
Monitoring Action CM6-1 Extent of channel margin enhanced to provide habitat for covered fish species.				
Base Condition: As-built restoration designs. Baseline documentation for acquired parcels **Approach:** Extent of enhanced habitat following restoration actions will be delineated, including habitat type (e.g., submerged bench, channel margin emergent vegetation, overhead shaded riverine cover) and vegetation communities. **Schedule**: Annually delineate habitat components for the first 5 years following restoration actions.	**Existing Programs:** DWR IISS section within DWR-DES (potentially) **Potential Program Additions:** 1. Development of spatial databases and mapping capabilities including photo-interpretation (GIS lab) 2. Vegetation sampling (on-the ground) for field verification to increase mapping accuracy (aquatic botanist/ field personnel) See Monitoring Action CM4-1, CM4-2, CM6-2)	1. Linear feet of enhanced habitat by habitat type	This monitoring action will provide information about the progress and spatial extent of channel habitat enhancement. This information will be used to determine if subsequent restoration designs can or should be modified to improve habitat conditions for covered fish species. It will also serve to guide and design management actions to increase or maintain enhancement results (see Monitoring Action CM16-2). The monitoring schedule may be adjusted for a particular project in response to monitoring results. The intensity of monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established.	MFNC1.1 MFNC1.2 CHSA1.1 STEE1.1 SASP1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
CM6-2: Quantify the extent and dynamics of establishment of emergent vegetation .				
Base Condition: As-built restoration designs. Targets for the establishment of emergent vegetation as identified in habitat enhancement design specifications for each channel margin enhancement site. Baseline documentation for acquired parcels. **Approach:** Percent absolute vegetative cover and extent of vegetated channel will be determined in years 1, 2, and 5 following enhancement. Enhancement sites will be monitored at least every 5 years to assess the extent of established non-native invasive vegetation.	**Existing Programs:** DWR IISS section within DWR-DES **Potential Program Additions:** 1. Development of spatial databases and mapping capabilities including photo-interpretation (GIS lab) 2. Vegetation sampling (on-the ground) for field verification to increase mapping accuracy (aquatic botanist/ field personnel) See Monitoring Action CM4-1, CM4-2, CM6-1)	1. Percent absolute vegetation cover over time 2. Linear extent of vegetated channel margin 3. Presence and extent of non-native invasive vegetation	This monitoring action is intended to provide information regarding the development of habitat structure and vegetation community structure in enhanced channel margin habitats over time. This information will provide the basis for determining if there is a need to modify subsequent enhancement designs to improve the development of emergent vegetation over time. It also may guide development of management actions to improve the establishment of emergent plant communities in enhanced channel margin habitats, including additional studies to identify such actions. The monitoring schedule may be adjusted for a particular project in response to monitoring results and the intensity of monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established.	FMNC1.1 FMNC2.1 MFNC1.1 MFNC1.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
CM6-3: Quantify the presence and abundance of covered and nonnative fish species using enhanced channel margin habitats.				
Base condition: If sufficient existing information is not available, conduct monthly fish sampling surveys along existing channel margin habitats to be enhanced for a least one year before enhancement is implemented using appropriate survey methods to be determined by the Implementing Office to establish base conditions. **Approach:** Following enhancement, initiate comparable surveys within enhanced channel margin habitats and continue surveys **Schedule**: Continue surveys until a relationship between the abundance of each covered fish species/non-native predatory fish species and the extent and function of enhanced habitat is established (at least 5 years). Subsequently, surveys will be conducted at least every 5 years to document any changes that may occur in use of enhanced channel margin habitats over the term of the BDCP.	**Existing Programs:** fish surveys 1. CDFG 20 mm Survey 2. CDFG delta smelt larva study 3. USFWS Spring Kodiak Trawl and 'Supplemental Surveys", Mossdale trawl 4. USFWS Midwater trawl 5. USFWS beach seine 6. CDFG Summer townet survey 7. UCD/IEP Suisun Marsh otter trawl **Potential Program Additions:** Expanded sampling location array to sampling locations along channel margin and within channel margin habitats. Beach seining to reflect micro-habitats and shallow areas not sampled by trawls. Trawl or townet surveys if channel margin extends too deep for beach seine sampling.	1. Presence of covered fish species by life stage in enhanced channel margin habitats 2. Abundance and length of covered fish species per unit area of habitat 3. Abundance of nonnative fish per unit area of habitat 4. Ratio of nonnative predatory fish to native fish	This monitoring action will provide quantitative information about the effectiveness of the enhanced channel margins to provide habitat for different life stages of covered fish species and their spatial response (presence and density) to these enhancements. Monitoring results will be used to evaluate if targets and objectives have been met, parameterize and evaluate conceptual models and other analytical tools, and to prioritize potential actions according to certainty, magnitude and timeliness of benefit. The information provided will also support decisions on potential modification of enhancement design and techniques. It will guide management actions to maintain enhanced habitats. It will also be used to determine if additional research activities or special survey technology should be developed. The monitoring schedule may be adjusted if the relationship between the abundance of each covered fish species/non-native predatory fish species and the extent and function of enhanced habitat cannot be established with acceptable certainty over the first 5 years, especially in cases where designs and enhancement techniques are changed through the adaptive management process. In these cases, annual monitoring will continue for 10 years post enhancement, and then be repeated every 5 years.	ECSY6.1 CHSA1.8 STEE1.7 SASP1.5 CHSA1.1 STEE1.1 SASP1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM6-4: Document occurrences and abundances of intertidal covered plant species.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	FMNC1.1 FMNC2.1 MFNC1.1 MFNC1.2 SOBB1.1 SOBB1.2 SUTH1.1 SUTH1.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
CM7: Riparian Habitat Restoration				
Monitoring Action CM7-1. Document the extent of riparian natural communities restored.				
Base Condition: As-built construction drawings. **Approach:** Delineate the extent of restored riparian habitat by vegetation community type, vegetation structure type, and seral stage; to characterize vegetation structure, measure vegetation attributes such as canopy height, canopy closure, and percent midstory cover. Also measure percent native trees and percent native shrubs **Schedule:** Annually delineate habitat components for the first 5 years following the implementation of individual riparian restoration projects and every 5 years thereafter.	**Existing Programs:** DWR IISS section within DWR-DES (potentially) **Potential Program Additions:** 1. Development of spatial databases and mapping capabilities including photo-interpretation (GIS lab) including terrestrial data 2. Vegetation sampling (on-the ground) for field verification to increase mapping accuracy (terrestrial botanist/ field personnel) See also Monitoring Action CM4-1, CM4-2, CM16-1, CM16-2)	1. Acres of each component of restored riparian habitat. 2. patch length, width 3. % absolute vegetation cover. 4. % relative cover of native plant species. 5. Canopy height 6. Canopy closure 7. % midstory cover 8. % native trees 9. % native shrubs	This monitoring action is intended to provide information regarding the development of restored riparian habitat components over time. This information will provide the basis for determining if there is a need to: Modify subsequent restoration designs to improve their ecosystem and habitat functions, Undertake management actions to improve development of desired habitat functions (e.g., control of non-native vegetation, planting of native vegetation, improve local hydrology to enhance development of riparian functions and diversify native vegetation types, habitat structure, and seral stage). The monitoring schedule may be adjusted for a particular project in response to monitoring results and the intensity of monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established.	VRNC1.1 VRNC2.3 RIBR1.1 RIWR1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM7-2. Document the extent of covered species habitat supported by restored riparian natural communities.				
Base Condition: As-built construction drawings. **Approach:** Evaluate and quantify the extent of each covered species habitat based on evaluation of data collected under Monitoring Action CM7-1. **Schedule:** Annually quantify the extent of restored, covered species habitats for the first 5 years following the implementation of every riparian restoration project and every 5 years thereafter.	**Existing Programs:** DWR IISS section within DWR-DES (potentially) **Potential Program Additions:** 1. Development of spatial databases and mapping capabilities including photo-interpretation (GIS lab) including terrestrial data 2. Vegetation sampling (on-the ground) for field verification to increase mapping accuracy (terrestrial botanist/ field personnel) See also Monitoring Action CM4-1, CM4-2, CM16-1, CM16-2)	1. Acres of each covered species habitat restored.	This monitoring action is intended to provide information regarding the development of habitat functions for covered species in restored riparian habitats over time. This information will provide the basis for determining if there is a need to modify subsequent restoration designs to improve the development of habitat functions for target covered species. The monitoring schedule may be adjusted for a particular project in response to monitoring results and the intensity of monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established.	VRNC1.1
Monitoring Action CM7-3. Document the extent of restored riparian brush rabbit and riparian woodrat habitat.				
Base Condition: As built construction drawings. **Approach**: Annual stratified randomized surveys of Riparian brush rabbit for 10 consecutive days **Schedule**: Every 5 years in suitable riparian habitat followed by surveys every 5 years	**Existing Programs:** DWR IISS section within DWR-DES (potentially) **Potential Program Additions:** 1. Development of spatial databases and mapping capabilities including photo-interpretation (GIS lab) including terrestrial data **2.** field survey crews for riparian wildlife surveys	1. Acreage and net gain or loss (%) of suitable habitat with adjacent upland flood refugia 2. Number and size of largest patches of suitable riparian habitat with upland refugia 3. Connectivity between suitable riparian habitat in the Plan Area and occupied habitat outside the Plan Area 5. Presence/abundance of riparian woodrats in Conservation Zone 7		RIBR1.1 RIWR1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM7-4. Document the self-sustainability of restored riparian habitats and their functioning over time.				
Base Condition: As-built construction drawings. **Approach:** Evaluate and quantify the extent of restored riparian habitat exhibiting ecological succession, characteristic attributes and regeneration based on evaluation of data collected under Monitoring Action CM7-1. **Schedule:** Quantify the extent of restored riparian habitat exhibiting regeneration and/or ecological succession by spatially tracking changes in seral stage every 5 years beginning with the implementation of every riparian restoration project.	**Existing Programs:** None **Potential Program Additions:** 1. Habitat structural monitoring/inventory using standard forestry and/or botanical protocols 2. randomized sampling of riparian habitat structure	1. Percent relative cover of restored riparian habitat exhibiting succession 2. Percent relative cover of restored riparian habitat exhibiting regeneration. 3. Connectivity with existing riparian corridors	This monitoring action is intended to provide information regarding the self-sustainability of restored riparian habitats and their functioning over time. This information will provide the basis for determining if there is a need to modify subsequent restoration designs to improve the development of habitat functions for target covered species. The monitoring schedule may be adjusted for a particular project in response to monitoring results and the intensity of monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established.	ECSY1.5 VRNC2.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM7-5. Determine covered wildlife species use of restored riparian habitats.				
Base Condition: The existing distribution and abundance of covered wildlife species in restored riparian patches based on existing information and additional surveys if/where needed. **Approach:** Conduct standardized surveys using established methods to determine the abundance and type of use (e.g., foraging, nesting) of riparian habitats by covered wildlife species. **Schedule:** Conduct surveys for each species during each species' active period for 5 years following the implementation of each restoration project as determined through data collected under CM4-2 and every 5 years thereafter.	**Existing Programs:** 1. Breeding bird survey routes (partial) 2. historical and intermittent research results (e.g., Point Reyes Bird Observatory bird monitoring database from over 250 sites in riparian habitats throughout California, much of it in the Central Valley) 3. CALFED science program bird monitoring element of project plans **Potential Program Additions:** 1. Breeding bird surveys (USGS protocol) at additional locations in restored riparian habitats, surveys should be consistent with the Riparian Habitat Joint Venture's "Riparian Bird Conservation Plan" 2. Randomized amphibian an reptile surveys during peak activity times in restored riparian habitats and adjacent remnant riparian habitats (control sites).	1. Estimated abundance of each species using restored riparian habitat 2. Estimated extent of occupied covered species habitat	This monitoring action is intended to provide information regarding the type and extent of use of restored habitats by riparian-associated covered wildlife species. This information will provide the basis for determining if there is a need to modify subsequent restoration designs to improve the development of habitat functions for target covered species. The monitoring schedule may be adjusted for a particular project in response to monitoring results and the intensity of monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established.	VRNC1.1 VRNC2.1 RIBR1.1 RIWR1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
CM8: Grassland Community Restoration				
Monitoring Action CM8-1. Document the extent of grassland habitat restored.				
Base Condition: As-built construction drawings. **Approach:** Delineate the extent of grassland habitat by vegetation type, vegetation structure, and dominant species composition. **Schedule:** Annually delineate habitat components for the first 5 years following the implementation of individual grassland restoration projects.	**Existing Programs:** DWR IISS section within DWR-DES (potentially) **Potential Program Additions:** 1. Development of spatial databases and mapping capabilities including photo-interpretation (GIS lab) including terrestrial data 2. Vegetation sampling (on-the ground) for field verification to increase mapping accuracy (terrestrial botanist/ field personnel) See also Monitoring Action CM4-1, CM4-2, CM16-1, CM16-2)	1. Acres of each component of restored grassland habitat. 2. Percent absolute vegetation cover. 3. Percent relative cover of native plant species.	This monitoring action is intended to provide information about the development of grassland attributes in restored grassland habitat parcels over time. Monitoring results will be used to determine if subsequent restoration designs should be modified to improve their ecosystem and habitat functions. It will also guide adaptive management actions to improve development of desired habitat attributes (e.g., re-seeding, planting of native vegetation, control of non-native vegetation). The monitoring schedule may be adjusted for a particular project in response to monitoring results, especial the rangeland health assessment. The intensity of monitoring for subsequent projects may be decreased if strong causal relationships between restoration actions and grassland community responses are established.	ECSY1.3 ECSY1.5 ECSY3.2 GRNC1.2 GRNC2.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM8-2. Document the ecosystem functions of restored grassland habitat in comparison with site potential.				
Base Condition: Post-restoration conditions determined under CM8-1). Reference sheet for ecological site(s) – to be developed if necessary. **Approach:** Apply the "Interpreting Indicators of Rangeland Health" protocol to conduct rapid, qualitative assessment of soil/site stability, hydrologic function, and biotic integrity of restored grassland sites against a reference condition (ecological site; see Appendix I-xx, "Interpreting Indicators of Rangeland Health- version 3.0"). **Schedule:** Conduct rangeland health assessment in year 5 and every 10 years thereafter	**Existing Programs:** 1. NRCS National Grazing Lands Team, 2. County RCDs 3. NRCS local and regional offices **Potential Program Additions:** 1. ESD reference sheets for all restored grassland sites 2. Rangeland health assessment capabilities (terrestrial botanist, collaboration with NRCS soil specialists)	Rangeland health indicators: 1. Rills 2. Water Flow Patterns 3. Pedestals and/or Terracettes 4. Bare Ground 5. Gullies 6. Wind Scour or deposition 7. Litter Movement 8. Soil Surface Resistance to Erosion 9. Soil Surface Loss & Degradation 10. Plant Community Composition and Distribution Relative to Infiltration and Runoff 11. Compaction 12. Functional/Structural Groups 13. Plant Mortality and Decadence 14. Litter Amount 15. Annual Production 16. Invasive Plants 17. Reproductive Capability of Perennial Plants	This monitoring action is intended to provide information about the development of ecosystem functions in restored grassland habitat components over time. This information will provide the basis for addressing whether subsequent restoration designs should be modified to improve their ecosystem and habitat functions. It also will establish if adaptive management actions or interventions are required to halt deteriorative processes (erosion, invasive weeds). Furthermore, the information may provide reasons for additional research studies to address and resolve uncertainties in understanding ecosystem processes in restored grassland habitats. The monitoring schedule may be adjusted for a particular project in response to monitoring results. The intensity of monitoring for subsequent projects may be decreased if strong causal relationships between restoration actions and grassland community responses are established.	GRNC1.2 GRNC2.1 GRNC2.2 GRNC2.3 GRNC2.4 GRNC2.5

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM8-3. Document the extent of covered species habitat supported by restored grassland natural communities.				
Base Condition: Post-restoration conditions determined under CM8-1). **Approach:** Evaluate and quantify the extent of each covered species habitat based on evaluation of data collected under Monitoring Action CM8-1. **Schedule:** Annually quantify the extent of restored, covered species habitats for the first 5 years following the implementation of every grassland restoration project and every 5 years thereafter.	**Existing Programs:** 1. USGS Breeding bird survey routes (partial) 2. historical and intermittent research studies **Potential Program Additions:** 1. Breeding bird surveys (USGS protocol) at additional locations in restored grassland habitats 2. randomized camera trap, track, scat or spotlight surveys for mammals 3. Randomized amphibian an reptile surveys during peak activity times in restored habitats and adjacent remnant riparian habitats (control sites).	1. Acres of each covered species habitat restored.	This monitoring action is intended to provide information regarding the development of habitat functions for covered species in restored grassland habitats over time. This information will provide the basis for determining if there is a need to modify subsequent restoration designs to improve the development of habitat functions for target covered species. The information will also be used to determine what management actions (e.g., prescribed burning, controlled livestock grazing, weed control) are appropriate and indicated to advance progress towards achieving conservation targets. The monitoring schedule may be adjusted for a particular project in response to monitoring results and the intensity of monitoring for subsequent projects may be decreased if strong causal relationships between restoration actions and outcomes are established.	GRNC1.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM8-4: Determine covered wildlife and plant covered species use of restored grassland.				
Base Condition: Post-restoration conditions determined under CM8-1). **Approach:** Conduct standardized surveys using established methods to determine the abundance and type of use (e.g., foraging, breeding) of vernal pool complex by covered wildlife species. **Schedule:** Conduct surveys during each species' active period for 5 years following implementation of each restoration project as determined through data collected under CM8-3 and every 5 years thereafter.	**Existing Programs:** DWR IISS section within DWR-DES (potentially) **Potential Program Additions:** See CM 8-3	1. Estimated abundance of each species using restored grassland 2. Estimated extent of grassland habitat occupied by each covered species (or number of occurrences for covered plant species) 3. Occurrence of breeding activity	This monitoring action is intended to provide information regarding the degree of apparent response by covered species to grassland restoration and the habitat functions provided. This information will provide the basis for determining if there is a need to modify subsequent restoration designs to improve the development of habitat functions for target covered species. The monitoring schedule may be adjusted for a particular project in response to monitoring results and the intensity of monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established	GRNC1.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
CM9: Vernal Pool Complex Restoration				
Monitoring Action CM9-1. Document the extent of vernal pool complex restored.				
Base Condition: As-built construction drawings. **Approach:** Delineate the extent of restored vernal pool complex by type (e.g., vernal pools, vernal pool margins, and swales) and in relation to the local moisture gradient and dominant, associated plant communities. **Schedule:** Annually delineate habitat components for the first 5 years following the implementation of individual vernal pool complex restoration projects and every 5 years thereafter.	**Existing Programs:** DWR IISS section within DWR-DES (potentially) Various vernal pool monitoring and sampling plans (e.g., **Potential Program Additions:** 1. Development of spatial databases and mapping capabilities including photo-interpretation (GIS lab) 2. Vegetation sampling (on-the ground) for field verification to increase mapping accuracy (terrestrial botanist)	1. Acres of each component of restored vernal pool complex habitat. 2. Percent absolute vegetation cover. 3. Percent relative cover of native plant species.	This monitoring action is intended to provide information regarding the development of restored habitat components over time. This information will provide the basis for determining if restoration targets (acres) are met, if existing restoration designs and methods are adequate in providing the desired results, and if uncertainties exist that may require additional experimentation or research. Monitoring information will also provide information necessary to determine if habitat management actions are necessary to improve habitat functions (e.g., the need to implementing nonnative species control actions). The monitoring schedule may be adjusted for a particular project in response to monitoring results and the intensity of monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established.	VPNC2.1 VPNC2.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM9-2. Quantify the extent of covered species habitat and functions supported by restored vernal pool complex.				
Base Condition: As-built construction drawings. **Approach:** Evaluate and quantify the extent of each covered species habitat based on evaluation of data collected under Monitoring Action CM9-1 and based on inventory of key environmental correlates or habitat requisites of covered species. **Schedule:** Annually quantify the extent of restored, covered species habitats for the first 5 years with sufficient hydrology following the implementation of every vernal pool complex restoration project and every 5 years thereafter.	**Existing Programs:** DWR IISS section within DWR-DES (potentially) **Potential Program Additions:** 1. Development of spatial databases and mapping capabilities including photo-interpretation (GIS lab) 2. Vegetation sampling (on-the ground) for field verification to increase mapping accuracy 3. Delineation and mapping of species occurrences and special habitat features (key ecological correlates) that are pre-requisite for covered species using the site (e.g., small mammal burrows for burrowing owls) 4. Hydrological monitoring program (remote or on the ground tracking of inundation of vernal pool habitats 5. Survey team for vernal pool species (botanist, aquatic ecologist)	1. Acres of each covered species habitat restored. 2. Presence and abundance of habitat elements required by covered species for breeding, resting, foraging etc. Source of water feeding the restored vernal pool complex 3. Seasonal timing and duration of the inundation and water-logged soil phase 4. Estimated species diversity 5. Presence/abundance of non-native species 6. Presence/abundance of non-native predators	This monitoring action is intended to provide information regarding the development of habitat functions for covered species in restored vernal pool complex habitats over time. This information will provide the basis for determining if there is a need to modify subsequent restoration designs to improve the development of habitat functions for target covered species. The monitoring schedule may be adjusted for a particular project in response to monitoring results and the intensity of monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established.	VPNC2.1 VPNC2.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM9-3: Determine covered wildlife and plant covered species use of restored vernal pool complex.				
Base Condition: The existing distribution and abundance of covered wildlife species in restored vernal pool complex patches based on existing information and additional surveys if/where needed. **Approach:** Conduct standardized surveys using established methods to determine the abundance and type of use (e.g., foraging, breeding) of vernal pool complex by covered wildlife species. **Schedule:** Conduct surveys for each species during each species' active period for 5 years for which sufficient hydrology is present following the implementation of each restoration project as determined through data collected under CM9-2 and every 5 years thereafter.	**Existing Programs:** DWR IISS section within DWR-DES (potentially) **Potential Program Additions:** See CM 9-2	1. Estimated abundance of each species using restored vernal pool complex 2. Estimated extent of vernal pool complex habitat occupied by each covered species (or number of occurrences for covered plant species 3. Occurrence of breeding or regeneration at restored vernal pool complex	This monitoring action is intended to provide information regarding the degree of apparent response by covered species to vernal pool complex restoration and the habitat functions provided. This information will provide the basis for determining if there is a need to modify subsequent restoration designs to improve the development of habitat functions for target covered species. The monitoring schedule may be adjusted for a particular project in response to monitoring results and the intensity of monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established	VPNC2.1 VPNC2.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
CM10: Nontidal Freshwater Marsh Restoration				
Monitoring Action CM10-1. Document the extent of nontidal marsh habitat restored.				
Base Condition: As-built construction drawings, comprehensive ecological baseline documentation. **Approach:** Delineate the extent of nontidal freshwater marsh by vegetation type, vegetation structure, and plant species composition. **Schedule:** Annually delineate habitat components for the first 5 years following the implementation of individual non-tidal marsh restoration projects and every 5 years thereafter.	**Existing Programs:** DWR IISS section within DWR-DES (potentially) **Potential Program Additions:** 1. Development of spatial databases and mapping capabilities including photo-interpretation (GIS lab) 2. Vegetation sampling (on-the ground) for field verification to increase mapping accuracy (aquatic botanist/ field personnel) See Monitoring Action CM4-2, CM16-1	1. Acres of each component of restored nontidal marsh habitat. 2. Acres restored or created in Conservation Zones, 1,2,4,5, and 7, respectively) 2. Percent absolute upland, emergent and floating vegetation cover. 3. Percent relative cover of native plant species.	This monitoring action is intended to provide information regarding the progress of development of restored habitat components over time. This information will provide the basis for determining if future nontidal freshwater marsh restoration projects should be modified to improve ecosystem and habitat functions. It will also identify potential needs for management actions, such as hydroperiod modifications, non-native species control and vegetation management (controlled livestock grazing, prescribed burning). The monitoring schedule may be adjusted for a particular project in response to monitoring results and the intensity of monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established.	NANC2.1 NWNC2.1 GGSN1.1 GGSN2.1 GGSN2.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM10-2. Document the extent, attributes and functions of giant garter snake and other covered species habitat supported by restored non-tidal marsh communities.				
Base Condition: Baseline documentation, as-build construction drawings and maps **Approach:** Evaluate and quantify the extent of giant garter snake and other covered species habitats based on evaluation of data collected under Monitoring Action CM10-1 and from field surveys of specific key environmental correlates and habitat requisites for covered species. **Schedule:** Annually quantify the extent of restored, covered species habitats for the first 5 years following the implementation of every riparian restoration project and every 5 years thereafter.	**Existing Programs:** DWR IISS section within DWR-DES (potentially) **Potential Program Additions:** 1. Development of spatial databases and mapping capabilities including photo-interpretation (GIS lab) 2. Vegetation sampling (on-the ground) for field verification to increase mapping accuracy (aquatic botanist/ field personnel; see Monitoring Action CM4-1, CM16-1)	1. Acres of each covered species habitat restored. 2. Extent and dispersion/ connectivity of upland refugia for target covered species such as giant garter snake in areas prone to flooding 3. habitat attributes and habitat function (e.g., foraging, breeding, resting, etc) for Giant garter snake and western pond turtle.	This monitoring action is intended to provide information regarding the development of habitat functions for giant garter snake and other covered species over time. This information will provide the basis for determining if there is a need to modify subsequent restoration designs to improve the development of habitat functions for giant garter snake. The monitoring schedule may be adjusted for a particular project in response to monitoring results and the intensity of monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established.	NANC2.1 NWNC2.1 GGSN1.1 GGSN2.1 GGSN2.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM 10-3. Document the functionality and condition of restored nontidal marsh habitats over time.				
Base Condition: As-built construction drawings. Comprehensive ecological baseline documentation **Approach:** Conduct a California Rapid Assessment Method for Wetlands (CRAM, Appendix I-X "California Rapid Assessment Method for Wetlands version 5.0.2") to (a) evaluate wetland conditions and stressors and determine the need for intensive monitoring; (2) evaluate performance of restored nontidal marsh; and (3) assess progress of restoration relative to ambient conditions, reference conditions, and expected ecological trajectories. **Schedule:** Conduct a CRAM assessment 5 years after project implementation and every 5 years thereafter.	**Existing Programs:** none **Potential Program Additions:** **1.** develop CRAM capability either per contract with consultant or by training botanical staff.	1. Buffer and Connectivity Metrics 2. Water Source, Hydroperiod, Hydrologic Connectivity 3. Physical Patch Richness 4. Topographic Complexity 5. Organic Matter Accumulation 6. Biotic Patch Richness 7. Vertical Structure 8. Interspersion and zonation 9. Percent Invasive Plant Species 10. Native Plant Species Richness	This monitoring action is intended to provide information regarding the functionality, condition and self-sustainability of restored non-tidal marsh habitats and their ecological dynamics over time. The use of CRAM for ambient monitoring will, over time, help the Implementing Office to quantify the relative influence of anthropogenic stress, management actions, and natural disturbance on the spatial and temporal variability in reference conditions. This information can then be used in the design, management, and assessment of similar wetland projects. The monitoring schedule may be adjusted for a particular project in response to monitoring results and the intensity of monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established. If the causes are not readily apparent, then research might be recommended to determine the causes and to what extent they can be managed. If the causes are deemed natural, then management actions may not be warranted.	NANC2.1 NANC2.2 NWNC2.1 NWNC2.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM10-4. Determine covered wildlife species use of restored non-tidal marsh habitats.				
Base Condition: The existing distribution and abundance of covered wildlife species, especially giant garter snake, in restored and existing nontidal marsh habitats patches based on existing information and additional surveys if/where needed. **Approach:** Conduct standardized surveys using established methods to determine the abundance and type of use (e.g., foraging, resting) of giant garter snake; reconnaissance level surveys and incidental records of other covered species (primarily tricolored blackbird, western pond turtle) and non-native predators or competitors **Schedule:** Conduct surveys for each species during each species' active period for 5 years following the implementation of each restoration project as determined through data collected under CM4-2 and every 5 years thereafter.	**Existing Programs:** USGS studies of Giant Garter Snakes at four sites in the Sacramento Valley (1996–2006), USGS Natomas HCP Monitoring. **Potential Program Additions:** 1. Add the USGS Giant Garter Snake monitoring team under the IEP program for routine GGS effectiveness monitoring. Conduct, possibly localized mark-recapture /and radio-telemetry studies to determine habitat use patterns within proposed 1,000-acre giant garter snake conservation lands designed to enhance the Caldoni Marsh/White Slough and the Yolo Basin/Willow Slough giant garter snake populations. 2. Annual wildlife surveys for covered species.	1. Estimated abundance of each covered target species in created non-tidal, freshwater perennial emergent wetlands 2. Estimated extent of occupied covered species habitat in each created non-tidal, freshwater perennial emergent wetland 3. Acreage of created nontidal marsh that functions as habitat for the giant garter snake within or adjacent to habitat occupied by the Caldoni Marsh/White Slough and Yolo/Willow Slough giant garter snake subpopulations in Conservation Zones 2 and 4 3. Connectivity of water conveyance and habitat for giant garter snake 4. Acreage of created nontidal marsh that functions as habitat for the tricolored blackbird 4 5. Acreage of created nontidal marsh that functions as habitat for the western pond turtle 6. Abundance of feral pigs, cats and other non-native predators (non-native centrarchid fish and bullfrog) or competitors (non-native turtles), abundance of nest predators and parasites (brown-headed cowbirds)	This monitoring action is intended to provide information regarding the use and functionality of restored habitats for covered species, particularly the giant garter snake. This information will provide the basis for determining if there is a need to modify subsequent restoration designs to improve the development of habitat functions for target covered species. It will also determine if additional research studies are needed to assess the contribution of restored non-tidal marsh habitats to the viability of covered species. The monitoring schedule may be adjusted annually for a particular project in response to variable water levels and habitat conditions, marsh maintenance and enhancement activities, grazing or other circumstances that necessitate changes in the sampling schedule and/or protocol. Sampling intensity may take into account garter snake activity (and therefore detectability), unfavorable habitat conditions (i.e., lack of water), maintenance activities, trap theft and/or tampering, or other circumstances. Monitoring for subsequent projects may be decreased if causal relationships between restoration actions and outcomes are established.	NANC2.1 NANC2.2 NWNC2.1 NWNC2.2

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
CM11 Enhance and Manage Preserved Natural Communities				
Monitoring Action CM11-1. Document the planning and implementing progress for the development of Site-Specific Management Plans				
Base Condition: N/A **Approach**: Document completion of site-specific management plans for conservation lands in annual plans **Schedule**: Within 1 year of each conservation land acquisition.	**Existing Programs:** None **Potential Program Additions:** Project management database	Management plans	This monitoring action is intended to provide information to assess the progress the Implementing Office is making towards developing long-term guidance for site-specific management of each acquired BDCP conservation lands. The information in each management plan will provide the menu of actions to be undertaken and related implementation schedules.	

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM11-2 Quantify covered species habitat availability, function, and suitability of conservation lands				
Base Condition: Baseline condition reports, existing conditions (see Chapter 2, *Existing Ecological Conditions* and Appendix A, *Covered Species Accounts*). **Approach**: Inventory key habitat correlates and requisites for each covered species associated with natural communities to determine the extent and suitability of covered species habitat on conservation lands over time (e.g., percent of riparian with suitable structure and vegetation associations to support riparian brush rabbit; percent of agricultural habitat suitable for Swainson's hawk or greater sandhill crane foraging). Conduct comprehensive field surveys, map extent, and document conditions. **Schedule**: Conduct complete baseline survey the first year following implementation of Site-Specific Management Plan, then repeat biannually for 10 years, followed by 5-year interval surveys.	**Existing Programs:** DWR IISS section within DWR-DES (potentially) **Potential Program Additions:** 2. Vegetation and habitat sampling (on-the ground) for field verification to increase mapping accuracy (botanist) 3. Capabilities to determine habitat quality and presence of key habitat correlates for covered species (terrestrial ecologist) See also CM 7-1, CM 8-1, CM 10-1	1. Extent, distribution, age structure, size structure, canopy structure, vegetation associations, and species composition of each natural community on restoration sites 2. Presence of species-specific requisites (e.g., basking sites, roost and nest trees, foraging sites, burrows, cover) 3. Estimated abundance of suitable habitat for each targeted covered species. 4. occurrences of Suisun Thistle 5. proximity of non-rice agricultural lands to occupied Swainson's hawk nesting habitat 6. relative cover of native grasses and forbs in Alkali seasonal wetlands and grasslands 5. acres of greater sandhill foraging habitat within its winter use area and within 2 miles of known roosting sites in CZ 3,4,5, and/or 6 6. Prey abundance for grassland foraging species, especially insects, small mammals 7. Extent and severity of detrimental agricultural practices and disturbance from adjacent sites 7. extent of seasonal buffers around riparian habitats	This action is intended to provide information on the abundance of suitable habitat and habitat functions that addresses any or all life requisites for each covered species on all BDCP protected lands. The information will provide the basis of tracking specific habitat elements and habitat function throughout the Plan Area that is essential for Covered Species occurrence, including riparian structure and composition, functionality of water conveyance canals and associated wetlands, woodlots, tree and hedge rows, vegetation and winter water depth of created managed wetland, and the proportion of agricultural lands with suitable cover types that meet foraging habitat objectives for agriculture-associated covered species. . This monitoring is subject to modification if acquisition proceeds more slowly than expected and the periodicity can be extended.	ALNC1.2 ALNC1.4 AWNC2.1 FMNC1.1 FMNC2.1 TANC 2.1 GRNC1.1 GRNC2.2 GRNC2.1 IDSC1.1 NANC2.1 VRNC2.1 VRNC2.2 VRNC2.3 VPNC2.1 MWNC1.2 BMNC1.1 ONSW1.1 SUTH1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM11-3. Quantify abundance, locations and distribution of Invasive Plants on conservation lands				
Base Condition: Percent cover at the time of acquisition. **Approach**: Develop survey and control protocols and include in Site-Specific Management Plans. Implement periodic inventory of invasive plant populations on conservation lands. Establish thresholds for control actions and implement before thresholds are reached. **Schedule**: Conduct complete baseline survey the first year following implementation of the Site-Specific Management Plan; continue in 5-year intervals. Implement control actions as needed based on management thresholds.	**Existing Programs:** previous landowner's knowledge, agricultural agency (RCD, NRCS) weed abatement records **Potential Program Additions:** 1. Non-native invasive species survey protocols and identification skills 2. Weed control team (trained staff, equipment, GPS, etc).	1. Estimated percent cover of invasive species 2. Location 3. Species 4. Previous control measures	This Monitoring Action is intended to provide information on the extent of invasive plant infestations on BDCP protected lands, and to establish and implement a process of control of invasive species populations. This information will provide the basis for determining the extent of infestation, control triggers, and longterm monitoring to estimate the success of control actions. This monitoring action is subject to modification based on the response of nonnative invasive species to control measures.	ALNC1.1 AWNC2.1 BMNC2.1 CAGB1.1 CAGB1.2 CALT1.1 CCWF/ADEP1.1 CFTR1.1 CFTR1.2 CFTR1.3 DEBC1.1 DEBC1.2 ECSY1.5 ECSY4.1 ECSY3.1 GGNS2.2 GGSN1.1 GGSN2.1 GSHC1.1 GRNC2.1 GRNC2.2 HART/BRIT1.1 HART/BRIT1.2 HART/BRIT1.3 HART/BRIT1.4 HEPE1.1 HEPE1.2 IDSC1.1 MFNC1.2 MWNC2.1 NANC2.1 NWNC2.1 ONSW1.1 SOBB1.1 SOBB1.2 RIBR1.1 RIWR1.1 CRLF1.1 SUTH1.1 SUTH1.2 TANC1.1 TANC2.1 TCBB1.1 VPNC2.1 VRNC2.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM11-4. Fund Research				
Base Condition: N/A **Approach**: Provide funding to support the USFWS captive breeding and reintroduction program for Lange's metalmark butterfly and for implementation of the propagation and out-planting program for Contra Costa wallflower and Antioch Dunes evening primrose; and **Schedule**: As requested.	Existing Programs: Program Additions	Receipt of funds.	This Monitoring Action is intended to assist with established and ongoing research programs to benefit target species. This monitoring action is subject to modification based on continuing research activities and the need for additional funding.	IDSC1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM11-5. Increase habitat function for covered species				
Base Condition: Pre-acquisition condition. **Approach**: Each Site-Specific Management Plan will include specific enhancement objectives to increase habitat function by supporting or increasing specific key environmental correlates and habitat requisites for covered species depending on the location, existing habitat function, and opportunities for enhancement. For example, in grassland habitats where burrowing animals are determined to be limited based on results from implementation of Monitoring Action CM11.3, actions will be undertaken (e.g., manipulation of topography, reduction in rodent control programs, non-native predator control, etc.) to increase ground squirrel and small mammal populations. Another example is postponing tilling of harvested corn fields to increase available forage for wintering greater sandhill cranes. **Schedule**: Variable and ongoing.	**Existing Programs:** None **Potential Program Additions:** 1. Survey methodology to inventory habitat functions and stressors for individual covered species on conservation land 2. Database on non-native predator records on conservation lands (observations, surveys, control measures)	1. Burrowing owl occupancy of artificial burrows. 2. Swainson's hawk and white-tailed occupancy of planted trees. 3. Ground squirrel and rodent activity (burrows per acre). 4. Greater sandhill crane occupancy of created roosts. 5. Activity and reproductive performance of tricolored blackbird colonies. 6. Estimated abundance of California red-legged frogs in enhanced stockponds. 7. Extent of grazing activity in vernal pools 8. Condition of rangeland (cover and composition). 9. Percent cover of native grasses 10. Number of created riparian brush rabbit "bunny mounds" 11. Activity , reproductive success and percent of parasitized nests of tricolored blackbird and yellow-breasted chat breeding colonies, and least Bell's vireo and yellow-billed cuckoo nests. 12. Extent of upland refugia in restored marshes. 13. Documented predation events at nesting colonies. 14. Trend in predator populations. 15. Estimated abundance of feral pigs in Suisun Marsh and other conservation lands. 16. presence /abundance of black rats in suitable riparian woodrat habitat in Conservation Zone 7 17. Acres of each agricultural cover type. 18. Forage value of greater sandhill crane winter foraging habitat (lbs per acre). 19. Covered aquatic invertebrate occupancy of vernal pools. 20. Estimated abundance of giant garter snake	This action is intended to enhance the function of BDCP protected lands to meet specific covered species requirements. This information will provide the basis for determining the functioning of conservation lands with respect to meeting covered species objectives. Management actions are undertaken based on the guidance in the Site-Specific Monitoring Plan, which is subject to modification based on site-specific conditions, opportunities unforeseen at the onset of implementation, or to adjust to the progress of other site specific management plans and the need to meet overall Plan Area-wide goals.	ALNC1.1 ALNC1.1 AWNC2.1 BMNC2.1 CAGB1.1 CAGB1.2 CALT1.1 CCWF/ADEP1.1 CFTR1.1 CFTR1.2 CFTR1.3 DEBC1.1 DEBC1.2 ECSY1.5 ECSY4.1 ECSY3.1 GGNS2.2 GGSN1.1 GGSN2.1 GSHC1.1 GRNC2.1 GRNC2.2 HART/BRIT1.1 HART/BRIT1.2 HART/BRIT1.3 HART/BRIT1.4 HEPE1.1 HEPE1.2 IDSC1.1 MFNC1.2 MWNC2.1 NANC2.1 NWNC2.1 ONSW1.1 SOBB1.1 SOBB1.2 RIBR1.1 RIWR1.1 CRLF1.1 SUTH1.1 SUTH1.2 TANC1.1 TANC2.1 TCBB1.1 VPNC2.1 VRNC2.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
CM12: Methylmercury Management				
Monitoring Action CM12-1: Determine the trend in load of methylmercury or precursors discharged from treated sources				
Base conditions: Mercury concentrations in soils to be restored as tidal habitat before levees are breached based on survey information collected under Conservation Measure *CM4, Tidal Habitat Restoration*. **Approach**: Testing of monthly water and sediment samples in restored subtidal habitat areas for methylmercury concentrations. **Schedule**: Monitor monthly for five years or until relationships between restoration of tidal habitats at different locations in the Plan Area and methylmercury concentrations are understood. After the initial five year monitoring period, every 10 years monitor methylmercury concentrations bimonthly for one year.	**Existing**: 1. Environmental Monitoring program (IEP) 2. National Pollutant Discharge Elimination System (NPDES) Self Monitoring Program 3.Continuous Recorder Sites (USBR) 4. Delta Flows network and National Water Quality Assessment Program (USGS) 5. other (DWR, SFEI, etc) 6. UC Davis Biosentinel Hg Monitoring Program **Potential Program Additions:** 1. Establishment and monitoring of methylmercury monitoring stations in restored subtidal habitat areas. See also Monitoring Action CM4-4 and Monitoring Action CM4-6. 2. Expand UC Davis Biosentinel Hg Monitoring Program to include entire Delta and restored floodplain and tidal habitats.	Concentration of methylmercury and precursors	This monitoring is designed to determine the effectiveness of tidal habitat restoration designs in avoiding or reducing methylmercury concentrations in restored subtidal habitats. This information will be used by the Implementing Office to determine if adjustments in tidal habitat restoration designs are necessary to further reduce methylation of mercury. The monitoring schedule may be adjusted based on assessments of initial monitoring results at each restoration site.	TANC1.1 BMNC1.1 FMNC1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM12-2: Determine the extent of methylmercury exported into Delta channels.				
Base conditions: 1) Methylmercury concentrations in the water column and sediments in channels adjacent tidal marsh restoration sites before levees are breach based on existing data or survey data collected for this purpose. 2) Methylmercury concentrations in restored subtidal habitats from data collected under CM12-2. **Approach**: Testing of monthly water and sediment samples in channels adjacent to restored subtidal habitat areas for methylmercury concentrations in conjunction with sampling implemented under CM12-1. **Schedule**: Monitor monthly for five years or until relationships between restoration of tidal habitats at different locations in the Plan Area and export of methylmercury into adjacent channels are understood. After the initial five year monitoring period, every 10 years monitor methylmercury concentrations bimonthly for one year.	**Existing**: 1. Environmental Monitoring program (IEP) 2. National Pollutant Discharge Elimination System (NPDES) Self Monitoring Program 3. Continuous Recorder Sites (USBR) 4. Delta Flows network and National Water Quality Assessment Program (USGS) 5. Other (DWR, SFEI, etc) 6. UC Davis Biosentinel Hg Monitoring Program **Potential Program Additions:** 1. Establishment and monitoring of sampling stations in channels adjacent to restored subtidal habitats	Concentration of methylmercury and precursors	This monitoring is designed to determine the effectiveness of tidal habitat restoration designs in avoiding or reducing export of methylmercury into existing Plan Area tidal aquatic habitats. This information will be used by the Implementing Office to determine if adjustments in tidal habitat restoration designs are necessary to further reduce methylation of mercury. The monitoring schedule may be adjusted based on assessments of initial monitoring results.	TANC1.1 BMNC1.1 FMNC1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
CM13: Nonnative Aquatic Vegetation Control				
Monitoring Action CM13-1: Detect and document the establishment of non-native submerged (SAV) and floating aquatic vegetation (FAV) in subtidal aquatic habitats in restored tidal habitat areas.				
Base Condition: The current extent of SAV and FAV present in channels adjacent to tidal habitat restoration sites before breaching of levees based on existing information or field surveys. **Approach**: Monthly monitoring to detect and delineate the extent of SAV and FAV in newly restored tidal habitat areas to detect SAV and FAV establishment, conditions under which it establishes, and patterns of establishment. Monitoring data will be evaluated relative to water quality, hydrodynamic, and other physical parameters collected under other monitoring actions or by others to establish relationships between SAV/FAV establishment and restoration design and site conditions. **Schedule:** Monitoring will occur for five years at each site until relationships between tidal habitat restoration designs and SAV/FAV establishment are well understood.	**Existing Programs:** Department of Boating and Waterways is the lead agency for controlling aquatic weeds in the Delta **Potential Program Additions:** 1. SAV/FAV surveys of restored subtidal habitats	Temporal progress of SAV/FAV establishment Spatial extent of SAV/FAV within a restored subtidal habitat project area	This monitoring is designed to determine the SAV/FAV establishment process relative restoration design and parameters related to Plan Area location (e.g., water quality constituents, hydrodynamic conditions, wind patterns). This information will be used to determine if subsequent restoration designs should be adjusted to reduce the likelihood of establishment and extent of SAV/FAV in restored subtidal habitats and to help guide development of more effective SAV/FAV control methods. The duration of monitoring may be increased or decreased as indicated from evaluation of monitoring results.	ECSY6.1 TANC1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM13-2: Determine the need for implementation of SAV/FAV control actions and the effectiveness of SAV/FAV control actions.				
Base condition: the extent and distribution of SAV/FAV in restored subtidal habitat areas before implementation of control actions. **Approach**: Monthly surveys of restored subtidal habitats from [month] to [month] to assess the extent of SAV/FAV for use in determining need to implement control actions. Weekly surveys to document changes in extent and distribution of SAV/FAV relative to base conditions following implementation of control actions. **Schedule:** Monthly surveys to determine the need to implement control actions over the term of BDCP. Monitoring following control actions continues until monitoring indicates that the response of SAV/FAV has stabilized or SAV/FAV is determined to be spreading.	**Existing Programs:** Department of Boating and Waterways is the lead agency for controlling aquatic weeds in the Delta **Potential Program Additions:** 1. SAV/FAV surveys of restored subtidal habitats in conjunction with control actions	Areal extent of SAV/FAV or other appropriate measure (e.g., biovolume) Distribution of SAV/FAV in restored habitat	This monitoring action is designed to provide the information necessary to determine the need to implement control actions, the effectiveness of SAV/FAV control techniques over time, and to help determine the frequency with which control actions will need to be implemented in future years. Monitoring frequency and duration to determine the need to implement control actions may be adjusted if relationships between SAV/FAV establishment and need for control actions is established.	ECSY6.1 TANC1.1

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM13-3: Determine the effectiveness of SAV/FAV control actions in reducing the risk for nonnative predatory fish predation on covered fish species.				
Base condition: Nonnative predatory fish abundance before implementation of control actions as determined through CM15 or surveys conducted specifically for this purpose. **Approach:** Bimonthly surveys of control areas following control actions to determine the abundance and distribution of non-native predatory fish. **Schedule:** Monitoring following control actions continues until monitoring indicates that the response of nonnative predatory fish has stabilized or there abundance and distribution increases.	**Existing Programs:** DFG, USFWS, and NMFS fish monitoring programs **Potential Program Additions:** 1. Non-predatory surveys of restored subtidal habitats	Number of nonnative predatory fish per unit area	This monitoring action is designed to provide the information necessary to determine the need to implement control actions, the effectiveness of SAV/FAV control techniques over time, and to help determine the frequency with which control actions will need to be implemented in future years.	ECSY6.1 TANC1.1 CHSA1.8 SASP1.5 STEE1.7
Monitoring Action CM13-4: Determine if non-native SAV/FAV control results in measurable increase in turbidity.				
Base condition: Turbidity of the water column at sampling locations within restored subtidal habitat areas before implementation of SAV/FAV control actions. **Approach**: Weekly turbidity measurements at sampling sites within restored subtidal habitat areas following implementation of control actions. Conducted in conjunction with monitoring under CM2 **Schedule**: see Monitoring Action CM13-1	**Existing:** 1. Environmental Monitoring program (IEP) 2. National Pollutant Discharge Elimination System (NPDES) Self Monitoring Program 3.Continuous Recorder Sites (USBR) 4. Delta Flows network and National Water Quality Assessment Program (USGS) 5. other (DWR, SFEI, etc) **Potential Program Additions:** **1.** Establishment sampling stations and monitoring of turbidity in restored subtidal habitat areas	Turbidity (NTU, TSS)	This monitoring approach will provide information necessary to determine if removal of nonnative aquatic vegetation will increase turbidity of the water column to improve habitat conditions for delta smelt.	ECSY6.1 TANC1.1 CHSA1.8 SASP1.5 STEE1.7

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Species-Level Measures				
CM14: Stockton Deep Water Ship Channel Dissolved Oxygen Levels				
Monitoring Action CM14-1 Operate and maintain an oxygen aeration facility in the Stockton Deep Water Ship Channel (DWSC) to increase dissolved oxygen concentrations between Turner Cut and Stockton to meet Total Maximum Daily Load (TMDL) objectives(above 6.0 mg/L from September 1 through November 30 and above 5.0 mg/L at all times).				
Base condition: Existing aeration operations **Approach:** Keep daily operational and maintenance records for the oxygen aeration facility, tracking hours of operation, amount of Oxygen (lbs) injected, sensor operations and system failures or shutdowns. **Schedule:** Daily operational logs and maintenance records, DWSC Demonstration Dissolved Oxygen Aeration Facility monthly reports.	**Existing Programs:** DWR's Stockton DWSC Demonstration Dissolved Oxygen Project, Bay-Delta Office. **Potential Program Additions:** None	Operational statistics 1. hours of operation 2. lbs of dissolved oxygen 3. failures & shutdowns 4. operational costs 5. maintenance and repair records	This monitoring activity ensures that the operation of the DWSC dissolved Oxygen aeration facility is recorded accurately and operational data are publicly available. The Implementing Office will use this information to determine if system modifications need to be implemented based on system performance and cost/benefit ratios. The monitoring schedule may be adjusted if the existing aeration facility will be modified or additional aerators and associated infrastructure are added to optimize DO delivery to the river.	CHSA1.3

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM14-2 Measure levels of dissolved oxygen (DO) delivered to the river within the 7.5 mile low dissolved oxygen area of the ship channel				
Base condition: As built construction drawings **Approach:** measure dissolved oxygen levels at various distances from the diffuser(s) and depths via remote monitoring stations. Current DO sensors are placed at a depth of about 10 ft (at low tide) and record 15-minute data. Additional sensors will be installed concurrent with addition of diffuser facilities. **Schedule:** Measure minimum DO levels per 15 min interval at each DO sensor station over a 25 hr tidal cycle. Compile Monthly Dissolved Oxygen Data Reports.	Existing Programs: **1.** Demonstration Dissolved Oxygen (DO) Aeration Facility remote monitoring stations (NA 40, 42, 43 and 48), handheld instrument data, California Data Exchange Center (CDEC) Rough and Ready Island (RRI) station data, and CDEC San Joaquin River at Garwood Bridge (SJG) station data Potential Program Additions: Possibly additional remote monitoring stations Possible additional diffusers	1. diffused oxygen (mg/L)	Results from this monitoring will be used to assess the performance of the facilities operations at achieving the water quality objective. The BDCP Implementing Office will use this information to determine whether aeration facility operations result in measurable benefits to water quality of the DWSC. Based on review of performance and effectiveness monitoring results, the BDCP Implementing Office will adjust funding levels, oxygen diffuser methods, or other related aspects that will improve the performance and/or biological effectiveness of the project through the BDCP adaptive management process as appropriate. Such changes will be effected through the BDCP adaptive management process and would be included in the subsequent annual work plans.	CHSA1.3

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM14-3 Determine if aeration increases the use of the Stockton DWSC as a migration route for covered fish species.				
Baseline Condition: existing knowledge and study results on fish migration routes and channel-specific survival rates **Approach**: Through tracking of marked fish (e.g., acoustic tags, radiotelemetry or other suitable method), determine the proportion of tagged fish that successfully migrate through the DWSC. Determine the residence time within DWSC. **Schedule**: Implement covered fish species tracking until a precise (+- 5%) estimate of permeability can be established by species, location and season. Once permeability rates have been estimated, fish tracking can be discontinued for 5 years. Every 5 years thereafter, the Implementing Office will estimate permeation rates and residence times for covered fish species for at least 2 months.	**Existing Programs:** USFWS Delta Juvenile Fish monitoring program (DJFMP), various DFG fish survival and migration tracking studies. Potential Program Additions: Coordinate DJFMP with juvenile fish mortality tracking projects in coordination with operation of DWSC aeration facilities. Separate tracking of tagged adults	Permeation rates (% of tracked fish) Residence time of tracked fish within the DWSC Survival of tagged fish (see also CM 16-3)	This monitoring action is designed to provide information on the effects of DO aeration of the DWSC in enhancing migration of covered species through the DWSC. The Implementing Office will use this information to determine if oxygen diffusion is effective in the re-routing of migrating covered fish species. The monitoring action may be reduced if permeation rates are found to have minimal seasonal and location-dependent variance and are highly precise (+-5%). Results from tracking studies every 5 years will determine if increasing monitoring activities are necessary (i.e., if permeation rates fall below the initially determine value).	CHSA1.3 STEE1.3

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
CM15: Predator Control				
Monitoring Action CM15-1: Document the extent and locations of fish predator hotspots within the Delta.				
Base Condition: Estimated existing locations and types of predator hotspots such as abandoned structures, boats, deep holes , etc. where predators have an above-average effect on sensitive life stages of covered fish species, based on existing information. **Approach:** Using a combination of existing knowledge (e.g., survey of fishermen about striped bass catch locations), aerial surveys (e.g., during mapping of nonnative FAV/SAV), and direct observations (IEP and agency staff on boats within the Delta waterways), inventory and map all known and suspected predator hotspots within Delta waterways where sensitive lifestages of covered fish species are present. **Schedule:** Within 3 years and prior to implementing any predator control measures at hotspots, conduct complete mapping of all major fish-rearing habitats within each waterway to identify and rank potential hotspots of predators. Continue adding new hotspots as they become known.	**Existing Programs:** Extant knowledge of hotspots by fishery biologists, game wardens and agency staff.: DWR IISS section within DWR-DES (potential data warehouse and GIS repository) **Potential Program Additions:** **1.** Development of spatial databases and mapping capabilities including photo-interpretation (GIS lab) 2. tracking of incidental information of predator hotpots from agency staff	1.Location 2. Size 3. Type 4. Structural elements 5. Abundance and type of predatory fish present and relative threat to covered fish species	This monitoring action is designed to provide information on the location and extent of predator hotspots within Delta waterways. The Implementing Office will use this information to schedule removal/amelioration of structures and channel geometry to reduce favorable spots for predatory fish. It also will allow the Implementing Office to estimate costs and technical constraints in removing certain hotspots and adaptively prioritize these for removal. This information will be updated annually and the scheduling of removal/amelioration activities will be adjusted adaptively based on this information The schedule may be adjusted in response to unscheduled events that add significant hiding cover into the channel (floods, windthrow, etc), and to the removal and decelerating need of removals as the channels are being cleared.	ECSY6.1 CHSA1.8 SASP1.5 STEE1.7

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM15-2: Document the extent of predator hotspot removals/ameliorations.				
Base condition: Completed predator hotspot inventory and map (see CM15-1). **Approach**: Annually update the database by identifying removed hotspots. Track costs and disposal of removed materials. **Schedule**: Annual.	**Existing Programs:** none **Potential Program Additions:** **1.** Responsibility to track progress as predator hotspots are removed or ameliorated	Change in number of hotspots Type of hotspots removed/ ameliorated (abandoned structure, boat, etc.)	See CM 15-1	ECSY6.1 CHSA1.8 SASP1.5 STEE1.7
Monitoring Action CM15-3: Document the extent of predator removal activities within Delta hotspots				
Base condition: Existing knowledge of agency staff and experts pertaining to predator hotspots (see CM 15-1). Prior to predator control measures, the relative abundance (species, size and age composition) of predatory fish species must be sampled (non-lethally) at least twice per hotspot to establish baseline conditions. **Approach**: Implement localized predator control actions (e.g., electro-shocking, seining, gill netting or other appropriate methods) to remove targeted predators of covered fish species **Schedule**: Upon establishing baseline conditions and after implementing control measures, continue localized control measures each year at various locations throughout the Delta. Each hotspot will be treated several times (not more than 10 days apart) until predator numbers removed have declined and show a significant asymptotic trend (leveling off). Resample and retreat hotspots every 3-5 years.	**Existing Programs:** IEP fish predator control studies **Potential Program Additions:** Predatory fish control program to reduce localized predator densities and thus reduce covered fish mortality	Predators removed: Species number Size, age Location Diet (gut content)	This monitoring action will provide a estimate of the magnitude of the predator control efforts (Treatment size). This information will be used by the Implementing Office to estimate the effectiveness of controlling predators on sensitive lifestages of covered fish species in open systems (waterways of the delta). It will also provide insight in the life history of predatory fish and will allow addressing potential efficiency issues in an adaptive manner. The Implementing Office will also use these data to address cost effectiveness and to guide additional research, This schedule may be changed upon careful review of results to better encapsulate the response time of predator populations to control measures.	ECSY6.1 CHSA1.8 SASP1.5 STEE1.7

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM15-4: Determine the survival of covered fish species in response to predator control actions.				
Base condition: Baseline studies of predatory fish abundance and mortality levels of covered species due to predation prior to predator control measure implementation. **Approach**: Implement an adaptive experimental management program using a BACI approach to determine the existence and importance of compensatory predation mortality in sensitive lifestages of covered fish species. Specifically, this program investigates under which environmental conditions mortality of covered fish is additive and hence can be affected by localized predator control. Using a combination of fish tagging, sampling and radio- or acoustic telemetry tracking approaches, the Implementing Office will determine mortality rates due to predators at local predation hotspots in comparison to earlier (unmanaged) circumstances (before) and adjacent, randomly selected non-hotspot sites (control sites) **Schedule**: Annually, until uncertainty regarding predator management effectiveness (and density dependence) can be reduced and robust correlations between environmental conditions and predator control effectiveness can be established.	**Existing Programs:** USFWS Delta Juvenile Fish monitoring program (DJFMP), Delta smelt mortality monitoring, DFG hatchery fish radio tracking and acoustic tagging studies. **Potential Program Additions:** Coordinate DJFMP with fish mortality tracking projects in coordination with predator removal projects.	1. Survival rates of sensitive lifestages of covered fish species	This monitoring action is designed to provide information on the effects of predator removals on juvenile fish of covered species. The Implementing Office will use this information to determine if predator removal is effective in increasing the survival of juvenile covered fish species (i.e., mortality is not compensatory / juvenile fish are not regulated by density-dependent factors). To remove uncertainty regarding the role of varying habitat quality and spawning success, the Implementing Office will determine if targeted research or management experiments are needed to determine the conditions under which predator removal an effective management tool to support survival of sensitive lifestages of covered fish species.	ECSY6.1 CHSA1.8 SASP1.5 STEE1.7

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
CM16: Non-Physical Fish Barriers				
Monitoring Action CM16-1 Document the installation of non-physical fish barriers.				
Baseline Condition: As-built construction drawings. **Approach**: Document the installation and seasonal operation of non-physical fish barriers. **Schedule**: ongoing as barriers are installed.	**Existing Programs:** 2009 pilot study (Bowen et al. 2009), various research data. **Potential Program Additions:** 1. Fish barrier database that tracks seasonal operation, cost and incidental observations	Location Hours and dates of operations Performance/Failures and operational statistics of the three components (light, sound, bubbles) Other incidental observations Cost of operations	This monitoring action will provide information on the operation of non-physical fish barriers. This information will be used by the Implementing Office to schedule operations, redesign failing or faulty equipment, or implement other corrective measures as needed to ensure the continuous operation. The monitoring schedule will be adjusted to reflect additional data needs	CHSA1.5 STEE1.3

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM16-2: Determine the permeability of non-physical barriers for outmigrating juvenile salmonids.				
Baseline Condition: existing knowledge and study results on fish migration routes and channel-specific survival artes **Approach**: Through tracking of marked fish (e.g., acoustic tags, radiotelemetry or other suitable method), determine the proportion of tagged fish that penetrate non-physical fish barriers. Determine the residence time at or near barriers. **Schedule**: Implement juvenile salmonid tracking prior or at least simultaneously with the initiation of operation of each physical barrier. Continue tracking fish until a precise (+- 5%) estimate of permeability can be established by species, location and season. Use occasional failures as "experiments" to determine "control" values. Once permeability rates have been estimated, fish tracking can be discontinued for 5 years. Every 5 years thereafter, the Implementing Office will randomly select 3 non-physical fish barriers and estimate permeation rates and residence times for outmigrating juvenile salmonids for at least 2 months.	**Existing Programs:** USFWS Delta Juvenile Fish monitoring program (DJFMP), DFG hatchery fish radio tracking and acoustic tagging studies. **Potential Program Additions:** Coordinate DJFMP with fish mortality tracking projects in coordination with operation of non-physical fish barriers.	Permeation rates (% of tracked fish) Residence time of tracked fish within 500 ft of the barriers Lifestage of tracked fish Survival of tagged fish (see also CM16-3)	This monitoring action is designed to provide information on the effects of non-physical fish barriers in deterring juvenile fish of covered species to enter "low survival" channels. The Implementing Office will use this information to determine if non-physical fish barriers are effective in the re-routing of migrating juvenile covered fish species. This information will also be used to determine if outmigrating juvenile salmonids "pool" at the barriers. Intermittent replications of fish tracking will ensure that non-physical fish barriers are still functional and effective. The monitoring action may be reduced if permeation rates are found to have minimal seasonal and location-dependent variance and are highly precise (+-5%). Results from tracking studies at 3 randomly selected barriers every 5 years will determine if increasing monitoring activities are necessary (i.e., if permeation rates fall below the initially determined value).	CHSA1.5 STEE1.3

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM16-3 Determine the abundance of predators and their effect on the survival of outmigrating juvenile salmonids at non-physical fish barriers.				
Base condition: Baseline studies of predatory fish abundance and mortality levels of covered species due to predation.. **Approach**: Using a combination of fish tagging, sampling and radio- or acoustic telemetry tracking approaches, or visual sampling (underwater cameras) the Implementing Office will determine the abundance and composition of predator guilds at non-physical fish barriers in comparison to earlier (unmanaged) circumstances (before) and adjacent, randomly selected non-hotspots sites (control sites). In conjunction with CM16-3, estimate predation mortality to juvenile salmonids. Also, investigate if there are correlations between residence time of marked juvenile salmonids and predation risk and survival at barriers. **Schedule**: Annually, until uncertainty regarding predation rates can be reduced and robust correlations between residence time and survival of marked juvenile salmonids can be established	**Existing Programs:** USFWS Delta Juvenile Fish Monitoring Program (DJFMP), DFG hatchery fish radio tracking and acoustic tagging studies. **Potential Program Additions:** Coordinate DJFMP with fish mortality tracking projects in coordination with operation of non-physical fish barriers.	Survival of tracked juvenile salmonids (a) within 500 feet of non-physical fish barriers, and (b) for the entire migration (by migration route)	This monitoring action is designed to provide information on the effects of non-physical fish barriers in increasing total survival of outmigrating juvenile fish of covered species. The Implementing Office will use this information to determine to what degree survival of migrating juvenile covered fish species increases as a function of non-physical fish barriers. It will also use these data to determine if predation in the immediate vicinity of barriers increases due to juvenile fish aggregations at the barriers, and to what extent predation at the barriers alters survival during the entire outmigration This information will also be used to determine if predator control activities (see CM15) may be indicated. Results from intermittent replications of fish tracking will determine if non-physical fish barriers are still functional and effective. The monitoring action may be reduced if predation rates are found to have estimable, minimal seasonal and location-dependent variance and are highly precise (+-5%). Results from tracking studies at 3 randomly selected barriers every 5 years will determine if increasing monitoring activities are necessary (i.e., if predation rates increase above the initially determined value).	CHSA1.5 CHSA1.8 STEE1.3 STEE1.7 SASP1.5

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM16-4: Determine change in survivorship of outmigrating juvenile salmonids redirected by non-physical barriers.				
Baseline Condition: existing survivorship of outmigrating salmonids using existing migration pathways **Approach**: Through tracking of marked fish (e.g., acoustic tags, radiotelemetry or other suitable method), determine change in outmigration success relative to existing conditions **Schedule**: Annually during peak outmigration periods of affected runs until relationships between barrier operations and outmigration success are understood	**Existing Programs:** USFWS Delta Juvenile Fish monitoring program (DJFMP), DFG hatchery fish radio tracking and acoustic tagging studies. **Potential Program Additions:** Implementation of targeted studies to assess change in survivorship relative to barrier operations.	Change in proportion of outmigrating salmonids passing Chipps Island	This action is designed to provide the Implementing Office with information necessary to determine the effectiveness of non-physical barriers and barrier operations in improving juvenile salmonid survival by directing migration pathways.	CHSA1.5 CHSA1.8 STEE1.3 STEE1.7 SASP1.5
CM17: Hatchery and Genetic Management Plans				
Monitoring Action CM17-1 Document development and implementation of hatchery and genetic management plans for salmonid stocks.				
Base condition: Existing HGMPs and hatchery operations **Approach:** BDCP will evaluate progress towards HGMPs for each hatchery through annual accomplishment reports plans, fiscal accounting reports and interagency agreements and work plans. **Schedule:** within the first 5 years BDCP will have funded and achieved the development of HGMPs for each hatchery within the BDCP area. Updates of HGMPs are conducted every 10 years for the duration of the BDCP.	**Existing Programs:** Existing HGMPs and drafts (Nimbus Hatchery , Feather River Hatchery, Mokelumne River Hatchery) and Coleman National Fish Hatchery and Livingston Stone National Fish Hatchery 2001 Biological Assessment **Potential Program Additions:** none	Annual fiscal /accounting reports Interagency workplans HGMPs as they are developed	This monitoring action will provide information on the progress the BDCP Implementing Office is making towards the implementation of HGMPs for all salmonid hatcheries affected by BDCP. This information will be used by the Implementing Office to determine if modifications to targets or schedules are necessary, and how modifications will be implemented. Such changes will be effected through the BDCP adaptive management process and will be included in the subsequent annual work plans.	CHSA1.9 STEE1.8

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM17-2 Determine if HGMP development and implementation substantially and cost-effectively benefit covered salmonid stocks.				
Base condition: HGMPs as developed and implemented, research hypotheses and models. **Approach**: With funding from BDCP, the Implementing Office will collaborate in the Design and Evaluation of targeted studies, conducted by collaborating agencies that explicitly test the hypothesis that implemented HGMPs are reducing negative effects on wild Chinook salmon and steelhead. **Schedule:** 10 years after implementation of the BDCP, the Implementing Office will have completed a comprehensive meta-analysis and evaluation of the HGMP program.	**Existing Programs:** DFG and USFWS expert staff, UCD genetics lab, hatchery personnel and facilities **Potential Program Additions:** review and analysis capability (either in house or under contract) to comprehensively and rigorously evaluate studies and data on the impacts of hatchery fish on wild salmonid stocks.	Population viability of wild salmonid stocks Competition indices and models Genetic integrity of hatchery and wild stocks	This monitoring action will provide information on the cost-benefit relationship of implementing HGMPs to benefit wild salmonids. If results of review indicate that HGMP development and implementation does not substantially and cost-effectively benefit covered fish species, the BDCP Management Entity in coordination with Fishery Agencies may terminate this conservation measure. If terminated, remaining funding will be deobligated from this conservation measure and reallocated to augment funding for other more effective conservation measures identified in coordination with the Fishery Agencies through the BDCP adaptive management process. The monitoring schedule may be extended for up to 5 years if longer time series are needed to determine conclusively the effects of HGMPs on wild salmonid stocks.	CHSA1.10 STEE1.9

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
CM18: Illegal Harvest				
Monitoring Action CM18-1: Determine if hiring target of 17 additional game wardens for the BDCP Plan Area has been met				
Base Condition: Current staffing levels of CDFG enforcement officers within the BDCP Plan Area. **Approach:** Review annual employment reports provided by DFG to determine success in filling vacant game warden positions and to determined why positions were not filled (if applicable) **Schedule:** Annual monitoring until the 5-year deadline has been met	**Existing Programs:** none Potential Program Additions: 1. Collaborative data exchange with DFG enforcement and Human Resources	1. Hiring of 17 additional game wardens for the BDCP Plan Area	This monitoring action is intended to provide information regarding achieving enhanced enforcement of fishery regulations for covered species. This information will provide the basis for determining if there is a need to modify the hiring process. The monitoring schedule may be extended beyond the initial 5 year period if necessary.	CHSA1.7 STEE1.6 SASP1.3 GRST1.5 WHST1.5
Monitoring Action CM18-2: Determine the game warden's contact rate with the public				
Base Condition: Current 5-year average contact rate for Game wardens in the BDCP Plan Area **Approach:** The Implementing Office will review annual reports of enforcement statistics for the BDCP plan area, which details the number of contacts, warnings and citations issued per game warden **Schedule:** Annual monitoring of game warden contact rates	**Existing Programs:** Existing analytical methods for assessing effectiveness of contact rates **Potential Program Additions:** 1. Collaborative data exchange with DFG enforcement	1. Rates of contacts, warnings and citations by game warden	This monitoring action is intended to provide information regarding the achievement of enhanced enforcement of fishery regulations for covered species. This information will provide the basis for determining if there is a need provide additional training of game wardens. The monitoring schedule may be altered if necessary.	CHSA1.7 STEE1.6 SASP1.3 GRST1.5 WHST1.5

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
Monitoring Action CM18-3: Determine compliance ratios in routine enforcement activities				
Base Condition: 5-year average compliance ratios for Game wardens in the Bay Delta and similar areas **Approach:** The total number of contacts with the public and the total number of warnings and citations issued per year will be recorded annually, consistent with current game warden practices. **Schedule:** Annual monitoring of compliance ratios	**Existing Programs:** Existing analytical methods for assessing compliance effectiveness **Potential Program Additions:** 1. Collaborative data exchange with DFG enforcement	1. % change in compliance ratios (trend) 2. Annual deviation from the 5 year running average compliance ratio.	This monitoring action will provide an assessment of routine enforcement activity and effectiveness of enforcement to reduce illegal harvest This monitoring action will provide the basis for determining if enforcement actions and staffing levels are sufficient to reduce illegal harvest of covered fish in the BDCP Plan Area. The monitoring schedule may be reduced once compliance ratios have declined and are at satisfactory levels	
Monitoring Action CM18-4: Determine success of undercover and non-routine operations				
Base Condition: Current 5-year average arrest ratios for undercover and special enforcement actions in the BDCP Plan Area. **Approach:** The total number of contacts with the public and the total number of warnings and citations issued per year will be recorded annually, consistent with current game warden practices. **Schedule:** Annual monitoring of compliance ratios	**Existing Programs:** Existing analytical methods for assessing success of special enforcement operations **Potential Program Additions:** 1. Collaborative data exchange with DFG enforcement	1. Number of arrests in special undercover enforcement operations 2. Annual deviation (% change) from the 3 year running average of number of arrests per person-hour	This monitoring action will provide an assessment of undercover and non-routine enforcement activity and effectiveness of enforcement to reduce illegal harvest. This monitoring action will provide the basis for determining if undercover and special enforcement actions are sufficient to reduce illegal harvest of covered fish in the BDCP Plan Area. The monitoring schedule may be reduced once arrests/person-hour ratios have declined and are at satisfactory levels.	CHSA1.7 STEE1.6 SASP1.3 GRST1.5 WHST1.5

Table 3-20. Potential Effectiveness Monitoring Actions for Conservation Measures (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Objectives addressed*
CM19: Conservation Hatcheries				
Monitoring Action CM19-1: Support the development of a delta and longfin smelt conservation hatchery by USFWS to house a delta smelt refugial population and provide a source of delta and longfin smelt for supplementation or reintroduction, if deemed necessary by Fishery Agencies.				
Base condition: MOU **Approach**: IEP will 1) document the establishment of functional hatchery facilities and 2) track the funds expended towards implementing a collaborative development of conservation hatcheries by USFWS through its annual reports, financial and operational records. **Schedule**: Annually	**Resources:** 1. USFWS proposals **Potential Program Additions:** 1. Conservation hatchery program budget, 2. Conservation hatchery administration staff	1. Annual progress reports	This monitoring action will provide a detailed accounting of expenses and other support provided to USFWS to develop and operate Conservation hatcheries. This information will be used by the Implementing Office to determine if funding levels and expected benefits are within target levels. The annual reporting schedule is maintained for the duration of the conservation hatchery program.	
Monitoring Action CM19-2: Support the expansion of the refugial population of delta smelt and establishment of a refugial population of longfin smelt at the University of California, Davis Fish Conservation and Culture Laboratory to serve as a population safeguard in case of a catastrophic event in the wild.				
Base condition: MOU. **Approach**: IEP will 1) review annual reports to determine if hatchery operations are successful in establishing and maintaining sufficient refugial populations to meet BDCP objectives and 2) track the funds expended towards expanding refugial population of Delta smelt and longfin smelt at the University of California, Davis Fish Conservation and Culture Laboratory through its annual reports, financial and operational records. **Schedule**: Annually	Resources: 1. University of California, Davis Fish Conservation and Culture Laboratory Potential Program Additions: 1. Conservation hatchery program budget 2. Conservation hatchery administration staff	1. Annual progress reports	This monitoring action will provide a detailed accounting of expenses and other support provided to expanding refugial populations of Delta smelt and longfin smelt at the University of California, Davis Fish Conservation and Culture Laboratory. This information will be used by the Implementing Office to determine if funding levels and expected benefits are within target levels. The annual reporting schedule is maintained for the duration of the conservation hatchery program.	

*[**Note to Reviewers:** This table presents in-progress draft potential system-wide monitoring actions based on the five ecological characteristics described in Section 3.6.2, Monitoring Framework. This table will continue to be refined and populated to ensure that all of the system-wide monitoring actions, including incorporation of metrics from the logic chain, are addressed.]*

Table 3-21. Potential System-Wide Monitoring Actions

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Biological Goals and Objectives Addressed*
Ecosystem Monitoring Element: Foodweb				
Element 1: Primary and Secondary Production				
Monitoring Action SY1-1: Determine the seasonal abundance, distribution, and composition of phytoplankton and zooplankton in Delta and Suisun Marsh/Bay waterways.				
Condition: Seasonal abundances of phytoplankton and zooplankton in Delta and Suisun Marsh channels and waterways as currently sampled. **Approach:** Establish monitoring stations that are representative of different reaches of the Delta and Suisun marsh Take monthly grab samples and measurements of chlorophyll a and zooplankton. Invertebrate sampling should be adaptively adjusted to changes in fish diets. Plankton monitoring tracks changes in phyto- and zooplankton diversity, abundance, and distribution associated with physical and other biological factors in the Delta. Salinity and other water quality variables are monitored at all plankton sites. **Schedule:** Conduct sampling monthly every year for the first 10 years, then randomly sample 30% of all sampling stations annually for the duration of the BDCP.	**Existing Programs:** Ongoing discrete sampling through Environmental Monitoring Program (EMP, under IEP) **Potential Program Additions:** **1.** Additional sampling stations to represent the entire system by individual reach or major channel system. Locations of added stations will be fixed during the duration of the plan to detect increase on food availability in delta waterways. Note that additional stations are added under Monitoring Actions CM 4-3, CM4-4 , CM4-6, and CM16-5 as levees are breached and sites are flooded to track how food production in individual wetlands develops over time (i.e., flux from wetland restoration sites) Sampling stations will also provide water quality data (e.g., temperature, turbidity, pH for ammonia conversion, amount of organic carbon.	1. Phytoplankton: -mg/L chlorophyll a - species composition - relative abundance 2. Zooplankton: - number/1,000 m^3 - species composition - relative abundance 3. variations in oxygen concentration 4. organic carbon-14 content 5. Stable isotopes of Oxygen (16O, 18O and 17O	This monitoring action is intended to collect data necessary to determine and quantify the overall production and export of phytoplankton and zooplankton throughout the Delta This information, in combination with evaluation of other project-specific foodweb-related monitoring and research data, will provide the basis for : 1. Identifying sources of uncertainty and the design of management experiments and/ research studies, to address uncertainty. 2. evaluating underlying conceptual models and hypotheses (source-sink dynamics, variability and uncertainty in primary production response) 3. evaluating restoration design options to increase the production and export of primary production from restored tidal marsh plains 4. Implementing additional management actions to improve production and export of primary production within the Delta. The monitoring schedule will be modified if uncertainty or variances do not support current conceptual models and hypotheses	ECSY5.1 CHSA1.2 STEE1.2 SASP1.2 GRST1.2 WHST12

Table 3-21. Potential System-Wide Monitoring Actions (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Biological Goals and Objectives Addressed*
Monitoring Action SY1-2: Determine the seasonal abundance, distribution, and composition of benthic invertebrates in Delta and Suisun Marsh/Bay waterways.				
Base conditions: ongoing benthic monitoring by IEP throughout the Estuary. **Approach**: Benthic monitoring will be conducted at up to 20 sites within the estuary, with four benthic samples and one sediment sample taken at each site. Samples are analyzed by a contracting lab. Samples will be collected using a hydraulic winch and Ponar dredge or other appropriate grab sampler. **Schedule**: Quarterly	**Existing Programs:** Benthic monitoring component of IEP's Environmental Monitoring Program (EMP) **Potential Program Additions:** Increase the number of benthic sampling stations to up to 20 sites as a representatively sample of the entire BDCP plan area.	1. Species of macro-benthic organisms identified 2. Total number of individuals counted	This monitoring activity provides information on the benthic communities of the estuary, changes in benthic fauna presence, and abundance and distribution associated physical factors in the estuary. Data collected from the benthic monitoring program is also used to detect newly introduced species in the estuary. The Implementing Office will use this information to determine the status and change of benthic communities over the term of the BDCP and to evaluate possible causal relationships between physical factors and benthic invertebrate communities. This information will also provide important indicators of invasive species progress, impacts of toxics and water operations, and other changes within the Delta. The implementing office will use this information to address changes and modifications to conservation measures through the adaptive decision making process. The monitoring schedule may be adjusted to provide data at a higher temporal or spatial resolution of deemed necessary.	ECSY5.1 ECSY5.2 CHSA1.2 STEE1.2 SASP1.2 GRST1.2 WHST12

Table 3-21. Potential System-Wide Monitoring Actions (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Biological Goals and Objectives Addressed*
Ecosystem Monitoring Element: Physical/Chemical/Nutrient Processes				
Element 2: Water Quality				
Monitoring Action SY2-1: Determine the seasonal and spatial variability of water quality within the Plan Area.				
Condition: Existing seasonal water quality conditions based on existing information (see Applicable IEP and other Resources **Approach:** Continue current water quality monitoring as mandated by existing D-1641 North and Western Delta agricultural and municipal and industrial (M&I) standards and all water quality requirements contained in the North Delta Water Agency/DWR Contract and other DWR contractual obligations. **Schedule:** as currently implemented.	**Existing Programs:** 1. Continuous Multiparameter Monitoring, Discrete Physical /Chemical Water Quality Sampling (Environmental Monitoring program; IEP) 2.Continuous Recorder Sites (DWR, USBR) 3. National Pollutant Discharge Elimination System (NPDES) Self Monitoring Program (Central Valley Water Board) 4. Delta Flows Network and USGS)National Water Quality Assessment Program (, Toxic Substances Hydrology Program 5.. other (DWR, SRCSD, SWAMP, Central Valley Water Board, State Water Board, SFEI, etc) **Potential Program Additions:** **1.** There are over 100 water quality sampling sites within the Delta providing a baseline of water quality data. If needed, additional sampling stations may be added to reflect system-wide representative sampling efforts. Additional water quality sampling stations will be added as levees are breached and sites are flooded to track water quality changes at restoration sites. 2. Expand UC Davis Biosentinel Hg Monitoring Program to include entire Delta. see also Monitoring Action CM4-4 and Monitoring Action CM4-6.	1. Water temperature (^{o}C) 2. mg/L dissolved oxygen 3. NTUs 4. EC 5. pH 6. mg methylmercury/L 7. other nutrients and/or toxicants (e.g., Ammonia, Major Cations (Na, K, Ca, Mg), Metals (Cd, Co, Cu, Fe, Mn, Pb, Zn), inorganic Nitrate, pyrethrins,) 8. Derived location of X2 (isohyaline)	This monitoring action is intended to collect data necessary to determine if salinity conditions are meeting contractual and legal requirements. It also provides data necessary to determine if water quality conditions in the different portions of the Delta remain suitable or improve for supporting covered fish species. This information will also used as a reference condition to determine the possible impact of restoration activities on water quality. This information will be used to address deviations from salinity target conditions, and design modifications and/ research studies to address uncertainty in salinity control. This information will be used to evaluate underlying models and hypotheses of water quality responses conservation measures. This information will aid in identifying sources of uncertainty and will guide the design of further management experiments, design modifications and/ research studies to address uncertainty. The monitoring schedule may be adjusted in response to monitoring results to better understand causal relationships between water management and water quality.	CHSA1.1 GRST1.2 PALA1.1 RILA1.1 SASP1.1 STEE1.1 WHST1.1

Table 3-21. Potential System-Wide Monitoring Actions (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Biological Goals and Objectives Addressed*
Ecosystem Element 3: Hydrodynamics				
Monitoring action SY 3-1: Determine daily flow characteristics throughout the BDCP Plan area.				
Base Condition: Temporal and spatial patterns of flow throughout the Delta region; DAYFLOW, SI3D predictions. **Approach**: Continue monitoring Delta flow and hydrological dynamics through IEP's EMP,. Continue to monitor and calculate flow parameters through Suisun March and at Chipps Island (Delta Net outflow index), **Schedule**: as currently implemented	**Existing Programs:** 1. Delta Flows network (USGS) (21 continuously operating flow stations) 2. IEP EMP sampling station network (15 sites sampled monthly) 3. Flow models (e.g., DAYFLOW, SI3D) **Potential Program Additions:** Expand the USGS network to 29 stations as planned	1. Flow (CFS) 2. Salinity (EC) 3. Water temperature (C^o)	This monitoring action will provide data that will be used by water project operators to assess compliance with target flow levels. They provide a framework for understanding how the tidal currents, river inflows, water project exports, temporary barriers, and DCC gate operations impact transport within the upper estuary. These data are also used routinely for numerical model calibration and validation and are regularly leveraged into large interdisciplinary process-based studies.	ECSY2.1 ECSY2.2 ECSY2.3 ECSY2.4 ECSY2.5, ECSY0.1 CHSA1.5 GRST1.1, RILA1.4, PALA1.4
Ecosystem Element 4: Climate Change				
Monitoring action SY 4-1 Determine the long term dynamics of hydrological characteristics (water level, temperature, salinity) throughout the BDCP Plan area.				
Base Condition: Current monitoring conducted by the interagency network of recorder stations. **Approach**: Continue existing continuous USGS and other agency monitoring programs of Bay Delta water levels, salinity and water temperature; continue modeling of **Schedule**: as currently implemented	**Existing Programs:** Delta Flows network (USGS) comprised of 21 continuously operating flow stations **Potential Program Additions:** Expand the network to 29 stations as planned; See Monitoring Action SY4-1	1. Water level (m) 2. Salinity (EC) 3. Water temperature (C^o)	This monitoring action will provide the Implementing Office with information to determine the magnitude and direction of climate-driven environmental change within the Delta. This information will be used to (a) calibrate models and modify hypotheses as necessary, (b) determine if goals, objectives, or conservation measures are no longer linked with underlying models or hypotheses and thus should be adjusted, modified or eliminated, and (c) if and where changes to planned restoration activities should be considered and managed through the adaptive decision making framework.	ECSY2.1 ECSY2.2 ECSY2.3 ECSY2.4 ECSY2.5, ECSY0.1 CHSA1.5 GRST1.1, RILA1.4, PALA1.4

Table 3-21. Potential System-Wide Monitoring Actions (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Biological Goals and Objectives Addressed*
Ecosystem Monitoring Element: Ecological Processes				
Element 5: Nonnative Species				
Monitoring Action SY 5-1: Determine the seasonal abundance, distribution, and composition of established nonnative fish predators and competitors with native fishes.				
Base condition: Existing fish surveys and harvest statistics for non-native fish predators/competitors. **Approach:** Annual surveys of non-native fish populations to detect long-term trends. Continue representative sampling of non-native predators in trawls and fish surveys. Estimate harvest rate, population size (CPUE) and age distribution of non-native predatory fish caught in sport fisheries (mark-recapture). **Schedule**: annual	**Existing Programs:** fish surveys 1. CDFG 20 mm Survey 2. CDFG Delta smelt larva study 3. USFWS Spring Kodiak Trawl and 'Supplemental Surveys", (e.g., Mossdale trawl) 4. USFWS Midwater trawl 5. USFWS beach seine 6. CDFG Summer townet survey 7. UCD/IEP Suisun Marsh otter trawl 8. DFG striped bass mark-recapture program 9. IEP fish predator control studies **Potential Program Additions:** Expanded sampling location array to create representative systemwide monitoring network of fish populations. Beach seining to reflect micro-habitats and shallow areas not sampled by trawls. Creel surveys or mandatory harvest reporting for non-native sport fish	1.Abundance, density and diet of non-native predatory centrarchids species (e.g., largemouth bass and sunfishes) in size classes that prey on covered fish species in Delta channels 2. Abundance of non-native predatory fish per unit area of habitat 4. Ratio of non-native fish to native fish 5. Change in harvest success and size of non-native fish caught in sport fisheries	This monitoring action will provide quantitative information about the effectiveness of the conservation measures to reduce predator and competitor populations for different life stages of covered fish species and their spatial response (presence and density) to these enhancements. Monitoring results will be used to evaluate if targets and objectives have been met, parameterize and evaluate conceptual models and other analytical tools, and to prioritize potential actions according to certainty, magnitude and timeliness of benefit. The information provided will also support decisions on potential modification to conservation measures, goals and objectives. It will also be used to determine if additional research activities or special survey technology should be developed.	ECSY6.1 TANC1.2 CHSA1.8 STEE1.7 SASP1.5

Table 3-21. Potential System-Wide Monitoring Actions (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Biological Goals and Objectives Addressed*
Monitoring Action SY 5-2. Determine the abundance and species composition of non-native, submerged and floating aquatic vegetation.				
Base Condition: Existing knowledge/surveys/data by resource managers (DBW) will be used to delineate and estimate nonnative SAV and FAV extent in the Delta. **Approach**: This monitoring is implemented as a two-stage sampling: 1. determine the extent and locations of SAV/FAV by remote sensing or other appropriate methods; 2. Randomized stratified water column sampling. Once a close correlation has been established between actual vegetation samples and remote sensing, physical vegetation samples can be eliminated from the sampling protocol. **Schedule:** Every 3 years delineate areas of nonnative invasive aquatic vegetation and conduct Delta wide paired sampling.	**Existing Programs:** Department of Boating and Waterways (DBW) Aquatic Pest Control Program (DBW is the lead agency for controlling Water Hyacinth and Egeria in the Delta) **Potential Program Additions:** 1. Collaboration with DBW on delineation and inventory of aquatic weed extent 2. Remote sensing or aerial imagery acquisition multiple times throughout the growing season (additional delineation via GPS/GIS from vessels etc.) 3. Vessel-based subsampling to estimate composition of aquatic species See also Monitoring Actions CM 13-1, SY3.3	Extent (acres) of nonnative SAV and FAV Maps of the distribution of nonnative SAV and FAV Species composition of nonnative aquatic vegetation	This monitoring is designed to determine the extent of nonnative SAV and FAV in the waterways and floodplains of the BDCP. The BDCP Implementing Office will use results of plan-area wide monitoring to determine if and where controlling SAV and FAV is achievable and sustainable. This information will be used to determine if non-native aquatic vegetation control measures are sufficient to sustainably reduce their impact in important portions of the Delta. The results will also be used by the Implementing Office to determine if control activities should be adaptively adjusted to changing nonnative SAV/FAV extent. The Implementing Office will also use these results to address uncertainties with research studies and adaptive management experiments. The monitoring schedule may be adjusted to reflect changes in non-native aquatic control efforts.	ECSY6.1 TANC1.2 CHSA1.8, SASP1.5, STEE1.7

Table 3-21. Potential System-Wide Monitoring Actions (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Biological Goals and Objectives Addressed*
Monitoring Action SY5-3. Determine the status and distribution of nonnative clams.				
Base conditions: ongoing benthic monitoring by IEP throughout the Estuary. **Approach**: Benthic monitoring will be conducted at up to 20 sites within the estuary, with four benthic samples and one sediment sample taken at each site. Samples are analyzed by a contracting lab. Samples will be collected using a hydraulic winch and Ponar dredge or other appropriate grab sampler. **Schedule**: Quarterly	**Existing Programs:** Benthic monitoring component of IEP's Environmental Monitoring Program (EMP) **Potential Program Additions:** Increase the number of benthic sampling stations to up to 20 sites as a representatively sample of the entire BDCP plan area. Database to track observation and incidental records of non-native bivalves to estimate their habitat use and range expansion in the Delta	1. Species of non-native bivalves 2. Total number of individuals counted	This monitoring activity provides information on the non-native clams of the estuary, changes in their presence, abundance and distribution. Data collected from the benthic monitoring program is also used to detect newly introduced species in the estuary. The Implementing Office will use this information to determine the status and change of benthic communities over the term of the BDCP and to evaluate possible causal relationships between physical factors and benthic invertebrate communities. This information will also provide important indicators of invasive species progress, impacts of toxics and water operations, and other changes within the Delta. The implementing office will use this information to address changes and modifications to conservation measures through the adaptive decision making process. The monitoring schedule may be adjusted to provide data at a higher temporal or spatial resolution of deemed necessary.	ECSY6.1 TANC1.2

Table 3-21. Potential System-Wide Monitoring Actions (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Biological Goals and Objectives Addressed*
Monitoring Action SY5-3. Determine the status and distribution of Microcystis blooms.				
Base Condition: existing data on Delta microcystis abundance, productivity and correlations with water quality parameters **Approach:** Establish additional fixed monitoring stations as needed in areas where microcystis blooms are observed or likely to occur given water conditions. Take weekly grab samples and measurements of chlorophyll a. **Schedule:** Conduct sampling for the first 5 years following first detection and every 5 years thereafter.	**Existing Programs:** Environmental Monitoring Program (EMP, under IEP) **Potential Program Additions:** **1.** Locations of added stations will be fixed during the duration of the plan to detect increase on microcystis abundance and blooming activity in delta waterways Sampling stations will also provide water quality data (e.g., temperature, turbidity, pH for ammonia conversion, amount of organic carbon) *See Monitoring Actions CM 4-3, CM4-4 , CM4-6, and CM16-5*	1. Phytoplankton species composition/relative abundance 2. Phytoplankton density (mg/L chlorophyll a) 3. microcystis colony structure 4. Water temperature 5. $NH4^+$ concentration 6. EC 7. presence of non-native clams (see SY5-3)	This monitoring action is intended to collect data necessary to determine and quantify the degree of microcystis spread and toxic blooms in the Delta. This information, in combination with evaluation of other foodweb-related monitoring and research data, will provide the basis for : 1. Identifying sources of uncertainty and the design of management experiments and/ research studies, to address uncertainty. 2. evaluating underlying conceptual models and hypotheses (e.g., excessive N loading . grazing effects by clams, salinity and temperature limiting factors) 3. evaluating restoration design options to increase the production and export of primary production inundated floodplains 4. Implementing additional management actions to improve production and export of primary production from the floodplain.	ECSY6.1

Table 3-21. Potential System-Wide Monitoring Actions (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Biological Goals and Objectives Addressed*
Natural Community Monitoring Element				
Element 6: Landscape change				
Monitoring SY6-1: Determine the long-term changes in the location, extent, distribution and juxtaposition of Natural Communities within the Plan Area.				
Base Condition: Current landscape composition (see Chapter 2, *Existing Ecological Conditions*). **Approach**: GIS coverages of natural communities will be updated by remote sensing or other appropriate methods to provide estimates of the change occurring within natural communities and landscapes of the BDCP Planning Area. Classification will be field-checked using BDCP conservation lands as verification sites. **Schedule**: Every five years	**Existing Programs:** GIS database (BDCP) Agency databases (CASIL) **Potential Program Additions:** GIS and spatial analysis capability	1. Extent (acres) 2. Location (boundaries) 3. Distribution (number of parcels, parcel size) 4. Neighborhood spatial statistics	This monitoring action will provide the Implementing Office with a Planning Area-wide assessment of how landscapes change over time. This provides an important framework for assessing the effectiveness of the conservation lands system and its functionality and role within the overall landscape. It also indicates to what degree landscape change follows anticipated shifts in the distributions of covered species and natural communities in response to climate change. The Implementing Office will use this information to determine if current models and hypotheses on landscape and climate change are supported or need to be modified. It further will use this information to examine the context of conservation measures and to address conservation targets through the adaptive decision making process. For example, if certain natural community types become unexpectedly rare, the Implementing Office can adaptively respond by increasing acquisition of conservation lands of the rarest community type. The monitoring schedule may be adjusted if landscape change accelerates.	ECSY1.1 ECSY1.2

Table 3-21. Potential System-Wide Monitoring Actions (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Biological Goals and Objectives Addressed*
Monitoring Action SY6-2: Determine structural connectivity and identify corridors and landscape barriers of the BDCP Plan Area				
Base Condition: Current landscape composition (see Chapter 2, *Existing Ecological Conditions*). **Approach**: Connectivity will be evaluated from Planning Area -wide GIS mapping by calculating structural connectivity measures (e.g., mean inter-patch distance and other connectivity measures) and species specific functional connectivity assessments (e.g., least-cost corridor analyses, circuit theory). Connectivity maps will be produced to identify gaps and breaks in structural and functional connectivity throughout the BDCP Planning Area. **Schedule**: Every 10 years.	**Existing Programs:** GIS databases (BDCP) Agency databases (CASIL) **Potential Program Additions:** 1. GIS and spatial analysis capability 2. Connectivity assessment and analysis (including species modeling)	1. Landscape statistics (e.g., contagion, diversity, elevation, area-perimeter ratios)	This monitoring action will provide the Implementing Office with a Planning Area-wide assessment of structural and functional connectivity of habitats for covered species over time. This provides an important framework for assessing the effectiveness of the conservation lands system and its functionality in connecting habitats and improving covered species movement across the landscape. The Implementing Office will use this information to determine the locations where additional conservation land acquisitions are need to increase landscape connectivity. The monitoring schedule may be adjusted if landscape change accelerates or if major, landscape-altering events occur (floods, fire, seismic events).	ECSY3.1 ECSY3.2

Table 3-21. Potential System-Wide Monitoring Actions (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Biological Goals and Objectives Addressed*
Element 7: Biodiversity				
Monitoring Action SY7-1: Determine the diversity of native species within the BDCP Area.				
Base Condition: Current species occurrence and predicted habitat (see Appendix 1, Covered Species and Chapter 2, *Existing Ecological Conditions*). **Approach**: Calculate the change in the number of present covered species, based on (a) updated maps of natural communities (see Monitoring Action SY6-1), (b) actual surveys of conservation lands, (c) species occurrence databases (e.g., CNDDB) and other agency records. **Schedule**: Every 10 years.	**Existing Programs:** 1. GIS databases 2. CNDDB	1. Number of species 2. Acres of habitat per species	This monitoring action will provide information to the Implementing Office whether the presence/occurrence and diversity of covered species may have changed for the Planning Area. The Implementing Office will use this information to evaluate if conservation lands acquisition should be redesigned or modified. It will also use this information to initiate targeted research to determine causal relationships for this change. This monitoring schedule may be intensified to a 5-year interval if rapid change in biodiversity is indicated or following a major, planning area – wide disturbance (flood, seismic event, etc).	ECSY1.1

Table 3-21. Potential System-Wide Monitoring Actions (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Biological Goals and Objectives Addressed*
Fish, Wildlife, and Plant Monitoring Elements				
Element 8: Abundance and distribution of covered fish species.				
Monitoring Action SY8-1: Determine the distribution and abundance of juvenile salmonid abundance for each run.				
Base Condition: Current knowledge of presence and abundance of juvenile salmonids in Delta waterways **Approach**: Visual and non-lethal fish sampling (e.g., beach seining, electrofishing) of representative, randomly selected sections in Delta rearing habitats during the. **Schedule**: Annually during rearing/outmigration periods of juvenile salmonids, conduct biweekly sampling	**Existing Programs:** Historical sampling, USFWS weekly beach seining survey of juvenile salmonids (49 permanent locations Delta wide) **Potential Program Additions:** 1. Add sampling locations to ensure statistical representative sampling effort See also *Monitoring Action CM5-3.*	1. Abundance 2 . size 3. race 4. location	This monitoring action will provide information on the presence and abundance and relative use of delta waterways by juvenile salmonids. Results of monitoring will be assessed to determine if salmonid distribution and abundance is responding to increasing habitat and food availability as restoration progresses. The information will be used test and evaluate numerous models and hypotheses on stressors and limiting factors for salmonids in the Delta. The schedule of the monitoring action may be adjusted to reflect changes in management or research results on fish presence in inundated floodplains.	CHSA1.5 STEE1.3
Monitoring Action SY8-2: Determine the seasonal abundance and distribution of juvenile and adult delta smelt.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	
Monitoring Action SY8-3: Determine the location of delta smelt spawning habitats.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	

Table 3-21. Potential System-Wide Monitoring Actions (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Biological Goals and Objectives Addressed*
Monitoring Action SY8-4: Determine the seasonal abundance and distribution of juvenile and adult Sacramento splittail.				
Base condition: Conduct surveys of splittail adults, larvae, and eggs to determine the abundance of splittail larvae, juveniles and adult present during the reproductive period. **Approach:** Conduct fish sampling surveys to determine the change in densities of larvae and juveniles relative to base conditions and in-channel spawning. **Schedule:** Weekly fish sampling will be conducted in spawning habitat during the first 5 floodplain inundation periods during the splittail spawning season. Subsequently monitor every fifth flood event over the term of the BDCP.	**Existing Programs:** USFWS rotary screw traps USFWS beach seine **Potential Program Additions:** 1. Add sampling locations to include restored floodplain and adjacent channel habitats to ensure statistical representative sampling effort	1. Production of Sacramento splittail (number of larval and early juvenile splittail/10,000 m^3) during floodplain inundation periods	This monitoring action will provide information on productivity of Sacramento splittail populations and the contribution of inundated restored floodplains on spawning and rearing of splittail. This information will be used by the Implementing Office to decide if the production of splittail during floodplain inundation periods has increased significantly from base conditions. If monitoring results do not support conceptual models and hypotheses predicting increasing splittail spawning, the Implementing Office will conduct additional studies to determine 1. uncertainties and competing hypotheses 2. other factors/stressors that affect splittail spawning and rearing in restored habitats, and 3. restoration design modifications to increase splittail productivity. If causes are related to inundation duration, experimental management of flood control structures and floodplain topography may used to address uncertainties. The monitoring schedule may be extended or intensified if uncertainties of causal relationships persist.	SASP1.1 SASP1.3

Table 3-21. Potential System-Wide Monitoring Actions (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Biological Goals and Objectives Addressed*
Monitoring Action SY8-5: Determine the seasonal abundance and distribution of juvenile and adult green sturgeon and white sturgeon.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	GRST1.2 WHST1.1
Element 9: Survival of covered fish species.				
Monitoring Action SY9-1: Determine nonnative predatory fish predation rates on each run of juvenile salmonids.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	CHSA1.5 CHSA1.8 STEE1.3 STEE1.7 SASP1.5
Monitoring Action SY8-2: Determine annual outmigration success of juvenile salmonids.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	CHSA1.5 CHSA1.8 STEE1.3 STEE1.7 SASP1.5
Monitoring Action SY8-3: Determine entrainment levels of covered fish species.				
Implemented through Monitoring Actions CM-2 and CM-3.				
Monitoring Action SY8-4: Determine tissue concentrations of selenium, mercury, pyrethroids, and endocrine disrupting compounds in covered fish species.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	[To come.]
Monitoring Action SY8-5: Determine Pacific and river lamprey upstream and downstream migration success.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	[To come.]
Element 10: Growth rates of covered fish species.				
Monitoring Acton SY10-1: Determine the level of co-occurrence of juvenile fall-run Chinook salmon with preferred prey species.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	CHSA1.1
Monitoring Acton SY10-2: Determine the level of co-occurrence of delta smelt with preferred prey species.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	
Monitoring Acton SY10-3: Determine the extent of delta smelt rearing habitat.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	
Monitoring Acton SY10-4: Determine the spring abundance of preferred longfin smelt prey species.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	

Table 3-21. Potential System-Wide Monitoring Actions (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Biological Goals and Objectives Addressed*
Monitoring Acton SY10-5: Determine the seasonal abundance of preferred Sacramento splittail prey items.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	SASP1.2
Monitoring Acton SY10-6: Determine the size (weight, length) distribution of juvenile salmonids of each run outmigrating from the Delta.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	CHSA1.2 STEE1.2
Monitoring Acton SY10-6: Determine the seasonal size (weight, length) distribution of delta smelt and longfin smelt.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	
Element 11: Production of covered fish species.				
Monitoring Acton SY11-1: Determine the extent of longfin smelt spawning habitat.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	
Monitoring Acton SY11-2: Determine the upstream migration success of green and white sturgeon through the Delta .				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	
Monitoring Acton SY11-3: Determine adult recruitment of delta smelt and longfin smelt .				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	
Element 12: Genetic integrity of wild salmonid stocks.				
Monitoring Action SY12-1: Determine the degree of population genetic variability in each Chinook salmon run and Central Valley steelhead.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	CHSA1.9 STEE1.8

Table 3-21. Potential System-Wide Monitoring Actions (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Biological Goals and Objectives Addressed*
Element 13: Distribution, status, trends of covered wildlife species populations.				
Monitoring Action SY12-1: Determine the number of occupied Swainson's hawk, least Bell's vireo, and western yellow-billed cuckoo nesting territories.				
Base Condition: Pre-acquisition condition, existing knowledge on presence of covered species habitat requirements. **Approach**: Review of agency records, research results, expert knowledge and other data on locations of observations of nesting Swainson's hawk, least Bell's vireo, and western yellow-billed cuckoo. **Schedule**: Annual.	**Existing Programs:** None **Potential Program Additions:** 1. Database of observation records *See CM 11-5*	1. location 2. species	This action is intended to provide the basis for comparing plan-area-wide species performance to the functioning of conservation lands. Management actions are undertaken based on the guidance in the Site-Specific Monitoring Plan, which is subject to modification based on site-specific conditions, opportunities unforeseen at the onset of implementation, or to adjust to the progress of other site specific management plans and the need to meet overall Plan Area-wide goals.	ALNC1.8 ECSY1.5 VRNC1.1 VRNC2.1
Monitoring Action SY12-2: Determine the abundance and distribution of riparian brush rabbit and riparian woodrat if found in the Plan Area.				
Base Condition: expert knowledge **Approach**: track agency records, studies and incidental observations of riparian brush rabbit and riparian woodrat within the BDCP plan Area. If necessary, conduct 10 day trapping grid sampling to verify suspected occurrences. **Schedule**: Annual compilation of Continue for at least 5 inundation years. Ten repeat every 5 years, focusing on verifying presence in previously established occurrences	**Existing Programs:** historical surveys, research projects, approved sampling protocols. **Potential Program Additions:** 1. database to track annual information on riparian brush rabbit and riparian woodrat distribution and status	1. Presence and sex/age distribution of riparian brush rabbit and riparian woodrat in the BDCP plan area.	This monitoring action is intended to collect data on the distribution and population trend of riparian brush rabbit and riparian woodrat. Monitoring results will be used to determine if habitat restoration has a source or sink effect on the abundance of riparian brush rabbit and riparian woodrat. This information is necessary to determine if adaptive changes to the implementation schedule or additional measures may be necessary to increase the abundance and viability of of riparian brush rabbit and riparian woodrat populations.	RIBR1.1 RIWR1.1 VRNC1.1 VRNC2.1

Table 3-21. Potential System-Wide Monitoring Actions (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Biological Goals and Objectives Addressed*
Monitoring Action SY12-3: Determine the abundance and distribution of giant garter snake.				
Base Condition: expert knowledge **Approach**: track agency records, studies and incidental observations of Giant Garter Snakes within the BDCP plan Area. If necessary, conduct field trapping/sampling to verify suspected occurrences. **Schedule**: Annual compilation of Continue for at least 5 inundation years. Ten repeat every 5 years, focusing on verifying presence in previously established occurrences	**Existing Programs:** historical surveys, research projects, approved sampling protocols. **Potential Program Additions:** 1. database to track annual information o Garter snake distribution and status *See CM 2-16, CM10-4*	1. Presence and sex/age distribution of Giant Garter Snake	This monitoring action is intended to collect data on the distribution and population trend of giant garter snake. Monitoring results will be used to determine if habitat restoration has a source or sink effect on the abundance of giant garter snakes. This information is necessary to determine if adaptive changes to the implementation schedule or additional measures may be necessary to increase the abundance and viability of giant garter snake populations.	ALNC1.1 ALNC1.2 ALNC1.5 ALNC1.6 TANC1.1 FMNC1.1 FMNC2.1 NANC2.1 NWNC1.1 NWNC2.1 ALNC1.7 ALNC1.8 GGSN1.1 GGSN2.1 GGSN2.2
Monitoring Action SY12-4: Determine the abundance of waterfowl wintering in the Plan Area.				
Base Condition: Current waterfowl monitoring as conducted by USFWS, CDFG and CWA **Approach**: Continue USFWS and CDFG special fall and midwinter aerial surveys. The midwinter survey, the longest running population assessment, focuses on all ducks, geese, swans, and coots. **Schedule**: Annual mid-winter surveys as currently implemented by USFWS.	**Existing Programs:** USFWS midwinter waterfowl surveys **Potential Program Additions:** none	1. Number 2. Species 3. sex/age composition (if possible)	This monitoring action provides information on the abundance of wintering waterfowl. The Implementation office will use this information to determine area-wide trends in waterfowl numbers and to compare these with waterfowl use of restored or created wetland wintering habitat for waterfowl. The Monitoring schedule may be changed if necessary to improve accuracy and/or precision of waterfowl estimates.	MWNC1.1
Monitoring Action SY12-5: Determine the abundance of shorebirds using the Plan Area during spring and fall migration periods.				
[Text to come.]	[Text to come.]	[Text to come.]		MWNC1.2

Table 3-21. Potential System-Wide Monitoring Actions (continued)

Base Conditions, Approach, and Schedule	*Applicable IEP and other Programs and Potential Additions to those Programs*	*Metrics*	*Adaptive Management Considerations*	*Biological Goals and Objectives Addressed*
Element 14: Reproductive success of covered wildlife species.				
Monitoring Action SY12-1: Determine Swainson's hawk, least Bell's vireo, and western yellow-billed cuckoo the nesting success.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	[To come.]
Monitoring Action SY12-1: Determine the recruitment rate for riparian brush rabbit and riparian woodrat if found in the Plan Area.				
Base Condition: expert knowledge **Approach**: If riparian brush rabbit or riparian woodrat are verified within the BDCP plan Area, conduct 10day capture-recapture (trapping grid) sampling at the beginning, middle and end of the reproductive period **Schedule**: 3 consecutive seasons every 10 years .	**Existing Programs:** historical surveys, research projects, approved sampling protocols. **Potential Program Additions:** 1. trapping survey team, equipment and methodology to conduct capture -recapure	1. sex/age distribution of riparian brush rabbit and riparian woodrat 2. Lactation rates	This monitoring action is intended to provide information on recruitment of juvenile riparian woodrats and brush rabbits into the adult population. This information will be used in parameterizing a population viability model for each species. Model output will predict the probability of population persistence and extinction. Monitoring results will be used to determine if habitat restoration has a source or sink effect on the abundance of riparian brush rabbit and riparian woodrat. This information is necessary to determine if adaptive changes to the implementation schedule or additional measures may be necessary to increase the abundance and viability of of riparian brush rabbit and riparian woodrat populations.	

Table 3-21. Potential System-Wide Monitoring Actions (continued)

Base Conditions, Approach, and Schedule	***Applicable IEP and other Programs and Potential Additions to those Programs***	***Metrics***	***Adaptive Management Considerations***	***Biological Goals and Objectives Addressed***
Element 15: Distribution, status, and abundance of covered plant species.				
Monitoring Action SY12-1: Determine the abundance and distribution of intertidal covered plant species.				
[Text to come.]	[Text to come.]	[Text to come.]	[Text to come.]	MFNC1.2 BMNC1.2 FMNC1.2 SUTH1.1 SUTH1.2 SOBB1.1 SOBB1.2

3.7 ADAPTIVE MANAGEMENT PROGRAM

[***Note to Reviewers****: The text of this section of Chapter 3 on adaptive management was revised based on comments by Steering Committee members following the October 21, 2010 meeting. This section is subject to change and revision based on further input from the BDCP Steering Committee.*]

The BDCP Adaptive management program is premised on the concept that, as new information and insight is gained during the implementation of a conservation plan, adjustments can be made to the conservation actions to further advance the goals and objectives of the plan. The Natural Community Conservation Planning Act (NCCPA) recognizes this function, defining adaptive management as a process whereby "the results of new information gathered through the monitoring program of the plan and from other sources [is applied] to adjust management strategies and practices to assist in providing for the conservation of covered species."[45] Similarly, the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) describe adaptive management as a "method for examining alternative strategies for meeting measurable biological goals and objectives, and then if necessary, adjusting future conservation management actions according to what is learned."[46]

Consistent with these definitions, the BDCP adaptive management program will provide the basis for: (1) key gaps in data and knowledge to be identified and steps to be taken to close such gaps; ; (2) alternative approaches to conservation actions to be developed that would enhance the effectiveness of conservation measures; (3) new information gathered through monitoring and targeted research programs to be evaluated; and (4) analytical processes and feedback loops to be instituted to better inform decisions regarding adaptive changes. Outcomes of the adaptive management decision making process could include changes in conservation measures, biological objectives and targets, monitoring actions and metrics, and analytical tools within the boundaries established by the BDCP.

The Program Manager, through the Science Manager, will be responsible for the administration and implementation of the BDCP adaptive management program. The BDCP Implementation Board will oversee the Implementation Office's implementation of the program. The roles and responsibilities of the Implementation Office, the Implementation Board, the fish and wildlife agencies, and the Authorized Entities in the adaptive management program are summarized in Section 3.7.2 *Adaptive Management Decision Making Process.*

The conservation measures described in Section 3.4, *Conservation Measures*, are based on the best scientific and commercial information and data available and have been designed to address the biological goals and objectives of the Plan. As the BDCP is being implemented, however, new data and information will be developed through the monitoring and research program described in Section 3.6, *Monitoring and Research Program*, as well as through other efforts, that

[45] Fish and Game Code Section 2805(a)
[46] Five-Point Policy for HCPs, 65 FR 106, June 1, 2000

will further inform the Implementation Office on a number of matters affecting plan implementation.

Information gained through monitoring and research will help inform investigations into such matters as: maximizing the efficacy of conservation measures and understanding the factors that may account for poorer than expected ecological responses to the implementation conservation measures; the synergistic and cumulative effects associated with multiple conservation measures; the influence of factors present outside the BDCP Plan Area, including those associated with other conservation planning efforts; and the effects of operational criteria on ecosystem conditions. Additionally, monitoring and research conducted under the BDCP and other programs produce information and data regarding the effects of climate change on Delta conditions (e.g., sea level rise, hydrology in the Delta watershed, and increased water temperatures), seismic events, projected large-scale changes in land use, and other circumstances that fall outside of the scope of the BDCP to address.

As more is understood about the Delta ecosystem, modifications to the BDCP conservation measures may be necessary. Conservation measures may initially prove to be less effective than expected, but as more is learned through the adaptive management process, certain adjustments may be possible to increase the effectiveness of measures. Alternatively, conservation measures may prove initially effective, but changing conditions in the Plan Area may necessitate changes in the manner in which conservation measure are implemented or require a shift to more effective measures. The adaptive management process will afford the Implementation Office, in coordination with the Implementation Board, the flexibility to address the shortcomings of conservation measures in meeting BDCP goals and objectives by making adjustments to these measures. Specifically, adaptive management changes may include modifications to the conservation measures, their elimination altogether, or the addition of new measures. The adaptive management program may also indicate refinements to the biological goals and objectives and targets; changes in the priorities for implementation of conservation measures, including the shifting of funds among measures; and changes to the monitoring program as indicated by new scientific information. Should strong cause and effect relationships be established, the adaptive management program will provide the mechanism to concentrate efforts on the implementation of conservation measures that have been demonstrated to be effective and to de-emphasize or discontinue implementation of conservation measures that have proven to be less effective at achieving desired outcomes.

To address uncertainty regarding Delta ecological processes and species biology, to provide for flexibility in the Conservation Strategy through time as ecological knowledge expands, and to ensure that the BDCP becomes increasingly more effective over time and responsive to changing ecological conditions in the Delta, the BDCP adaptive management program has been developed with the following elements:

- **Process Framework –** the process by which the BDCP adaptive management program will be implemented, including gathering data through monitoring and targeted research, analyzing data, assimilating new knowledge, and making adjustments to the strategy (Section 3.7.1, *Adaptive Management Process Framework*);

- **Decision Making Process –** a decision making process that effectively uses new information in a timely manner to make adaptive management changes and that allows for sufficient input from various participants (Section 3.7.2, *Adaptive Management Decision Making Process*; see also Chapter 7, *Implementation Structure*) under the governance structure of the BDCP;
- **Adaptive Ranges –** specifically established upper and lower boundaries and limits that govern the scope of changes that can be made to conservation measures, including water operations criteria, pursuant to the adaptive management program. These ranges are reflected in the BDCP and its associated regulatory authorizations. (Section 3.7.3, *Concept of a "Defined Adaptive Range" and Water Operations Adaptive Management*);
- **Targeted Research** – experiments and pilot studies specifically designed to test uncertainties and the hypotheses underlying conservation measures, and to rapidly gain knowledge that could improve performance (Section 3.7.5, *Adaptive Management Experiments*);
- **Status Reviews –** required regular reviews of the Conservation Strategy's performance, achievement of goals and objectives, and status of covered species (Section 3.7.7, *Program Status Reviews*; see also Section 6.2, *Compliance and Progress Reporting*).

This adaptive program of knowledge expansion and implementation flexibility is central to the BDCP Conservation Strategy and the achievement of the BDCP biological goals and objectives.

3.7.1 Adaptive Management Process Framework

The process framework for the BDCP adaptive management program is depicted in Figure 3-63.

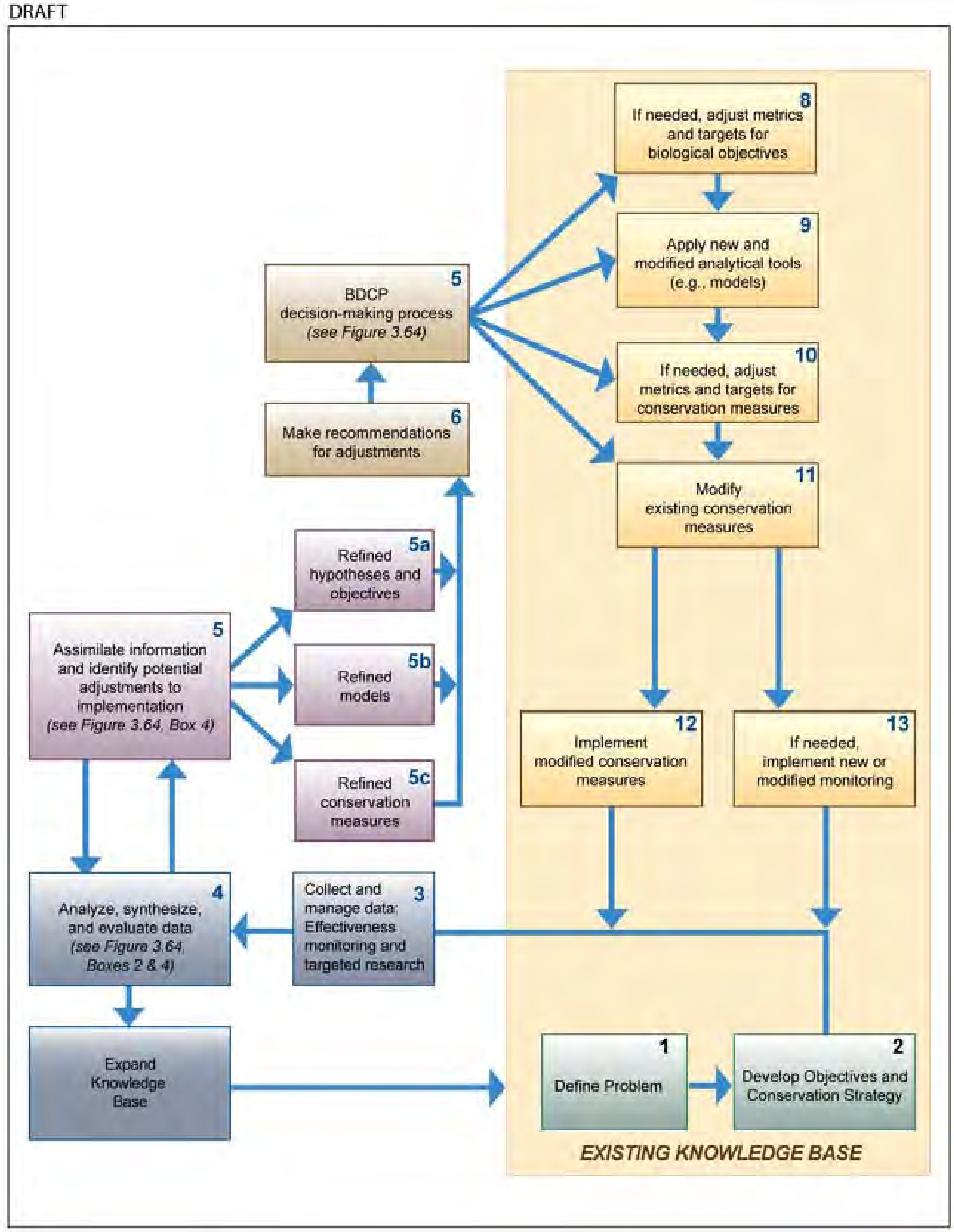

Figure 3-63. BDCP Adaptive Management Process Framework

To ensure development of a scientifically-based BDCP adaptive management program, independent science advisors were engaged to provide expert input on best approaches to adaptive management. The results of the deliberations of these scientists are reflected in the *BDCP Independent Science Advisors Report on Adaptive Management, February 2009* (Appendix G). The report set out the following principles for effective adaptive management:

1. The scope and degree of reversibility of each proposed action (i.e., conservation measure) determines the form of adaptive management that can be applied (e.g., “active” or versus “passive” adaptive management)[47].
2. The knowledge base about the ecosystem is key to decisions about what to do and what to monitor, and includes all relevant information, not just that derived from monitoring and analysis within the context of BDCP.
3. Program goals should relate directly to the problems being addressed and provide the intent behind the conservation measures; objectives should correspond to measurable, predicted outcomes.
4. Models should be used to formalize the knowledge base, develop expectations of future conditions and conservation outcomes that can be tested by monitoring and analysis, assess the likelihood of various outcomes, and identify tradeoffs among conservation measures.
5. Monitoring should be targeted at specific mechanisms thought to underlie the conservation measures, and must be integrated with an explicitly funded program for assessing the resulting data.
6. Prioritization and sequencing of conservation measures should be assessed at multiple steps in the adaptive management cycle.
7. Specifically targeted institutional arrangements are required to establish effective feedback mechanisms to inform decisions about whether to retain, modify, or replace conservation measures.
8. A dedicated, highly skilled agent (person, team, office) is essential to assimilate knowledge from monitoring and technical studies and make recommendations to senior decision makers regarding programmatic changes.

The advisors report included an adaptive management process framework. The BDCP adaptive management process depicted in the flow diagram in Figure 3-64 follows the recommendations provided in the independent science advisors report.

47 Active adaptive management is experimental, involving manipulations intended to achieve conservation goals but also to improve knowledge. Passive adaptive management is not experimental, but is nevertheless approached from a scientific perspective to improve knowledge and adapt strategies during project implementation.

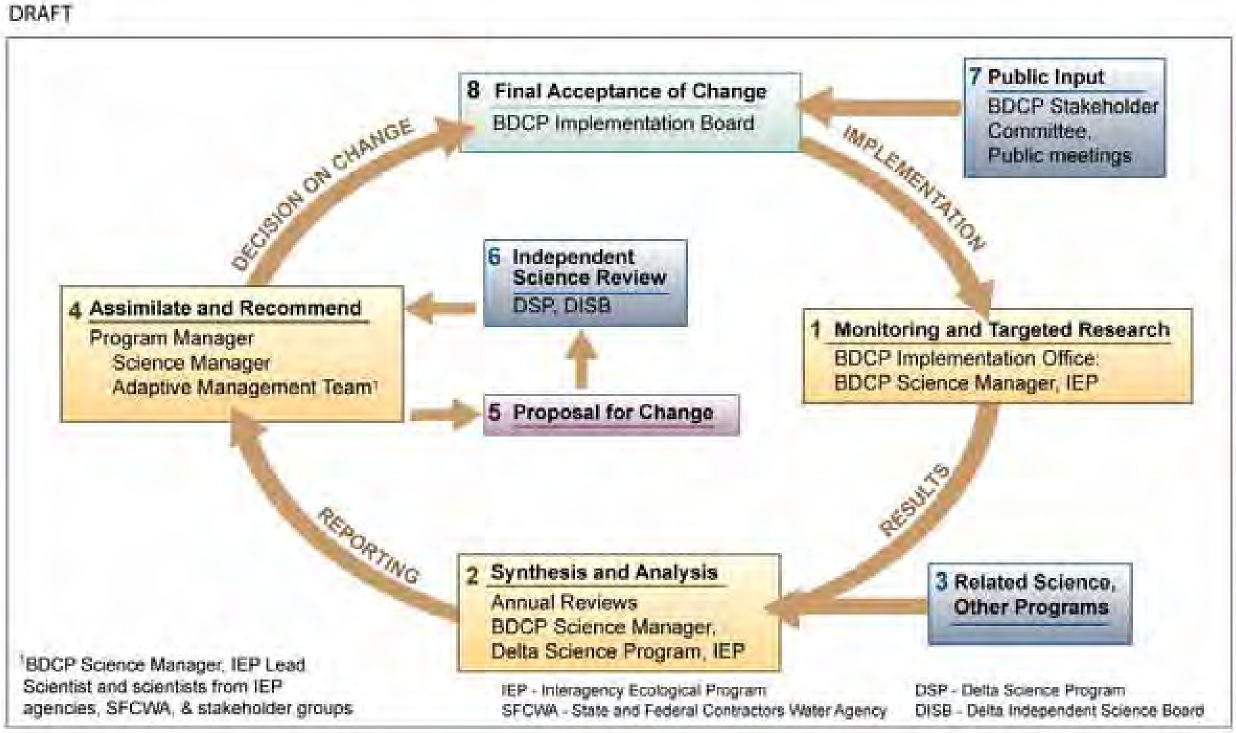

Figure 3-64. BDCP Adaptive Management – Decision-Making Process

3.7.1.1 Plan Objectives and the Knowledge Base

The starting point for the BDCP adaptive management process is with the definition of global problems and the identification of BDCP-specific, measurable and practical biological goals and objectives (see Figure 3-63, Boxes 1 and 2). BDCP objectives are based on the best available information about covered species, natural communities, ecosystem function in the Delta, and about the environmental stressors affecting these biological resources, and anticipated ecological and species responses to the conservation measures. The current information about system function and stressors comprises the existing "knowledge base" (see large shaded box underlying the right side of Figure 3-63). The adaptive management process is designed to use new information (i.e. contributions to the knowledge base) to inform a systematic and integrated critical review, at regular intervals, of the entire Conservation Strategy, including BDCP objectives, conservation measures, hypotheses relating to predicted outcomes and targets. As the knowledge base is expanded, and biological models are revised, changes may be made to the BDCP objectives and associated hypotheses, metrics, targets, and monitoring metrics (Figure 3-63, Box 5; see Section 3.7.1.3). The Science Manager, within the BDCP Implementation Office, is responsible for ensuring that the adaptive management program is focused on the achievement of BDCP biological goals and objectives and that the program draws from be best scientific and commercial information available to support adaptive management decisions.

3.7.1.2 Collect and Manage Data

Critical to the adaptive management process is the collection and management of existing and new data (see Figure 3-63, Box 3) to assess conservation measure performance and the achievement of biological goals and objectives. Monitoring and targeted research data collection and management will be the responsibility of the Science Manager within the BDCP Implementation Office with assistance from the Interagency Ecological Program (IEP), and in coordination with the Delta Science Program and other science and monitoring programs (see Section 3.6, *Monitoring and Research Program*). Monitoring actions and metrics are described in Section 3.6, *Monitoring and Research Program*. In addition, results of targeted research and scientific modeling conducted by programs other than the BDCP will contribute to the knowledge base to support understanding of ecological cause and effect relationships. Monitoring data and research results will provide the BDCP Implementation Office with information to help determine the effectiveness of conservation measures in providing benefits to species and habitats, the effectiveness of adjusting or modifying approaches to the implementation of the measures, and the effectiveness of combinations of measures to achieve desired objectives. Because new data provide the foundation for making effective adjustments to plan implementation over time through the adaptive management process, collected data will undergo quality assurance reviews. Recommendations to modify implementation of conservation measures will be guided by information gathered through the monitoring and research program and other research sources (Figure 3-63, Box 3, see also Figure 3-64, Box 3). The BDCP monitoring and research program is designed to establish cause and effect relationships between implementation of specific conservation measures and the type and magnitude of ecosystem and species responses to those measures, as well as responses to the implementation of combinations of conservation measures.

The Implementation Office will establish processes and procedures to govern the systematic control and management of information obtained through BDCP monitoring and research. Specifically, the Implementation Office will ensure that all information is appropriately classified, stored, secured, and shared. This includes:

- Ensure that records of permanent value are preserved.
- Ensure the security and protection of regulatory, statutory or business importance from unauthorized access and/or modification.
- Ensure that all BDCP data is of the highest quality (accuracy and precision).
- Ensure responsive and transparent sharing of data across the widest-possible spectrum of users, including scientists, government agencies, non-governmental organizations and the public.

3.7.1.3 Analyze Data, Assimilate Information, and Develop and Recommend Adjustments to Implementation.

The science advisors report on adaptive management (Appendix G) pointed out that the weakest aspect of most adaptive management plans is in the sequence of steps required to link the knowledge gained from implementation monitoring and research and other sources to decisions about whether to continue, modify, or stop actions, refine objectives, or alter monitoring (Figure 3-63, Box 5 and Box 6; Figure 3-65). See the discussion of internal and external science review in the 3.7.2, *Adaptive Management Decision Making*.

Collected data will be analyzed and synthesized at appropriate intervals by the Implementation Office, in coordination with Delta Science Program and IEP, and these results will be evaluated by the Adaptive Management Team. The BDCP Science Manager may utilize IEP, the Delta Science Program, and other expertise to support the evaluation of monitoring and research data. Results will include information related to cause and effect relationships between conservation measures and ecological processes, covered species, and natural communities; the status of ecosystem conditions and covered species; and the effectiveness of the conservation measures and the monitoring program (Figure 3-63, Box 5). The results will also clearly identify the inferential reliability of this knowledge (sensu Romesburg 1981), statistical performance measures (e.g. power accuracy, precision) and, if appropriate, alternative hypotheses generated from the results. Information gained through this process may indicate the need to redefine hypotheses underlying biological objectives and conservation measures; refine, discontinue, or expand conservation measures; or develop and implement new conservation measures within limits set by the plan and its associated regulatory authorizations.

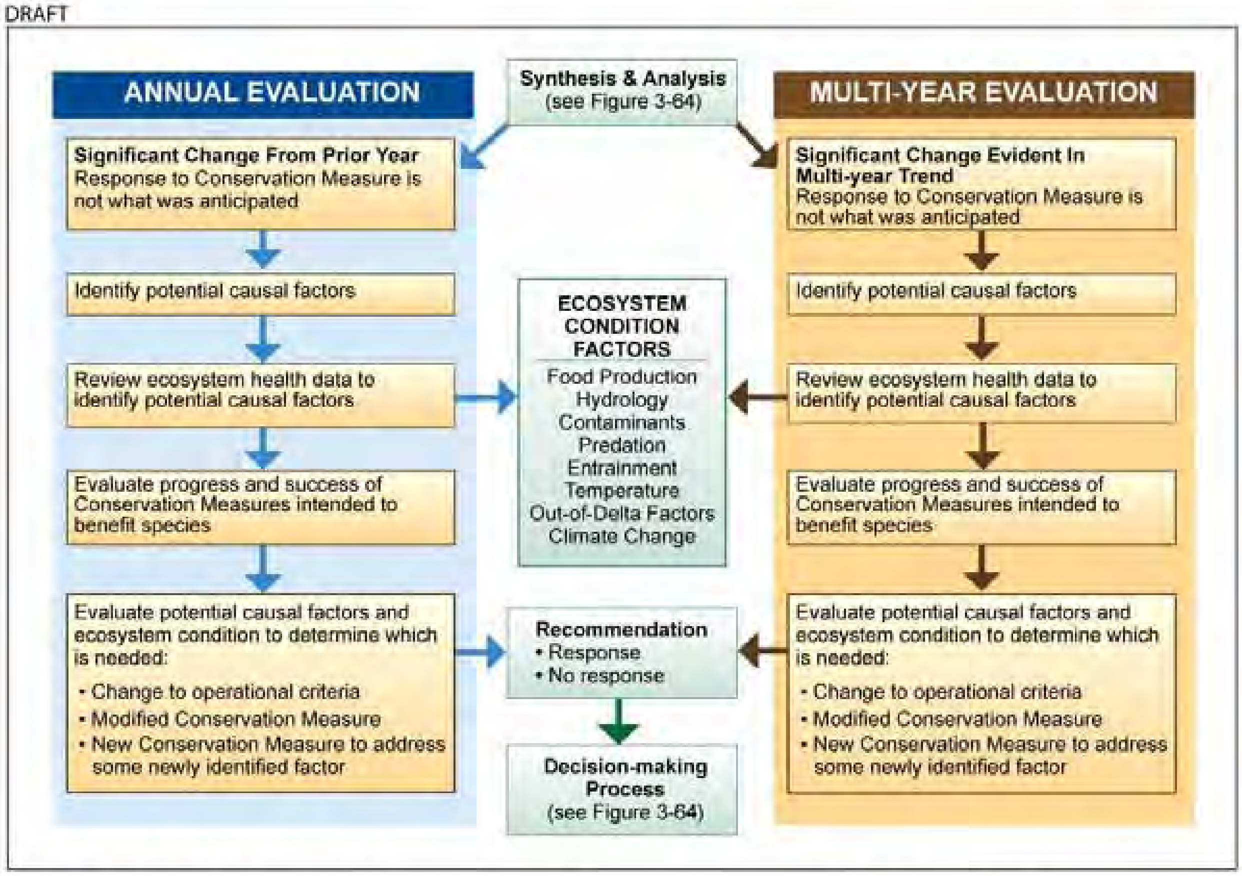

Figure 3-65. BDCP Adaptive Management Process: Response to a Significant Declining Trend in Covered Species

The science advisors also emphasized the need to integrate the evaluation of the efficacy of conservation measures across suites of measures that are inter-related, and to use and expand upon the existing (and new) modeling capabilities to assist in that integrated evaluation. New data will therefore also be used to update models (e.g., conceptual, statistical, and process models) and other analytical tools that are useful in assessing the performance of both individual conservation measures and suites of interrelated measures in helping to achieve the goals and objectives of the plan as the magnitude of stressors are better understood and uncertainties are resolved. New data and modeling work will also help predict the magnitude and trajectory of ecosystem and covered species responses to conservation measures and identify the need for new models and tools (Figure 3-63, Box 5 which corresponds to Box 4 of decision making process illustrated in Figure 3-64). Ecological models (either conceptual or mathematical) are extremely valuable for formalizing the link between objectives and proposed conservation measures to clarify how and why each conservation measure is expected to contribute to objectives and are a key element of adaptive management. Models will be used to formalize knowledge about the system and to predict the outcomes of and design modifications to conservation measures.

Based on assimilation of new information, the Adaptive Management Team (see Section 3.7.2.1, *Roles and Responsibilities*) working with the IEP, Real Time Operations Response Team (see Chapter 7, *Implementation Structure*) and the Implementation Facilitation Team (see Chapter 7, *Implementation Structure*), as appropriate, will formulate recommended new approaches for BDCP implementation intended to increase the effectiveness of conservation measures, the monitoring program, analytical tools, and metrics in meeting the biological goals and objectives of the BDCP (see Figure 3-63, Box 6). The BDCP Program Manager may include such recommendation in the Annual Workplan and Budget (see Section 6.2, *Compliance and Progress Reporting*). Recommended new approaches to conservation actions would be considered, and potentially adopted, through the BDCP adaptive management decision making process (Figure 3-64).

3.7.1.4 Implement Modified Conservation Measures, Tools, Metrics, and Targets

BDCP Implementation Office through the adaptive management program, and within the limits of the adaptive ranges set out in the BDCP and reflected in the associated regulatory authorizations, would implement adaptive changes to the BDCP Conservation Strategy that may include:

- **Adjustments to metrics and targets for biological objectives** (Figure 3-63, Box 8) – Metrics and targets for BDCP biological objectives were developed based on the existing knowledge base. New information developed during the BDCP implementation could result in the need to revise metrics and targets for these objectives (as allowable under the authorizing permits).
- **Development and application of new analytical tools** (Figure 3-63, Box 9) – As knowledge grows over time, new analytical tools are expected to be developed including monitoring technologies and techniques, physical and biological models, statistical

relationships, etc. These new tools would be applied to the monitoring and evaluation of implementation of the BDCP Conservation Strategy as they become available.

- **Adjustments to metrics and targets for conservation measures** (Figure 3-63, Box 10) – Specific metrics and targets have been identified for BDCP conservation measures based on existing knowledge. As understanding of the Delta ecosystem improves, revisions would be made to these metrics and targets to reflect this new knowledge, as appropriate.

- **Modification of conservation measures** (Figure 3-63, Box 11) – The adaptive management program guides the modification of BDCP conservation measures to improve effectiveness in meeting BDCP goals and objectives. The adaptive management program can also modify priorities and timetables for implementing conservation measures based on new knowledge.

- **Discontinuance of ineffective conservation measures** (Figure 3-63, Box 11) – The adaptive management program allows for the elimination of unsuccessful conservation measures. The funds allocated to these measures may be reallocated to expand successful measures.

- **Identification of new conservation measures** (Figure 3-63, Box 11) – As a result of BDCP monitoring and research and new knowledge, new stressors may be identified which are drivers of ecosystem change and species response. The adaptive management program may be used, subject to the limits established in the Plan, to incorporate new conservation measure to address these stressors in the Conservation Strategy. [***Note to Reviewers****: Could refer to Section 3.5, Potential Conservation Measures to Address Other Stressors, depending on the approach decided for those potential conservation measures.]*

- **Implementation of new or modified monitoring methods** (Figure 3-63, Box 13) – The adaptive management program will inform and guide the subjects of monitoring, monitoring metrics, and the duration and scope of monitoring. Monitoring technology and techniques improve through time and as new methods are developed they will be incorporated into the BDCP monitoring program. The adaptive management program would also identify and implement modifications to the research program and adaptive management experiments to address new uncertainties and fill knowledge gaps.

BDCP actions related to SWP and CVP water operations remain under the authority and are the responsibility of DWR and Reclamation, not the Implementation Office. Adjustments to the water operations criteria set out in the BDCP and reflected in its associated authorizations, and within the adaptive range for water operations described in CM1 *Water Facilities and Operations*, may only be conducted through the process identified in Section 3.7.3.2, *Decision Process for Adjusting Water Operations within the Adaptive Range.*

3.7.2 Adaptive Management Decision Making Process

This section describes the process by which adaptive management decisions will be made, including those that result in adjustments to conservation measures, operational criteria, biological objectives, metrics and targets, the monitoring program including monitoring methods, and analytical tools, as warranted by new information. This section describes the relationships among, and coordination between, the entities that comprise the governance structure (Chapter 7, *Implementation Structure*) in the context of the adaptive management decision-making process (Figure 3-64).

3.7.2.1 Roles and Responsibilities

3.7.2.1.1 Science Manager

The BDCP Implementation Office, under the direction of the BDCP Program Manager, is responsible for Plan implementation, including the monitoring, research, and adaptive management programs. The BDCP Science Manager, under the direction of the Program Manager, is the primary Implementation Office staff responsible for ensuring the proper implementation of these programs.

3.7.2.1.2 Adaptive Management Team

The Science Manager may create an “Adaptive Management Team” and will serve as the chair of and recommend membership for the BDCP Adaptive Management Team to the Program Manager. Membership of the Adaptive Management Team will be reviewed and approved by the BDCP Program Manager and the BDCP Implementation Board. The Adaptive Management Team may include:

- BDCP Science Manager (chair);
- IEP Lead Scientist;
- Senior scientists from IEP member agencies[48];
- SFWCA scientists;
- Other scientists; and
- Scientists from the Stakeholder Committee, as appropriate.

Adaptive Management Team members may change as necessary depending on specific the technical issues that need to be addressed (e.g., fisheries, terrestrial wildlife, habitat restoration, water operations).

[48] IEP has ten member agencies: three State (DWR, DFG, and State Water Resources Control Board); six Federal (USFWS, Reclamation, U.S. Geological Survey, USACE, NMFS, and U.S. Environmental Protection Agency), and one non-government organization (The San Francisco Estuarine Institute).

The Science Manager will utilize the Adaptive Management Team to support the conduct of annual and multi-year reviews, in coordination with the Delta Science Program, including efforts to identify issues that may benefit from independent science advice; consider potential adaptive management actions that may be indicated by the results of monitoring and research efforts; and identify research that may be useful to effectively address uncertainties. The Adaptive Management Team will make recommendations to the Program Manager for adaptive management changes to the BDCP Conservation Strategy.

The Science Manager may utilize the Adaptive Management Team to support the synthesis and presentation of current scientific knowledge on relevant Delta resources to the Program Manager and BDCP Implementation Board.

3.7.2.2 Adaptive Management Decisions and Responses (Not Related to Water Operations)

The Program Manager will manage the BDCP adaptive management program through the Science Manager. The Program Manager will facilitate and coordinate discussion and consideration of adaptive management issues among the various participating entities, including the authorized entities, fish and wildlife agencies, and the Implementation Board to facilitate decision-making regarding changes in the implementation of the Plan. Adaptive management decisions to take new actions within the BDCP Plan Area will take into account and be coordinated with changes that may be made to upstream operations, which may result from changes made pursuant to existing or future biological opinions for the CVP/SWP project operations outside the Delta. The decision-making process described in this section does not apply to changes or modifications to water operations that may be made by DWR and USBR. The process for adaptive management decisions affecting water operations is set out in Section 3.7.3.2, *Decision Process for Adjusting Water Operations within the Adaptive Range*. The approach depicted in Figure 3-64 will be used to make adaptive management decisions relating to BDCP actions that are not related to water operations.

1. Monitoring and targeted research (Figure 3-64, box 1) will be conducted under the direction of the Science Manager, with support provided by the IEP.

2. The BDCP Science Manager, in coordination with the IEP, Adaptive Management Team, and the Delta Science Program, will assemble, synthesize, and analyze the results of BDCP monitoring and targeted research (Figure 3-64, box 2) efforts and integrate the results of new and relevant scientific research and studies conducted by other parties (Figure 3-64, box 3).

3. Based on this information and the advice of independent scientists, as appropriate (Figure 3-64, boxes 5 and 6), the Adaptive Management Team, through the Science Manager, will provide recommended program changes to the Program Manager (Figure 3-64, Box 4), either as part of the annual and five year workplan development process or on an *ad hoc* basis, where an adaptive change should occur on a shorter than annual timeframe.

4. The Program Manager will recommend adaptive management changes to the Implementation Board (Figure 3-64, Box 4). The Implementation Board will provide an opportunity for stakeholder input (Figure 3-64, box 7). The Implementation Board will review the Program Manager's recommendation and make final acceptance of the proposed adaptive management changes (Figure 3-64, Box 8).

The BDCP Implementation Board will receive information on the implementation of the BDCP generally, and will review major aspects of the adaptive management program described in the Annual Workplan. Members of the Board will have the right to object to adaptive management proposals made by the Program Manager on the basis that the proposed change, a) will not adequately contribute to achievement of the goals and objectives of the BDCP, or, b) is inconsistent with the requirements of the Plan or the permits/authorizations. If changes are accepted by the Board, they will be implemented by the Implementation Office under the accepted timetable. If the Board cannot come to agreement on an adaptive management change, the dispute resolution process described in Chapter 7, *Implementation Structure,* will be used.

As the BDCP is being implemented, it is expected that some changes in implementation actions and some adaptive management decisions will be considered to be minor. These minor decisions will not be subject to the formal adaptive management decision process as described above. Once such a type or category of change is accepted as minor by the Implementation Board, the Program Manager will be able to undertake such minor adjustments to conservation measures, without the need for extensive coordination with the other entities, thereby encouraging efficiency and timeliness in the implementation process. Such changes to the manner in which actions are implemented under the Plan include, for example, refinements to techniques used to restore habitat or to remove invasive species.

Plan implementation and adaptive management responses that will require full review as part of the adaptive management process include:

- Any change in the water operating criteria within the adaptive range;
- Discontinuation of a conservation measure;
- Expansion of a conservation measure;
- Addition of a new conservation measure;
- Decisions to reallocate available funding or resources away from ineffective conservation measures and toward more promising ones; or
- Any change to BDCP goals and objectives.

The Program Manager will consult with the Implementation Facilitation Team, the Real Time Operations Response Team and Adaptive Management Team regarding ongoing implementation issues which may require changes to broad elements of the Plan or specific actions to determine if such changes should be considered through the adaptive management process. Changes to the

Plan would be subject to the limits, boundaries, parameters and sideboards established for adaptive management actions, including funding caps established to implement the BDCP Conservation Strategy.

In some instances, a significant change in population trends for a covered species may occur, necessitating responsive actions (Figure 3-65). Efforts to respond to such circumstances would be conducted within the framework of the adaptive management program, as appropriate.

3.7.2.3 Internal Scientific Review

The Program Manager will use the Adaptive Management Team to provide internal scientific review (internal to the Implementation Office) on specific technical issues of immediate importance to the success of the adaptive management program and the Conservation Strategy implementation. The Adaptive Management Team will also assess on a regular basis the overall efficacy of the adaptive management program, including the results of effectiveness monitoring, selection of research and adaptive management experiments, and relevance of new scientific information developed by others (e.g., universities, Delta Science Program) to determine whether changes in the implementation of the conservation measures and the monitoring program would improve the effectiveness of the BDCP in achieving its biological goals and objectives

Recommendations made by the Adaptive Management Team and by other scientists and experts will be memorialized in a standardized format and will include a description of the recommended change in implementation; a description of the justification for the recommended change; an assessment of effects the change may have on other elements of BDCP implementation, if any; and any other relevant information in support of the recommendation. The rationale for rejection of adaptive management recommendations made during the internal science review process will also be documented.

3.7.2.4 External Independent Scientific Review

Working in coordination with the Delta Science Program and the Adaptive Management Team, the Program Manager will from time to time seek additional science input on specific implementation and adaptive management-related issues. The Program Manager may convene, at its discretion, experts on selected topics that are not affiliated with the Implementation Office, permit holders, or fish and wildlife agencies. The Program Manager will consult with the Implementation Board regarding the selection of scientists to provide advice on specific matters.

3.7.3 Concept of a “Defined Adaptive Range” and Water Operations Adaptive Management

[***Note to Reviewers**: The process for making adjustments to water operations within the adaptive range needs to be consistent with the process in Section 3.7.2.2, with recognition that these kinds of changes will likely be made more frequently.*]

To allow for flexible and responsive implementation of the BDCP, several conservation measures include a defined "adaptive range" that establishes the parameters within which a conservation measure may be adjusted to improve its effectiveness or respond to changing biological conditions. For example CM6 *Channel Margin Habitat Enhancement* identifies a target of 20 linear miles of enhancement of channel margins in areas important to salmonid outmigration and identifies an adaptive range that allows for an additional 20 miles of margin enhancement through the adaptive management program should this measure prove to be highly effective.

3.7.3.1 Water Operations Adaptive Range

Defined adaptive ranges are included in the BDCP Conservation Strategy for a number of operational criteria established for water operations (see CM1 *Water Facilities and Operations* in Section 3.4 *Conservation Measures*). For example, initial operational criteria (to be implemented once new facilities become operational) are identified in CM1 for Sacramento River bypass flows at the north Delta diversions, along with a defined adaptive range. This adaptive range includes allowance for increasing the bypass flows, through the adaptive management process, should an initial flow criterion prove to be less effective than expected (as defined by the Plan; *e.g.*, objectives established to protect covered fish species). Similarly, a lower limit to the defined adaptive range includes an allowance for narrowing the bypass criteria (allowing increased diversions) should flows or other conservation measures prove more effective in meeting objectives than expected, as defined by a standard or measure set out in the biological objectives and monitoring program.

3.7.3.2 Decision Process for Adjusting Water Operations within the Adaptive Range

SWP and CVP water operations are under the authority and are the responsibility of DWR and Reclamation, not the Implementation Office. Accordingly, DWR and Reclamation will implement the BDCP water operations conservation measures, under CM1 *Water Facilities and Operations*. Adjustments of the water operations criteria within the adaptive range for water operations, established at the time of BDCP authorization and described in CM1 *Water Facilities and Operations,* may only be conducted through the following process.

1. **Proposal to change operating criteria within the adaptive range provided to Program Manager -** Proposals to change the criteria for water operations are likely to come primarily from the IO staff, but may come from an outside body. However, proposed changes may also be requested by member of the Stakeholder Committee. All proposals related to changes in the water operations criteria will be submitted to the Program Manager. A proposal to change the real time operational range within the adaptive range will be identified in the draft Annual Water Operations Strategy and the draft Annual Workplan and Budget. Out-of-cycle proposals for changes may be requested, if necessary, to address biological objectives in situations that are time sensitive.

2. **Review of proposed change** - The Program Manager, through the Science Manager, will solicit independent science input on the proposed change from the Delta Science Program, Independent Science Board, and other appropriate independent scientists with expertise in the resources and operational change proposed.

3. **Submittal of proposal for change by Program Manager to the "Decision Body" –** The Program Manager will submit the proposed change to the "Decision Body" for review as part of the draft Annual Workplan and Budget. Out-of-cycle proposals for changes may be submitted, if necessary to address biological objectives in situations that are time sensitive. [***Note to Reviewers****: The placeholder "Decision Body" is used here until the appropriate entity(ies) is/are identified to serve in the role*.]

4. **Review of proposal for change by "Decision Body" -** The program manager will facilitate a review by the "Decision Body." The "Decision Body" will review the proposed operational change and determine if it is acceptable.

5. **Resolutions of disputes among directors –** If the "Decision Body" cannot reach consensus, then the decision on the proposed change will be elevated to the "Higher Level Decision Body" for joint resolution.

6. **Establish the changed criteria** - Once changes are agreed to by the "Decision Body" or through the dispute resolution process, they will be incorporated into the Annual Water Operations Strategy by DWR and Reclamation and implemented under the accepted timetable. These changed criteria will become the new operational criteria for the conservation measure within which the Real Time Operations Response Team may make real time operational decisions.

The process described above applies only to changes in operational criteria that are within the bounds of the operational adaptive range established at the time of BDCP authorization and described in CM1 *Water Facilities and Operations*. .

3.7.4 Concept of Adaptive Management Triggers

The Program Manager, with Implementation Board concurrence, may elect to develop adaptive management triggers for specific parameters and metrics during Plan implementation as a tool to support the adaptive management program, should the development of such triggers prove valuable to the program. Adaptive management triggers are quantified thresholds established for objectives or conservation measures that, if exceeded, would identify the need for an analysis of cause and effect and development of alternative actions to improve effectiveness of the conservation measure. Adaptive management triggers related to effectiveness identify specific conditions in which targets are not likely to be achieved and therefore adaptive changes should be considered and undertaken.

3.7.5 Adaptive Management Experiments

Because the biological outcome of many management actions is uncertain, the adaptive management program is based on scientific principles that guide continual refinement of conservation efforts in order to achieve the biological goals of the plan. The adaptive management program will develop alternative management strategies and test the effectiveness of these strategies. To that end, there is a continuum of management actions that incorporate scientific principles of adaptive management to varying degrees. The simplest studies involve monitoring effects once a conservation action has been taken, without replication, controls, or comparison of management treatments. At the other end of the spectrum is targeted research that tests a hypothesis in a manner that can be validated through statistical inference.

3.7.5.1 Targeted Research

There are a number of key uncertainties surrounding covered species, ecological processes, and biotic/abiotic interactions, and regarding the effectiveness of the conservation measures (see discussions of hypothesized benefits for individual conservation measures in Section 3.4, *Conservation Measures).* Some of these key uncertainties are expected to be resolved using adaptive management targeted research and others may be resolved by studies outside BDCP.

The Implementation Office may undertake or fund targeted research through the BDCP research program to provide information necessary to adaptively implement the BDCP (see Section 3.6, *Monitoring and Research Program*). This research should answer specific management-related questions that arise based on results of monitoring and to address data gaps to provide information necessary to successfully implement the conservation measures.

Results of research will inform management decisions to and increase the effectiveness of conservation measures. It is expected that most or all targeted research will be conducted by or in partnership with outside scientists from academic institutions, consulting firms, and non-profit organizations. It is anticipated that funding provided by the Implementation Office for targeted research could be matched or supplemented by other entities to increase the level of research and to achieve results that integrate with broader issues in the research community. The amount of targeted research will be limited by funding available to the Implementation Office.

In addition to targeted research undertaken by the Implementation Office, it is also expected that scientists within the Implementation Office will develop partnerships with academic institutions to encourage academic research that could inform and improve management and monitoring techniques.

3.7.5.2 Management-Oriented Conceptual Models

Conceptual models describe our current understanding of a functioning ecosystem. They provide a framework for learning about a system and help formulate hypotheses about cause-and-effect relationships. Conceptual models are useful for management because they can help to identify which factors may be important in a system, which of these factors may be influenced by management, and hence which attribute (component or condition) of the system should be assessed. Conceptual models can inform the research program in several important ways: by providing a basis from which to test assumptions about the relative importance of certain processes, by helping to identify threats or stressors, by identifying species or other attributes that function as ecosystem indicators, and by serving as a repository of our changing understanding of the system as more data become available. Conceptual models can also be used to communicate understanding of the system to other scientists and the public and to facilitate review. For a multi-species, ecosystem-process-based and habitat-based conservation plan such as the BDCP, models provide a useful framework for understanding how individual species react to the same management actions. Therefore, models must be sufficiently complex as to capture the relationships that drive the system and translate these relationships to covered species, but streamlined enough to be useful as management and monitoring tools. Models are only as good as the information used to develop them. Several types of conceptual models have been used in the development of the BDCP Conservation Strategy, and other models may be developed as more data become available, and as more efficient tools are developed.

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) Conceptual Models developed by the CALFED Ecosystem Restoration Program are a suite of process, habitat, and species models incorporating the current scientific understanding of the Delta. These conceptual models describe the relationship of life history components to known drivers or stressors, and include categorical evaluations of the relative importance, predictability and level of understanding of the linkages between these drivers/stressors and outcomes. The DRERIP Evaluation Process was used to evaluate the relative magnitude and certainty of effects of proposed BDCP conservation measures on aquatic covered species (i.e., fish and aquatic plants), aquatic and estuarine natural communities, and related ecosystem processes using these DRERIP models and other available data (see Section 10.3.5, *DRERIP Evaluation Process* and Appendix F, *BDCP DRERIP Evaluation Results of Draft Conservation Measures.*). The DRERIP process was also used to explicitly identify key data gaps that should be filled through directed research or other exploratory studies. In most cases these models consist of diagrams that show the hypothesized relationships that characterize the ecosystem and are supplemented by written materials. There is also a need to develop full life history model for all of the covered fish species to facilitate plan implementation and guide adaptive management decision making process. Additional models may be developed as needed during the development and refinement of detailed monitoring plans. As new information becomes available, the DRERIP models will be updated to improve confidence in model parameters.

Species-habitat models have been developed for terrestrial Covered Species and natural communities; (see Appendix A, *Covered Species Accounts*). Species-habitat models, which can also be considered conceptual models, are useful tools that make explicit the assumptions about the relationship between species and habitat type. Species-habitat models were developed for the BDCP to hypothesize a relationship between land cover type and other habitat components and the distribution of covered species. These models have served as the basis for identifying current habitat distribution, predicting habitat distribution after restoration-related conservation measures are implemented, estimating impacts of conservation measure implementation, and prioritizing land acquisition. Information from pre-acquisition surveys and the planning surveys for covered activities will further refine these models such that they can be used to more accurately predict distribution, occupancy, and assess population trends.

3.7.6 Database Development and Reporting

Proper data management, analysis, and reporting are critical to the success of the adaptive management program. Data on monitoring methods, results, and analysis must be managed, stored, and made available to Implementation Office staff, decision-makers, scientific advisors, and other appropriate persons. A database and clear reporting procedure is also required for permit compliance. See Section 3.6.8, *Database Development and Maintenance,* for a discussion of the proposed database structure.

3.7.7 Program Status Reviews

Requirements for annual and five year reports and work plans by the Implementation Office that include discussions of implementation results and adaptive management changes are described in Section 6.2, *Compliance and Progress Reporting*.

3.7.8 Public Involvement

Public involvement is an especially important component of successful adaptive management. The responsibility for public outreach by the Implementation Office is described in Section 7.5, *Public Outreach*.

CHAPTER 4. DESCRIPTION OF COVERED ACTIVITIES AND ASSOCIATED FEDERAL ACTIONS

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CHAPTER 4. DESCRIPTION OF COVERED ACTIVITIES AND ASSOCIATED FEDERAL ACTIONS

[***Note to Reviewers****: This is a revised version of BDCP Chapter 4, Covered Activities. The last draft of Chapter 4 was presented to the Steering Committee at the October 7, 2010 meeting. Revisions have been made throughout the text to address comments received, to clarify concepts, and to bring the document up to date with the progress on various components of the BDCP in 2010. The BDCP Steering Committee members have submitted comments to various drafts of this chapter during development, which may or may not have been incorporated into this November 18, 2010 draft. While the text of this chapter is subject to change and revision as the BDCP planning process progresses, the chapter has been drafted and formatted to appear as it may in a completed draft HCP/NCCP. Although the chapter includes declarative statements (e.g., the Implementation Office will…), it is nonetheless a "working draft" that will undergo further modification based on input from the BDCP Steering Committee, state and federal agencies, and the public.]*

4.1 INTRODUCTION

*[**Note to reviewers**: Issues relating to take authorization for the State and federal water contractors are still under discussion.]*

The BDCP is intended to provide the basis for the issuance of regulatory authorizations under the federal Endangered Species Act (ESA) and the California Natural Community Conservation Planning Act (NCCPA) for a broad range of ongoing and anticipated activities that are associated with the operations of the State Water Project (SWP) in the Sacramento-San Joaquin River Delta, as well as for actions related to the operation of certain power plants located in the Plan Area (Figure 4-1). Additionally, the BDCP is intended to provide the basis for a Section 7 consultation. This chapter identifies and describes the activities that are addressed by the BDCP. The chapter further categorizes these activities on the basis of the party chiefly responsible for their implementation, characterizing activities as either "covered activities" for those actions undertaken by non-federal parties or as "associated federal actions" for those actions that are authorized, funded, or carried out by the Bureau of Reclamation (Reclamation). The potential effects of all of these activities on covered species, their habitats, and natural communities have been evaluated as part of an overall assessment of the effects of the BDCP, as described in Chapter 5, *Effects Analysis*. All construction and maintenance activities included as covered activities and actions would comply with the avoidance and minimization measures described in Chapter 3, *Conservation Strategy*, to avoid or reduce adverse effects on covered species and natural communities.

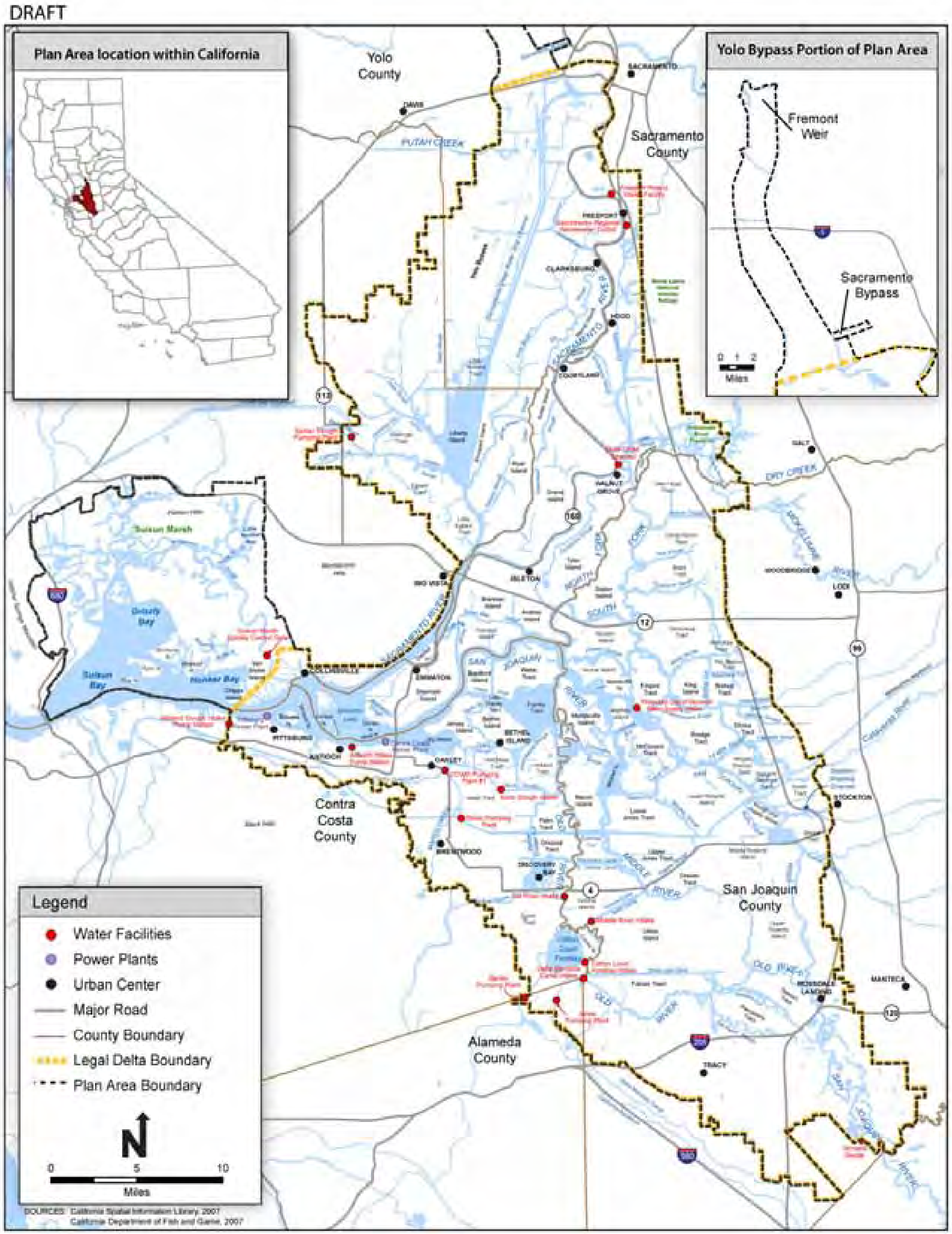

Figure 4-1. BDCP Plan Area Location

As a joint HCP/NCCP, the BDCP has been designed to meet the requirements of both State and federal endangered species laws and provide the basis for non-federal entities to obtain take authorizations from the U.S. Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS) pursuant to Section 10 of the ESA and from the California Department of Fish and Game (DFG) under Section 2835 of the NCCPA, and potentially under Section 2081 of the California Endangered Species Act (CESA).[1]

Specifically, the Department of Water Resources (DWR), certain SWP contractors, and Mirant Delta LLC (Mirant) are seeking regulatory coverage under the ESA and the NCCPA to ensure that their activities within the geographic scope of the Plan, including conveyance, diversions, exports, or use of water from the Delta associated with energy generation, comply with these laws. The BDCP further provides the basis for the biological assessment (BA) to facilitate consultation under Section 7 of the ESA.

*[**Note to Reviewers:** The regulatory mechanism of the ESA that will be used to provide regulatory coverage to the CVP contractors has yet to be determined. Also, it has not yet been determined if coverage will be provided or what mechanism may be used to provide coverage for other diversions in specific areas of the Delta.]*

To meet these regulatory objectives, the BDCP sets out a comprehensive conservation strategy that addresses the effects of SWP, CVP, and Mirant existing and future actions that may occur within the Plan Area on aquatic and terrestrial species, including those listed under the ESA or CESA as threatened, endangered, or candidates for listing, as well as on critical habitat, if any, that has been designated for these species (see Chapter 3, *Conservation Strategy*). The BA for federal actions in the Delta will incorporate the BDCP Conservation Strategy as it relates to those actions and will serve as a companion document to the BDCP. The BDCP does not attempt to distinguish precisely between the effects on covered species and their habitat attributable to the CVP-related federal actions and to covered activities associated with the SWP. Rather, the BDCP includes a comprehensive analysis of the effects related to both the SWP and the CVP within the Plan Area and sets out a conservation strategy that adequately addresses the totality of those effects. On the basis of the BDCP and the companion BA, it is expected that the FWS and NMFS will issue Section 10 permits and a new joint biological opinion that supersede biological opinions existing at that time as they relate to SWP and CVP actions addressed by the BDCP, as well as CVP and SWP operations affected by BDCP that occur upstream of the Delta.

4.1.1 History and Overview of the SWP and CVP

This section provides an overview and a summary of the history of the SWP and the CVP. Additional detail may be found at: http://www.water.ca.gov/swp/.

[1] The BDCP has also been developed to meet the permit issuance standards of CESA for the activities described in this chapter.

4.1.1.1 SWP

The SWP is currently operated to provide water for agricultural, municipal, industrial, recreational, and environmental purposes, and to control flooding. As conditions of the water right permits and licenses, the State Water Board requires that the SWP meet specific water quality, quantity, and operational criteria within the Delta. The development of the SWP was necessitated by the tremendous population growth that occurred in California after the Second World War. The State recognized at the time that local water supplies alone would not be sufficient to meet future regional demands, prompting the legislature in 1945 to commission an investigation of statewide water needs. That investigation resulted in recommendations for substantial new water infrastructure, including the development of various aqueducts and channels, a multipurpose dam and reservoir near Oroville on the Feather River, and an aqueduct to carry water from the Delta to the San Joaquin Valley and Southern California (http://www.water.ca.gov/swp/history.cfm).

In 1960, California voters authorized the first phase of the SWP, which enabled water deliveries from watersheds of Northern California to the cities of Southern California and to farmers in the Tulare Basin that were beyond the reach of the CVP. After the SWP was passed by voters in 1960, the California Aqueduct, the main conveyance for the SWP, Clifton Court Forebay (CCF), and Harvey O. Banks Pumping Plant west of Tracy were constructed (Figures 4-1 and 4-2 depict both CVP and SWP facilities).

Today, the SWP consists of 34 storage facilities (reservoirs and lakes), 20 pumping plants, four pumping-generating plants, five hydroelectric power plants, and about 701 miles of open canals and pipelines. It provides water which supplements local sources for approximately 20 million Californians and about 660,000 acres of irrigated farmland (http://www.water.ca.gov/swp/).

The SWP distributes water to 29 urban and agricultural water suppliers in Northern California, the San Francisco Bay Area, the San Joaquin Valley, the Central Coast, and Southern California. These suppliers, known as the State Water Project contractors, receive specified annual amounts of water as provided by contracts with DWR.[2] These contracts are subject to renewal during the period 2035 through 2042. Of the total water supply under contract, 70 percent is allocated to urban users and 30 percent to agricultural users. (http://www.water.ca.gov/swp/)

[2] Under existing contract conditions, DWR is currently (2010) obligated to make 4.167 MAF/year of water available to its contractors, except under certain conditions specified in the contract, including shortage of supply availability, under which a lesser amount may be made available.

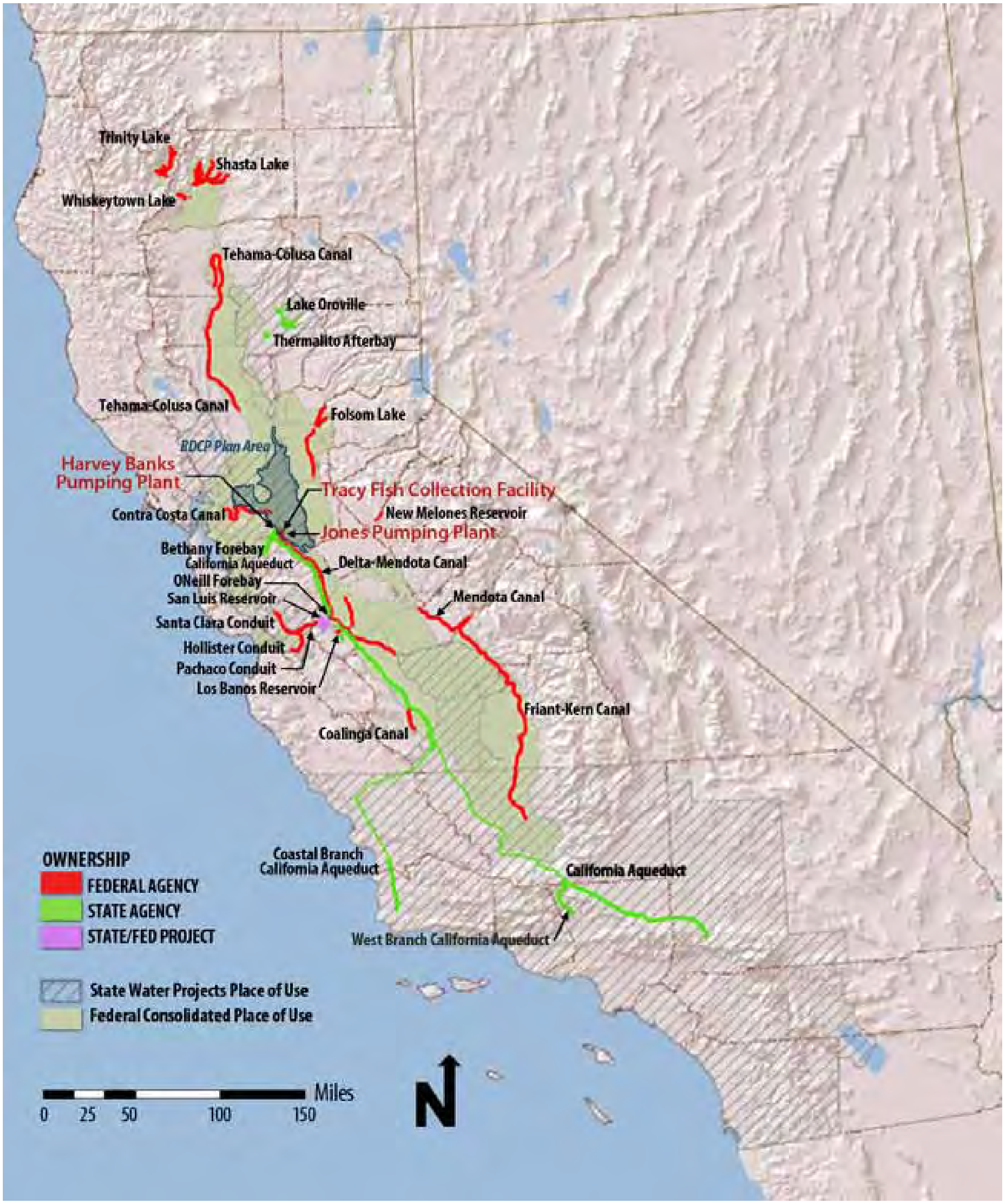

Figure 4-2. CVP and SWP Facilities

4.1.1.2 CVP

Beginning in the late 1800s, the State of California recognized the potential to deliver surplus water from the Sacramento River to the dry, but potentially productive, San Joaquin Valley (Alexander et al. 1874). The State further recognized, as reflected in the 1930 State Water Plan (Department of Public Works 1930), that the development of upstream storage capacity along the Sacramento River could simultaneously resolve two major water problems facing the State: water shortages in the San Joaquin Valley, where pumping in excess of natural groundwater recharge was occurring; and salinity intrusion into the Delta, which could be addressed with a hydraulic salinity barrier created through controlled releases of water from upstream storage (Lund et al. 2007). This water plan served as a blueprint for the eventual CVP.

In 1933, the State legislature and the voters of California approved the CVP. Shortly thereafter, California ceded control of the project to the federal government to maximize federal financial contributions during the Great Depression. Construction of Shasta Dam, one of the primary components of the CVP, began in 1938. In the 1940s, federal agencies agreed on an approach to divert water from the Sacramento River, which relied on a small cross-channel to move water through the Delta. This channel, which was constructed by Reclamation in 1944, is known as the Delta Cross Channel.

Following the construction of the Friant Dam (1942) and the Friant-Kern Canal (1948), the CVP began diverting San Joaquin River water to supply irrigators on the east side of the San Joaquin Valley. Subsequent projects on the west side of the Sacramento Valley, notably the Tehama-Colusa Canal (1980), increased capacity for upstream diversions from the Sacramento River. The CVP's major water storage facilities are located at the Shasta, Trinity, Folsom, and New Melones dams (USBR 2008) (Figure 4-2). The primary water pumping facility for the CVP is the Jones Pumping Plant, which is located west of the City of Tracy.

The CVP presently consists of 20 dams and reservoirs, 11 powerplants, and 500 miles of major canals, as well as conduits, tunnels, and related facilities. These facilities provide sufficient quantities of water to irrigate approximately one-third of the agricultural land of California and to provide for municipal and industrial use to support close to 1 million households for one year (http://www.usbr.gov/projects/Project.jsp?proj_Name=Central%20Valley%20Project). Over 250 contractors in 29 out of 58 counties in California have entered into long-term contracts for CVP water (http://www.water.ca.gov/swp/cvp.cfm).

The Central Valley Project Improvement Act (CVPIA) of 1992 mandated that the CVP be partly managed for the protection, restoration, and enhancement of fish and wildlife. The CVPIA provided for annual allocations of water to support fish and wildlife resources, a habitat restoration fund financed by water and power users, and a moratorium on new water contracts until such time as fish and wildlife goals are achieved (http://www.usbr.gov/mp/cvpia/index.html).

4.1.2 Overview of Covered Activities and Associated Federal Actions

4.1.2.1 SWP and CVP

The SWP and CVP function as two inter-basin water storage and delivery systems that divert and re-divert water from the southern portion of the Delta. The SWP and CVP utilize major reservoirs upstream of the Delta to store water, and use natural watercourses and canal systems to transport water to areas south and west of the Delta. The CVP also includes facilities and operations on the Stanislaus and San Joaquin rivers, such as the New Melones and Friant dams.

The Projects are permitted by the State Water Board to store water during wet periods, divert water that is surplus to the Delta, and re-divert Project water that has been stored in upstream reservoirs. Both Projects operate pursuant to water right permits and licenses issued by the State Water Board that allow for the appropriation of water by diverting to storage or by directly diverting to use and re-diverting releases from storage later in the year. As conditions of their water right permits and licenses, the State Water Board requires that the CVP and SWP meet specific water quality, quantity, and operational criteria within the Delta.[3] Reclamation and DWR closely coordinate their management of the operations of the CVP and SWP to meet these conditions.

The BDCP covered activities consist of activities in the Plan Area associated with the conveyance and export of water supplies from the SWP's Delta facilities and with the implementation of the BDCP Conservation Strategy. Each of these activities falls into one of four categories: 1) operation of existing and new Delta facilities used to transport and deliver water for Project purposes; 2) construction of new facilities; 3) facility maintenance, monitoring and other associated ongoing activities; and 4) implementation of certain BDCP conservation measures and the biological monitoring and adaptive management programs.

The BDCP associated federal actions comprise those activities that are authorized, funded, or carried out by Reclamation within the Plan Area and relate to the operation of the CVP's Delta facilities to meet CVP purposes. These actions include: 1) operation of existing CVP Delta facilities to convey and export water for project purposes; and 2) associated maintenance and monitoring activities. The CVP is operated in coordination with the SWP under the Coordinated Operations Agreement (COA). While the CVP and SWP are separate systems, they function in an integrated and coordinated manner. Reclamation, and/or the CVP contractors may seek to wheel CVP water through a new conveyance facility.

Under the BDCP, the type of water conveyance infrastructure in use serves to demarcate the near-term and long-term components of the Plan. Specifically, the near-term component of the BDCP encompasses those actions related to the operations of the projects under existing water conveyance infrastructure, including conservation measures associated with this operational

[3] DWR has a separate contract to provide water to NDWA and that contract has separate water quality standards.

framework. The long-term component of the BDCP comprises those actions related to project operations under new isolated conveyance infrastructure, including the construction of and operation of the infrastructure and the implementation of an array of conservation measures.[4] The actions that will be implemented during the near-term and long-term periods will involve both covered activities and associated federal actions.

Other actions associated with the CVP and SWP are not within the scope of the BDCP. These actions occur upstream of the Delta, outside of the Plan Area, and include the operations of certain reservoirs and the diversion and delivery of certain water supplies. Although these other activities are not addressed by the BDCP, the effect of the BDCP on those activities and the effects of those activities on listed species will be analyzed and addressed in the joint biological opinion to be issued pursuant to the BDCP or in subsequent biological opinions that cover project-related activities that are outside of the Plan Area.

4.1.2.2 Mirant Delta, LLC Power Plants

The operation of Mirant's power plants, which are located in the cities of Pittsburg and Antioch (referred to as the "Pittsburg Power Plant" and the "Contra Costa Power Plant" and collectively as the "Delta Plants"), requires the diversion of water from the Delta. Mirant's generating units burn natural gas and are cooled with Delta water. As described below, Mirant's current operational parameters are set by (1) its Clean Water Act (CWA) National Pollution Discharge Elimination System (NPDES) permits, which include requirements pursuant to Section 316(b); (2) incidental take permits issued by the National Marine Fisheries Service and U.S. Fish and Wildlife Service pursuant to the Endangered Species Act; and (3) a Memorandum of Understanding with the California Department of Fish and Game authorizing incidental take of species listed under the California Endangered Species Act.

The BDCP covers those Mirant activities associated with the generation of power at its Pittsburg and Contra Costa power plants. These activities involve either (1) current power generation activities and water intake and discharge flows associated with those activities; or (2) recurrent maintenance activities required to ensure continued proper operation of those existing facilities.

4.2 COVERED ACTIVITIES

The activities described in this section are considered to be "covered activities" under the BDCP. Covered activities are those actions that are carried out by non-federal entities, such as DWR and Mirant, and are expected to be covered by regulatory authorizations under Section 10 of the ESA and Section 2835 of the NCCPA. Covered activities are distinguished from "associated federal actions," which are those BDCP-related actions that are carried out, funded, or authorized by Reclamation and will be authorized under Section 7 of the ESA.

[4] The activities related to the development of a tunnel/pipeline facility are included in the long-term component of the BDCP. As such, the period associated with the long-term component of the BDCP will likely overlap with the near-term period as development of a tunnel/pipeline facility will occur during the implementation of the near-term operational regime.

4.2.1 Operations and Maintenance of Existing SWP Facilities

This section describes covered activities carried out by DWR to operate and maintain the existing SWP facilities in the Delta. These activities involve the daily operation of water diversion, conveyance, and delivery systems, and appurtenant facilities within the Plan Area. The near-term and long-term criteria and adaptive ranges set out in Chapter 3, *Conservation Strategy,* establish parameters under which certain operations-related actions identified in this chapter will be carried out.

The SWP's facilities within the Plan Area consist of the Clifton Court Forebay; Banks Pumping Plant; Skinner Delta Fish Protective Facility; the installation, operation and removal of the temporary barriers in the south Delta; the northern portion of the California Aqueduct; Barker Slough Pumping Plant; and the eastern portions of the North Bay Aqueduct (Figures 4-1 and 4-2). These SWP facilities are used to export water from the south Delta (Banks Pumping Plant) and from the north Delta (Barker Slough Pumping Plant) into canals and pipelines that carry it to municipal and industrial (M&I) and agricultural water contractors in the San Francisco Bay Area and Southern California. These facilities are integral components of the SWP and contribute to the functional capacity of the overall system. This section describes these facilities, their operational requirements, and the actions necessary to maintain their viability. The manner in which these facilities are operated and maintained is not only integral to the proper functioning of the water supply system, but intertwined with the actions in the BDCP Conservation Strategy to provide for the conservation of the aquatic ecosystem and covered fish species.

The existing SWP facilities described in this section will continue to operate under both the near-term and long-term components of the BDCP, but will be subject to different operating criteria following completion of new water conveyance facilities. The BDCP near-term and long-term operational criteria and adaptive operational ranges are described in Chapter 3, *Conservation Strategy*, and include descriptions of operations of SWP facilities in the Plan Area.

The following descriptions of SWP-related covered activities are intended to be sufficiently broad to cover all aspects of the development, operation, and maintenance of identified SWP facilities that may potentially affect resources covered by this Plan, including covered species and their habitats. The measures to address the effects of these covered activities on covered resources are set out in the BDCP Conservation Strategy (see Chapter 3, *Conservation Strategy*).

4.2.1.1 Clifton Court Forebay

4.2.1.1.1 Background

Water for the SWP is diverted into Clifton Court Forebay (CCF) and pumped at Banks Pumping Plant (Banks). Clifton Court Forebay is a 31,000-acre-foot regulatory reservoir located in the southwestern edge of the Delta, about 10 miles northwest of the City of Tracy. Inflows to the Forebay from surrounding channels are controlled by radial gates, which are generally operated based on the tidal cycle to reduce approach velocities, prevent scour in adjacent channels, and minimize water level fluctuation in the south Delta by taking water in through the gates at times other than low tide. When a large head differential (difference in water surface elevation) exists between the outside and the inside of the gates, theoretical inflow can be as high as 15,000 cfs for a short time.

4.2.1.1.2 Activity

See Chapter 3, *Conservation Strategy*, for description of BDCP near- and long-term operations criteria and adaptive range for south Delta operations of the SWP and CVP to provide for protection of covered fish species in conjunction with water conveyance and diversion. DWR is seeking ESA Section 10 and NCCPA Section 2835 permits for all existing and future operations and maintenance of Clifton Court Forebay.

4.2.1.2 Harvey O. Banks Pumping Plant

4.2.1.2.1 Background

The Banks Pumping Plant is in the south Delta, about 8 miles northwest of Tracy and marks the beginning of the California Aqueduct. By means of 11 pumps, including two rated at 375-cfs capacity, five at 1,130-cfs capacity, and four at 1,067-cfs capacity, the Banks Pumping Plant provides the initial lift of water 244 feet into the aqueduct. The nominal capacity of the Banks Pumping Plant is 10,300 cfs. The pumps can be operated at full capacity to enable diversions to utilize power in off-peak periods.

4.2.1.2.2 Activity

Chapter 3, *Conservation Strategy*, includes a description of the near-term and long-term operations criteria and adaptive ranges for south Delta operations of the SWP and CVP. These measures have been designed to address the effect on covered fish species of water conveyance and diversion actions associated with the Banks Pumping Plant. As such, the BDCP provides the basis for federal and State regulatory authorizations under the ESA and NCCPA for coverage of all existing and future operations and maintenance activities of the Banks Pumping Plant. Refer to the background discussion above with respect to existing operations, to Chapter 3, *Conservation Strategy* for the near-term and long-term operations criteria and adaptive ranges for south Delta operations of the SWP and CVP, and refer to Section 4.2.1.7 below for a description of the types of maintenance activities that may occur. DWR is seeking ESA Section 10 and NCCPA Section 2835 permits for all existing and future operations and maintenance of Banks Pumping Plant.

4.2.1.3 John E. Skinner Delta Fish Protective Facility

4.2.1.3.1 Background

The John E. Skinner Delta Fish Protective Facility is located at the head of the Intake Channel that connects Clifton Court Forebay to the Banks Delta Pumping Plant. The Skinner Fish

Facility screens fish away from the pumps. Debris is directed away from the pumps by a 388-foot-long trash boom. Fish are diverted from the intake channel into bypasses by a series of metal louvers, while the main flow of water continues through the louvers and toward the pumps. These fish pass through a secondary system of screens and pipes into seven holding tanks, where they are later counted and recorded. The salvaged fish are then returned to the Delta in oxygenated tank trucks.

4.2.1.3.2 Activity

Chapter 5, *Effects Analysis*, describes the level of take associated with the operations of the Skinner Fish Facility. DWR is seeking ESA Section 10 and NCCPA Section 2835 permits for all existing and future operations and maintenance of the Skinner Fish Facility not otherwise restricted by the BDCP Conservation Strategy. Refer to the background description above with respect to operations of this facility, and to Section 4.2.1.7 for a description of the types of maintenance activities that may occur.

4.2.1.4 Barker Slough Pumping Plant and North Bay Aqueduct

4.2.1.4.1 Background

The Barker Slough Pumping Plant diverts water from Barker Slough into the North Bay Aqueduct (NBA) for delivery in Napa and Solano counties. The NBA intake is located approximately 10 miles from the mainstem Sacramento River at the end of Barker Slough. The maximum pumping capacity is 175 cfs (pipeline capacity). During the last few years, daily pumping rates have ranged between 0 and 140 cfs. Each of the 10 NBA pump bays is individually fitted with a positive barrier fish screen consisting of a series of flat, stainless steel, wedge-wire panels with a slot width of 3/32 inch. This configuration is designed to exclude fish 25 millimeters (mm) or larger from being entrained. The bays tied to the two smaller units have an approach velocity of about 0.2 ft/sec. The larger units were designed for a 0.5-ft/sec approach velocity, but actual approach velocity is about 0.44 ft/sec. The screens are routinely cleaned to prevent excessive head loss, thereby minimizing increased localized approach velocities.

4.2.1.4.2 Activity

DWR is seeking ESA Section 10 and NCCPA Section 2835 permits for all existing and future operations and maintenance of the Barker Slough Pumping Plant not otherwise restricted by the BDCP operating criteria. Combined operations of a new intake on the Sacramento River (described below in Section 4.2.2.3) and the existing intake at Barker Slough would be included under BDCP covered activities for future peak demand of up to 240 cfs.

4.2.1.5 State Water Project Diversions

4.2.1.5.1 Background

The amount of water delivered by the SWP in any year has been and will continue to be variable, but in any year, will be equal to the amount of water that is hydrologically available and that can be diverted under current contractual rights consistent with the terms and conditions of the BDCP and existing permits and regulations. SWP "project water" is water made available for delivery to the contractors by the project conservation and transportation facilities included in the system. Under existing contract conditions, DWR is currently (2010) obligated to make 4.167 MAF/year of water available to its contractors, except under certain conditions specified in the contract, including shortage of supply availability, under which a lesser amount may be made available. The obligation incrementally increases to a maximum amount of 4.173 MAF/year in 2021. This quantity may be exceeded if DWR determines surplus water is available above and beyond that needed to satisfy all regulations, permits, and operational requirements.

The California Water Code requires the State to allow the use of SWP facilities to convey non-Project water as long as the conveyance will not interfere with SWP operations. During drier years, conveyance capacity is available in SWP facilities for the transfer of water by other entities. Non-Project water for Drought Water Banks, Dry Water Purchase Programs, and individual transfers has been conveyed through SWP facilities in the past and is expected to continue into the future. SWP facilities are also used to support groundwater banking programs, such as the Semitropic Water Banking and Exchange Program.

4.2.1.5.2 Activity

Chapter 3, *Conservation Strategy*, includes a description of the near-term and long-term operations criteria and adaptive ranges for the SWP and CVP under the BDCP. These measures have been designed to address the effect on covered fish species of water conveyance and diversion actions associated with the SWP and CVP. As such, the BDCP provides the basis for federal and State regulatory authorizations under the ESA and NCCPA for coverage of all existing and future diversion activities of the SWP in the Plan Area.

4.2.1.6 Temporary Barriers in the South Delta

4.2.1.6.1 Background

The South Delta Temporary Barriers Project consists of four barriers across south Delta channels for the purpose of benefitting southern Delta agricultural diverters by increasing water levels, improving circulation, and improving water quality, and for the purpose of benefiting San Joaquin River fall-run Chinook salmon by keeping them away from the export facilities. The existing South Delta Temporary Barriers Project consists of the annual installation and removal of temporary barriers at the following locations:

- Middle River near Victoria Canal, about 0.5 mile south of the confluence of Middle River, Trapper Slough, and North Canal;
- Old River near Tracy, about 0.5 mile east of the Delta-Mendota Canal intake;
- Grant Line Canal near Tracy Boulevard Bridge, about 400 feet east of the Tracy Boulevard Bridge; and
- At the Head of Old River (in Old River near its divergence from the San Joaquin River).

The barriers on Middle River, Old River near Tracy, and Grant Line Canal are tidal control facilities composed of rock and gated culverts designed to improve water levels and circulation for agricultural diversions and are in place during the growing season.

A rock barrier may be installed during the fall at the Head of Old River to improve flow quality for salmon migration in the San Joaquin River. In the past, the barrier has been installed at the direction of the Department of Fish and Game.[5] The objective of the barrier is to improve dissolved oxygen levels by reducing the amount of flow diverted into Old River and, therefore, keeping more flow moving downstream in the San Joaquin River. A non-physical or physical (rock) barrier may also be installed at the Head of Old River in the spring. This barrier would be designed to discourage salmonids migrating downstream in the San Joaquin River from entering Old River and being exposed to the effects of the export pumps. Since 2009, a non-physical barrier utilizing sound, light, and a “bubble curtain” has been tested at this location in the spring to determine its effectiveness at discouraging fish passage. Depending upon the observed effectiveness of this barrier under various operational conditions, its installation may continue as part of Conservation Measure number 7 (*CM16 Non-physical Fish Barriers* [see Chapter 3, *Conservation Strategy*]). If the monitoring program indicates that the non-physical barrier is not effective at addressing passage concerns relating to the out-migrating salmonids under certain operational conditions, a rock barrier may be tested as an alternative means of minimizing fish passage into Old River. [6]

4.2.1.6.2 Activity

These barriers will likely continue to be utilized in the near-term in conjunction with the BDCP near-term conservation measures. The four barriers are generally installed beginning in early April. The barrier at the Head of Old River is operated mid-April through mid-May and,

[5] The Department of Fish and Game has been responsible for directing DWR to install the fall barrier. Both DWR and DFG monitor the dissolved oxygen levels in the Stockton Deep Water Ship Channel. If dissolved oxygen is at a level that inhibits or prevents salmon from migrating up the San Joaquin River, then DFG directs DWR to install the barrier. This is a covered activity under BDCP and, therefore, can continue on into the future.

[6] The 2008 National Marine Fisheries Service Biological Opinion for the Temporary Barriers Project required that a three-year fisheries monitoring program using biotelemetry techniques be established to examine the movements and survival of juvenile salmon and juvenile steelhead through the channels of the south Delta. The biological opinion also required that predation effects associated with the project be examined. A pilot-scale biotelemetry study was conducted March-July 2009 to develop an understanding of the movement and survival of salmonids through the south Delta with specific focus at the three agricultural barrier locations. The pilot study was designed to identify movement patterns of predatory fish within the south Delta. Information gained from the pilot study was used to develop the 2010 and 2011 experimental design for the full-scale, mark-recapture, salmonid survival study. To meet these objectives, Hydroacoustic Technology Incorporated (HTI) acoustic tags and receivers were used as steelhead, salmon, largemouth bass, striped bass, and white catfish were tagged, released, and tracked in south Delta channels.

possibly, into June. The barriers in Middle River, Old River at Tracy and Grant Line Canal are partially operated through the end of May while delta smelt are in south Delta channels. During June, once the risk to delta smelt has passed, those barriers are allowed to begin full operations and continue full operations through the remaining summer and fall. Removal of the barriers begins in early November. All barriers are completely removed by November 30. Long-term use of the barriers will be evaluated under the BDCP adaptive management program.

4.2.1.7 Maintenance and Monitoring Activities

4.2.1.7.1 Background

Maintenance activities are covered activities under the BDCP. Maintenance activities include actions necessary to maintain the capacity and operational features of the existing water diversion and conveyance facilities, as described in this chapter, including Banks Pumping Plant, Clifton Court Forebay, the Temporary Barriers Project, Barker Slough Pumping Plant, North Bay Aqueduct, and Skinner Fish Facility. Maintenance activities also include canal maintenance; placement of riprap for bankline protection and erosion control; vegetation management and weed control; and operation and maintenance of electrical power supply facilities. Maintenance activities also include repair and replacement as needed to ensure continued operations of facility or system components.

Monitoring activities for the operation of the SWP are included under BDCP covered activities. This includes water quality and other SWP monitoring activities. For BDCP fish and other biological monitoring activities, see Section 4.2.7, *Monitoring and Research Program* below. DWR's Division of Operations and Maintenance conducts monitoring of chemical, physical and biological parameters to evaluate conditions of concern for drinking water, recreation, and fish and wildlife. Fish monitoring may also be conducted by DWR for the Temporary Barriers Project.

4.2.1.7.2 Activity

All SWP maintenance and monitoring described in this section that could affect species or modify critical habitat protected under ESA or CESA are covered activities, and the effects of those activities are addressed by the BDCP (see Chapter 3, *Conservation Strategy* and Chapter 5, *Effects Analysis*).

4.2.2 New Water Facilities Construction, Operations and Maintenance

*[**Note to reviewers**: The tunnel/pipeline conveyance facility is described here as the new BDCP conveyance approach to allow for dual operations of the new north and existing south Delta diversions, however, it has not been decided if the conveyance facility would be a tunnel/pipeline or, alternatively, a canal facility.]*

4.2.2.1 Tunnel/Pipeline Facility Construction and Operations

4.2.2.1.1 Background

DWR is planning to construct new diversion and conveyance facilities that will be designed and operated to improve protections for fish by bringing water from the Sacramento River around the Delta to the existing water export pumping plants in the south Delta. This new tunnel/pipeline facility would allow for reductions in diversions from the existing SWP and CVP south Delta facilities and hence reduced entrainment of covered fish species. For a more detailed description of the biological benefits of the tunnel/pipeline see Chapter 3, *Conservation Strategy*. The new facility will include five intake structures located on the Sacramento River between Freeport and Courtland. These intakes will be fitted with state-of-the-art positive barrier fish screens. The conveyance would consist of a tunnel/pipeline system that will convey water diverted from the Sacramento River to a new regulating forebay. The conveyance would follow an alignment generally through the central portion of the Delta to a new forebay located adjacent to and south of the existing Clifton Court Forebay. Water would be conveyed to the existing Banks and Jones pumping plants serving the SWP and CVP, respectively. The tunnel/pipeline system would improve protections for water supplies from flood, earthquake, and sea level rise.

The system design would include:

- Five intake facilities, each with fish screens and pumping plants;
- 7.8 miles of twin 16 ft diameter cut and cover intake pipelines to convey water from intake pumping plants to the intake tunnel or the Intermediate Forebay
- 5 miles of tunnel (29 ft inside diameter) to convey water from intake pipelines to an Intermediate Forebay;
- 750-acre Intermediate Forebay and an intermediate pumping plant with a gravity bypass system;
- 33.5 miles of twin-bore tunnel (33 ft inside diameter each) connecting the Intermediate Forebay to the Byron Tract Forebay;
- 600-acre Byron Tract Forebay; and

Other actions necessary to support the development and operation of a new tunnel/pipeline facility are covered under the BDCP. They include activities to improve local drainage systems affected by the new conveyance infrastructure, upgrade existing utilities and develop new utility infrastructure, establish temporary construction staging sites, install temporary and permanent roads, and dispose of spoils on certain sites. More detail on specific features of the tunnel/pipeline facility is provided in Appendix M, *Facilities Design Information*.

New intake and conveyance facilities specifications are summarized in Table 4-1.

Chapter 3, *Conservation Strategy*, includes a description of the long-term operations criteria and adaptive ranges for SWP and CVP with dual operations, including the new intakes and tunnel/pipeline facilities. These measures have been designed to minimize the potential effects of water conveyance and diversion actions associated with the new intakes and tunnel/pipeline facilities on covered fish species and their habitat.

The proposed intake facilities will require routine or periodic adjustment and tuning to ensure operations are managed consistent with design intentions. Facility maintenance includes activities such as painting, cleaning, repairs, and other routine tasks that ensure the facilities are operated in accordance with design standards after construction and commissioning. Activities will involve performing routine, preventive, predictive, scheduled, and unscheduled maintenance aimed at preventing equipment/facility failure or deterioration.

Continuous general inspections will be important for monitoring and logging performance; recording the history of facility conditions and deterioration, and preventing mechanical and structural failures of project elements. Sediment removal will be carried out through suction dredging, mechanical excavation, and dewatering to remove sediment buildup. If large debris is found to have accumulated around intakes, removal would require underwater diving crews, boom trucks or rubber wheel cranes, and possibly a small barge and crew to rig the leads to the debris. While cleaning frequency will need to be varied for screen operations commensurate with debris load conditions in the river, the continuous traveling brush mechanisms, or other screen cleaning technologies applied, are expected to maintain a relatively clean screen face and adequate open area. Over time, biofouling can occlude the screens and jeopardize function. The key design provision for intake facilities is that all mechanical elements can be removable from the top surface for convenience of inspection, cleaning, and repairs, as needed. The intakes will feature top-side gantry crane systems for removal and insertion of screen panels, louver assemblies, and bulkheads. It is expected that all panels will require annual removal (at a minimum) for pressure washing. Additionally, individual intake bays will require dewatering (one pair at a time) for inspection and assessment of biofoul growth rates. Dewatering is accomplished by closing off portals with pre-fabricated bulkheads. Metalwork in intakes is expected to consist of plastics and austenitic steels (stainless); therefore, corrosion is not expected to be detrimental to the life of the facilities. Maintenance associated with these systems consists of replacing sacrificial (zinc) anodes at multi-year intervals.

Table 4-1. Summary of Tunnel/Pipeline Facility Physical Characteristics

Feature Description	*Approximate Characteristics*
Overall Project	
Conveyance Capacity (cfs)	15,000 cfs
Overall Length (miles)	45 miles
Intake Facilities	
Number of Fish-Screened Intakes	5 intakes
Flow Capacity at Each Intake (cfs)	3,000 cfs
Intake Pumping Plants	
6 Pumps per Intake plus one spare, Capacity per Pump (cfs)	500 cfs
Total Dynamic Head (ft)	30 to 57ft
Total Electric Load (MW)	65 MW
Intake Pipelines	
Intake Pipelines connect each Intake Pumping Plant to the Intake Tunnel or the Intermediate Forebay	
Total Pipeline Length (ft)	41,000 ft
Number of Pipelines	2 each side by side
Pipeline Finished Inside Diameter (ft)	16 ft
Tunnels	
Intake Tunnel connecting Intakes #1and #2 to Intermediate Forebay, maximum flow 6,000 cfs	
Tunnel Length (ft)	27,260 ft
Number of Tunnel Bores; Number of Shafts (total)	1 bores; 2 shafts
Tunnel Finished Inside Diameter (ft)	29 ft
Main Conveyance Tunnel connecting Intermediate Pumping Plant to Byron Tract Forebay, maximum flow 15,000 cfs	
Tunnel Length (ft)	176,000 ft
Number of Tunnel Bores; Number of Shafts (total)	2 bores; 14 shafts
Tunnel Finished Inside Diameter (ft)	33 ft
Intermediate Forebay	
Water Surface Area (acres)	750 acres
Active Storage Volume (AF)	5,250 AF
Intermediate Pumping Plant	
In Reach 2, at southern end of Intermediate Forebay	
Number of Pumps, Capacity per Pump (cfs)	10 at 1,500 (high head) 6 at 1,500 (low head)
Total Dynamic Head (ft)	0 to 90 ft
Total Electric Load (MW)	136 MW
Byron Tract Forebay	
Water Surface Area (acres)	600 acres
Active Storage Volume (AF)	4,200 AF
Power Requirements	
Total Conveyance Electric Load (MW)	210 MW

Intake, Screen, and Tunnel/Pipeline Facilities Maintenance Activities

Impact damage incurred by the intake facilities (such as boat collisions, debris impact, stone and sediment abrasion, etc.) may require repairs.

The only systems associated with the intakes involving power-driven and routinely moving parts are the screen cleaning systems and gantry crane hoist systems. Lubrication of bearings, continuity checks of limit/torque switches, and periodic inspections of equipment per manufacturer recommendations are the primary O&M tasks expected for these systems. Strip brushes for the screen cleaning systems will need replacement every several years.

Maintenance would be needed for the intake pumping plants, sedimentation basins, and solids lagoons. This includes service based on a schedule recommended by the manufacturers, mussel and solids removal, and checking and replacing worn parts. Major equipment repairs and overhauls will be conducted at a centralized maintenance shop. Routine site maintenance would include landscape maintenance, trash collection, and outdoor lighting repair or replacement.

Some of the critical considerations in terms of tunnel/pipeline maintenance will include evaluating whether the tunnel/pipeline needs to be taken out of service for inspection and, if so, how frequently this will be required. Typically, new water conveyance pipelines are inspected at least every 10 years for the first 50 years and more frequently after 50 years of age. Dewatering of the tunnel/pipeline facility for maintenance purposes is expected to be conducted but it is assumed that only one of the tunnel/pipelines at a time would be dewatered, allowing continued north Delta diversions to the Intermediate Forebay. Depending on the monthly demands diversion needs could be met or may be temporarily reduced. The entire dewatering and non-routine maintenance process would likely be complete in a month and can be timed for low diversion periods. Dewatering for maintenance would be conducted approximately once every 5, 10 or 20 years. This type of non-regular maintenance would require an additional set of pumps, temporarily located at either the Byron Tract Forebay or at one of the shafts along the tunnel/pipeline route. While these pumps will have some noise associated with them, their operation would be less than a month and would occur at 5, 10 or 20 year intervals. Use of remotely operated vehicles for inspection of the tunnel/pipeline would be inside the tunnel/pipeline with a crane at the shaft site to launch and retrieve the vehicle and possibly a portable generator to supply power. All work would be within the right-of-way at the shaft.

Forebay maintenance considerations would include regular harvesting of pond weed to maintain flow and forebay capacity, the installation of automatic trash raking equipment and disposal facilities, and potential sediment dredging approximately every 50 years. Maintenance requirements for the forebay embankments would include control of vegetation and rodents, embankment repairs in the event of island flooding and wind wave action, and monitoring of seepage flows. Maintenance requirements for the spillway would include the removal and disposal of any debris blocking the outlet culverts. Debris in the stilling basin would also have to be removed to ensure normal water flow through outlet culverts.

Additional activities may include maintenance of: powerlines (insulator washing and routine tower/pole maintenance and replacement) and interconnection substations; permanent roads and fencing; pipelines that could require excavation; back-up power supplies (e.g., testing); general buildings and facilities; and any permanent marine facilities such as barge uploading facilities that provide access to tunnel/pipeline shaft locations (may require localized dredging and other maintenance work, such as painting, decking replacement/repair, and removing barnacles).

4.2.2.1.2 Activity

All construction, operations and maintenance of the new intakes, screens, pumps, and conveyance facilities described in this section are covered activities and the effects of those activities are addressed by the BDCP (see Chapter 3, *Conservation Strategy* and Chapter 5, *Effects Analysis*). DWR is seeking ESA Section 10 and NCCPA Section 2835 permits for all maintenance of these new facilities not otherwise restricted by the BDCP Conservation Strategy.

4.2.2.2 Fremont Weir and Yolo Bypass Improvements and Maintenance

4.2.2.2.1 Background

The purpose of this activity is to modify the Fremont Weir and Yolo Bypass and operate the Fremont Weir to increase the availability of floodplain habitat for spawning and rearing for covered fish species, enhance food production within and downstream of the Yolo Bypass, and improve fish passage within and nearby the Yolo Bypass (see *CM2 Yolo Bypass Fish Habitat Improvements* in Chapter 3, *Conservation Strategy*). Specifically, the Fremont Weir and Yolo Bypass modifications and operations (1) improve rearing and spawning habitat for covered fish species; (2) provide for a higher frequency and duration of inundation of the targeted portion of the Yolo Bypass; and (3) improve fish passage in the Yolo Bypass, Putah Creek, and past the Fremont and Sacramento weirs.

Ten physical modifications to the Fremont Weir, Yolo Bypass and the Sacramento Weir and their resulting effects are proposed as covered activities and are listed below (additional details may be found in Chapter 3). While not all of these actions would occur, some combination of the actions would be implemented and, therefore, are all proposed as covered activities.

1. Replace the Fremont Weir fish ladder. The covered activities include removing and replacing the existing Fremont Weir Denil fish ladder with new experimental fish passage facilities designed to allow for the effective passage of all covered fish species including adult sturgeon and salmonids.
2. Install experimental sturgeon ramps. The covered activities include constructing experimental ramps at the Fremont Weir to allow for the effective passage of adult sturgeon and lamprey.
3. Construct a deep fish passage gates and channel. The covered activities include removing a section of the Fremont Weir, soil excavation, fitting the remaining notch with operable “fish passage gates” that allow controlled flow into the Yolo Bypass, and excavation of a deeper “fish passage channel” to convey water from the Sacramento River to the new fish passage gates, and from the fish passage gates to the Tule Canal to convey water from the Sacramento River, through the gates, and to the Tule Canal.

4. Modify the existing Fremont Weir stilling basin. The covered activities include modifications to the existing Fremont Weir stilling basin to ensure that the basin drains sufficiently into the deep fish passage channel.

5. Make improvements to the Sacramento Weir. The covered activities include excavation of a channel to convey water from the Sacramento River to the Sacramento Weir and from the Sacramento Weir to the Tule Canal/Toe Drain, construction of new gates at a portion of the weir, and minor modifications to the stilling basin of the weir to ensure proper basin drainage.

6. Make improvements to the Tule Canal/Toe Drain and Lisbon Weir. The covered activities include physical modifications to passage impediments in the Tule Canal and Toe Drain (e.g., road crossings and agricultural impoundments) and redesigning Lisbon Weir to improve fish passage while maintaining or improving water capture efficiency for irrigation.

7. Realign Lower Putah Creek. The covered activities include realigning Lower Putah Creek to improve upstream and downstream passage of Chinook salmon and steelhead in Putah Creek, and restoring floodplain habitat to provide benefits of seasonal floodplain habitat.

8. Create a notch in the Fremont Weir and a connecting channel. These covered activities include the addition of new operable gates on the weir that allow for the control of the timing, duration, magnitude and frequency of inundation of the Yolo Bypass during non-flood stage periods of the Sacramento River.

9. Modify the Yolo Bypass. The covered activities include grading, removal of existing berms, levees, and water control structures, construction of berms or levees, re-working of agricultural delivery channels, and earthwork or construction of structures to reduce Tule Canal/Toe Drain channel capacities.

10. Create a gated westside channel. The covered activities include the creation of a gated channel to provide flows into Yolo Bypass along the west side, and potential modification of the existing configuration of the discontinuous channels along the western edge of the Yolo Bypass to reduce diversion of Delta water for Yolo Bypass irrigation while maintaining or improving fish passage for all covered fish species.

Maintenance of Fremont Weir and Yolo Bypass Improvements

Routine maintenance of the Fremont Weir and Yolo Bypass are covered activities. Vegetation maintenance activities may include mowing, discing, livestock grazing, dozing, spraying, and/or hand-cutting of young willow groves, cottonwoods, arundo, brush, debris, and young selected oak trees. Trees with a trunk diameter of four inches or greater may be pruned up six feet from the ground. Clearing of areas will be done in stripes to open areas for water flow and to avoid islands and established growth. On a non-routine, but periodic basis, sediment will be removed from the Fremont Weir area using graders, bulldozers, excavators, dump trucks, or other machinery. Outside of the new channel, sediment removal of approximately one million cubic-yards (MCY) within one mile of the weir can be reasonably expected to occur on an average of approximately every five years based on recent maintenance history. Primarily inside the new channel, an additional one million cubic yards every other year of sediment removal is anticipated as a conservative estimate of sediment management. Where feasible, work will be conducted under dry conditions; if necessary some dredging may be required to maintain connection along the deepest part of the channel for fish passage. Where agreements can be made with landowners, sediment may be disposed of on properties in the immediate vicinity of the Fremont Weir area. It may also be used as source material for levee or restoration projects, or otherwise beneficially reused.

The spatial extent of the maintenance activities would be expected to be from the Sacramento River to the Fremont Weir, the Fremont Weir to the southern end of the Yolo Bypass, and between the associated levees.

4.2.2.2.2 Activity

All activities related to the construction, maintenance, replacement, and operations of the facilities described in this section, as well as access road improvements, are covered by the BDCP. In addition, construction of facilities necessary to provide electrical power to these facilities will also be covered by the Plan. The operations of the new Fremont Weir gates under the near- and long-term criteria and adaptive range as described in Chapter 3, *Conservation Strategy*, are also covered by the BDCP.

4.2.2.3 North Bay Aqueduct Alternative Intake Project

4.2.2.3.1 Background

The BDCP will cover all operational components of the North Bay Aqueduct Alternative Intake Project. The project includes an additional intake on the Sacramento River that will operate in conjunction with the existing North Bay Aqueduct intake at Barker Slough (described in Section 4.2.1, *Operations and Maintenance of Existing SWP Facilities*). The project would be used to accommodate projected future peak demand of up to 240 cfs. The construction of any new facilities (any intakes, pipelines, and supporting facilities) associated with the North Bay Aqueduct Alternative Intake Project is not covered under the BDCP. Consequently, any such State and/or federal regulatory compliance requirements that would be applicable to the development of the project would be addressed through processes separate and apart from the BDCP.

Combined operations of a new intake on the Sacramento River and the existing intake at Barker Slough would be included under BDCP covered activities for future peak demand of up to 240 cfs. Operations of the North Bay Aqueduct Sacramento River intake will conform, in combination with the new BDCP intake facilities on the Sacramento River, to the water operations criteria and adaptive range as described in Chapter 3, *Conservation Strategy*. The North Bay Aqueduct Alternative Intake Project may also consider an alternative that would involve the export of water from the Sacramento River through the proposed BDCP North Delta facilities.

4.2.2.3.2 Activity

The BDCP will cover all water operations components of implementing the North Bay Aqueduct Alternative Intake Project.

4.2.3 Power Generation Water Use - Mirant Delta, LLC

Mirant Delta's covered activities are those activities associated with the generation of power at its Pittsburg and Contra Costa power plants (the “Delta Plants”). These activities can be divided into two categories: 1) current power generation activities, and water intake and discharge flows associated with those activities; and 2) recurrent maintenance activities required to ensure continued operation of those existing facilities.

4.2.3.1 Existing and Future Plant Operations

4.2.3.1.1 Background

The Pittsburg Power Plant is located on the southern shore of Suisun Bay near Pittsburg, California (Figure 4-1), and the Contra Costa Power Plant is located 12 miles upstream on the southern bank of the San Joaquin River near Antioch, California (Figure 4-1).

The Delta Plants have a total generating capacity of 2,090 gross megawatts (1,985 net megawatts). Mirant's generating units burn natural gas and are designed to be cooled by water from the Sacramento-San Joaquin River Delta. Cooling water is drawn into the plants through 9.5 mm (3/8 inch) screens, pumped to condensers, used to cool spent steam and then discharged immediately back into the Delta. Source waters for the Delta Plants' cooling water systems are characteristic of this part of the Bay-Delta that separates the upstream, freshwater Delta from the downstream, saltwater bays.

Pittsburg Power Plant

The Pittsburg Power Plant (PPP) consists of seven natural gas-fired generating units, four of which have been retired. PPP Units 5&6 were built in 1960 and 1961, respectively, and generate a total of 660 gross megawatts (gMW) of power. PPP Unit 7 was built in 1972 and generates 740 gMW. Cooling water for the PPP is withdrawn from Suisun Bay through two adjacent shoreline intake structures. Units 5&6, both once-through cooled units, are each serviced by two variable frequency circulating water pumps (CWP) that withdraw water from the Units 5&6 intake structure. Each pump has a maximum design flow of 115.6 million gallons per day (MGD) (354.7 acre-feet (AF)/day) or 231.1 MGD (709.3 AF/day) per unit. The approach water velocity in front of the bar racks can range from 0.5 to around 0.2 feet per second depending upon how much electric generation is needed and the number of the variable frequency pumps in operation. Unit 7, which is equipped with two mechanical-draft cooling towers and a large cooling water canal, withdraws make-up water through the Units 1-7 intake structure. Unit 7's closed-cycle system uses up to 43.6 MGD (133.9 AF/day) of make-up water.

In addition to the Units 5-7 cooling water intake requirements, the PPP withdraws water from the Units 1-4 intake structure for station water supplies, for intermittent intake screen washing, and for fire suppression purposes. At maximum operation, these additional uses account for approximately 43.6 MGD (133.7 AF/day). The total current design flow for all PPP operations is approximately 549.4 MGD (1,686.2 AF/day).

Contra Costa Power Plant

The Contra Costa Power Plant (CCPP) consists of seven natural gas-fired generating units, five of which have been retired. Units 6&7 were built in 1964 and generate a total of 690 gMW of power. Units 6&7 are equipped with once-through cooling which utilizes water withdrawn from the San Joaquin River. Units 6&7 are each serviced by two variable frequency circulating water pumps (CWP) that each have a maximum design flow of 152,800 gpm, or 220 MGD (675 AF/day). The total design flow for both Unit 6 and Unit 7 is approximately 305,600 gpm, or 440 MGD (1,351 AF/day). The approach water velocity in front of the bar racks can range from 0.6 to around 0.2 feet per second depending upon how much electric generation is needed and the number of the variable frequency pumps in operation.

In addition to the Unit 6 and Unit 7 cooling water intake requirements, the CCPP utilizes water for station water supplies, for intermittent intake screen washing, and for fire suppression purposes. At maximum operation, these additional uses account for approximately 22 MGD (67.5 AF/day). The total current design flow for all CCPP operations is approximately 462 MGD (1,418 AF/day).

Variable Frequency Drive (VFD) Circulating Water Pump Operations

The circulating water pumps at CCPP Units 6&7 and PPP Units 5-6 are mixed flow vertical centrifugal pumps equipped with A-C induction motor drives. The drives have been modified to utilize VFD controls, as well as to operate at full rated speed. The VFD controls provide a means to vary drive speed by varying frequency. For a centrifugal pump, flow is proportional to pump speed. Therefore as frequency and drive/pump speed are reduced, pump flow is also reduced proportionally (i.e., 50 percent pump speed => 50 percent pump flow).

When operating in VFD mode, the circulating water pump speed/flow is typically at its minimum level when the unit is at minimum load. The minimum circulating water pump speed/flow is limited by both the pump and motor design and the system head requirements. For PPP Units 5&6 and CCPP Units 6&7 minimum flow is 50 percent of design and minimum load is ~25–45 MW. As unit load increases, pump speed and flow are increased in accordance with unit conditions. Maximum circulating water speed/flow, 95–100 percent of design, is typically reached at ~90–145 MW for PPP Units 5&6 and CCPP Units 6&7. River water temperature, tide, condenser vacuum, steam flow, etc., all have an effect on circulating water flow requirements.

Current Actual Operational Cooling Water Flows

Actual flow rates at the Delta Plants have steadily decreased in recent years to be consistently substantially below all maximum permitted flow limits. Capacity utilization rates (the ratio between the annual net generation of power and the total net capability of the facility to generate power) at the Plants have steadily declined in recent years, and intake flows have correspondingly decreased (Table 4-2). While the California Independent System Operator (CAISO) requires that the Delta Plants be available at any time during the year, the Delta Plants are primarily used during California's peak energy demand periods, particularly in the crucial summer months.

Table 4-2.Electrical capacity utilization and cooling water flows for CCPP and PPP from 2004 to 2008

Plant/Year	*Capacity Utilization (MWh)/(MW Capacity* hours of generation)*			*Combined Annual Cooling Water Flows (MG/yr)*	*Combined Annual Cooling Water Flows (million AF/yr)*
CCPP	**Unit 6**	**Unit 7**		**Units 6&7**	**Units 6&7**
2004	4.1	21.7		60,926	0.19
2005	1.2	10.1		29,874	0.09
2006	0.8	3.9		15,641	0.05
2007	1.4	3.3		12,879	0.04
2008	1.9	3.4		18,004	0.06
PPP	**Unit 5**	**Unit 6**	**Unit 7**	**Units 5&6**	**Units 5&6**
2004	24.0	20.8	9.5	71,751	0.22
2005	12.5	7.3	1.8	34,710	0.11
2006	7.7	5.3	1.4	25,112	0.08
2007	2.7	2.6	0.8	11,562	0.04
2008	2.3	2.4	0.8	14,859	0.05

In addition to once-through cooling flows, Mirant discharges process wastewater and stormwater (quantity and quality of discharges are subject to permits issued by the State Water Resources Control Board and San Francisco and Central Valley Regional Water Quality Control Boards).

Mirant's operations are constrained by (1) its Clean Water Act National Pollution Discharge Elimination System (NPDES) permits and specifically by Clean Water Act Section 316(b) of the federal Clean Water Act; (2) incidental take permits issued by the National Marine Fisheries Service and U.S. Fish and Wildlife Service pursuant to the Endangered Species Act; (3) a Memorandum of Understanding with the California Department of Fish and Game authorizing incidental take of species listed under the California Endangered Species Act; and (4) regulatory requirements imposed by federal and State energy agencies. These independent regulatory constraints may alter Mirant's covered activities for the purposes of the BDCP in both the short-term and long-term.

Future Operations

The remaining PPP units (Units 5-7, of which Units 5-6 use once-through cooling and Unit 7 uses closed-cycle cooling) are currently contracted through a tolling agreement with PG&E through the end of 2010. Over the course of 2010, Mirant Delta will determine whether the PPP units (1) will be retired, (2) will continue to operate for a certain term in their existing configuration followed by retirement (as at CCPP Units 6-7 discussed below), or (3) will continue to operate for a certain term with retrofits to reduce or eliminate the use of once-through cooling. Mirant Delta anticipates that, under any of these scenarios, capacity utilization at the PPP units will be consistent with the last five years of operations and will remain in the low single digits, with the units being called on to run for reliability purposes primarily in August and September.

The State Water Resources Control Board recently issued its statewide once-through cooling policy which provides for the gradual phase-out of once-through cooled units throughout California and includes a compliance due date of 2017 for the PPP. Independent of ESA/CESA requirements, Mirant Delta's once-through cooled units will be required to comply with this policy.

Mirant Delta entered into a tolling agreement with PG&E in 2009 providing for the continued operation of the remaining CCPP units (Units 6-7) until April 30, 2013, at which time Mirant Delta will permanently retire CCPP Units 6-7, the only remaining once-through cooled units at the CCPP. The CCPP units are called on to operate for reliability purposes, primarily in August and September, and capacity utilization rates have been and are anticipated to continue to be in the low single digits.

4.2.3.1.2 Activity

Mirant Delta, LLC is seeking ESA Section 10 and NCCPA Section 2835 permits for all existing and future operations of the CCPP and PPP not otherwise restricted by BDCP operating criteria.

4.2.3.2 Existing and Future Plant Maintenance, Modification Activities, and Monitoring Activities

4.2.3.2.1 Background

<u>Maintenance Dredging, Equipment Maintenance, Modifications and De-commissioning, and Levee and Flood Control Maintenance</u>

Maintenance and modification activities include those routine and non-routine activities that maintain the capacity and operational features of the existing power generation facilities at the Delta Plants described above. These activities include periodic maintenance dredging in front of and in the plant cooling water intake structures to remove naturally occurring accumulated sediments to ensure that the approach velocity of cooling water entering the intake structure remains relatively uniform across the intake screen and as close to design levels as possible, and to prevent undue damage to the facility from sediment in the cooling water and the related abrasion and wear of power plant equipment, such as condenser tubes and circulating water pumps. Dredging is also sometimes required around the docks and in the discharge outfalls to remove the sediment buildup so that these structures can function and operate as designed. These activities also include recurrent equipment maintenance and modifications (such as shoreline and pier maintenance, maintenance and repair of all improvements, infrastructure, roads, electrical facilities, underground linear facilities, vegetation management, etc.), as well as modifications to existing facilities and infrastructure as needed to ensure continued power generation; levee maintenance (such as placement of riprap for shoreline protection and erosion control) as needed to protect the power generation facilities; and flood control maintenance (such as maintenance of Willow Creek at the PPP) as needed. As existing power generation units are retired, de-commissioning activities may include demolition and/or removal of improvements and fixtures as needed. Regarding de-commissioning activities, simply retiring the units would not involve any construction or demolition activities and therefore would have no physical effects. If and when demolition occurs, most improvements would be located on disturbed uplands within the industrial site footprint and would not impact natural habitats. Shoreline improvements (e.g. cooling water intake structures), would likely be retired in place, however, if these structures are removed, restoration of the associated bankline would be conducted and would be a covered activity.

Aquatic Studies & Covered Species Monitoring

Mirant Delta is conducting, and will recurrently conduct, aquatic and covered species studies and monitoring, specifically involving data collection in the vicinity of the plants, in front of the intake and outfall structures, and within the cooling water system.

4.2.3.2.2 Activity

All maintenance, modification, de-commissioning, and monitoring described in this section that could affect species or modify critical habitat protected under ESA or CESA are covered activities, and the effects of those activities are addressed by the BDCP (see Chapter 3, *Conservation Strategy* and Chapter 5, *Effects Analysis*).

4.2.4 Habitat Restoration, Enhancement, and Management Activities

Habitat restoration, enhancement, and management activities are covered activities under BDCP include all actions that may be undertaken to implement the physical habitat conservation measures described in Chapter 3, *Conservation Strategy*. Types of actions necessary to implement habitat restoration and enhancement conservation measures are anticipated to include, but are not limited to:

- Grading, excavation, and placement of fill material;
- Breaching, modification, or removal of existing levees and construction of new levees;
- Modification, demolition, and removal of existing infrastructure (e.g., buildings, roads, fences, electric transmission and gas lines, irrigation infrastructure);

- Construction of new infrastructure (e.g., buildings, roads, fences, electric transmission and gas lines, irrigation infrastructure);
- Removal of existing vegetation and planting/seeding of vegetation;
- Controlling the establishment of nonnative vegetation to encourage the establishment of target native plant species; and
- Control of nonnative predator and competitor species (e.g., feral cats, rats, and nonnative foxes).

Habitat management actions include all activities undertaken to maintain the intended functions of protected, restored, and enhanced habitats over the term of the BDCP. Habitat management actions are anticipated to include, but are not limited to:

- Minor grading, excavation, and filling to maintain infrastructure and habitat functions (e.g., levee maintenance, grading or placement of fill to eliminate fish stranding locations);
- Maintenance of infrastructure (e.g., buildings, roads, fences, electric transmission and gas lines, irrigation infrastructure, fences);
- Maintaining vegetation and vegetation structure (e.g., grazing, mowing, burning, trimming); and
- Ongoing control of terrestrial and aquatic nonnative plant and wildlife species.

The scope of the physical habitat actions provided for under the BDCP is presented in Table 4-3. The extent of the habitat and natural communities conservation actions set out in this section reflects both an assessment of the long-term conservation needs of individual covered species (i.e., habitat function, quantity, connectivity, and distribution), and an analysis of existing and future constraints that could affect habitat conservation, including land surface subsidence, habitat values, and land use.

A primary conservation goal of the BDCP is to restore 80,000 acres of tidal habitat, riparian habitat, and new floodplain for the benefit of fish, wildlife, and plants and ecosystem processes in the Delta and Suisun Marsh. The BDCP physical habitat conservation program is organized geographically across the northern, eastern, southern and western regions of the Delta. It is also organized by habitat type, and temporally into near-term and a long-term implementation phases. The schedule for protection, enhancement, and restoration of physical habitat is described in Chapter 6, Implementation Plan. Protection, enhancement, and restoration of other natural communities and habitats would be undertaken in both the near-term and long-term implementation periods as described in Chapter 6, Implementation Plan. In the near-term, prior to completion of the tunnel/pipeline facility, the BDCP targets for habitat restoration include 14,000 acres of tidal habitat. Within 15 years, the goal is for tidal habitat restoration to reach 25,000 acres and riparian restoration to reach 400 acres and the addition of 1,000 acres of new seasonally inundated floodplain habitat. By year 40, the BDCP goal is to have established

65,000 acres of tidal habitat, 5,000[7] acres of riparian habitat, and 10,000 acres of new seasonally inundated floodplain.[8]

In the near-term BDCP implementation period, actions to restore tidal habitat and riparian habitats will likely be directed at the Cache Slough, West Delta, Cosumnes/Mokelumne and Suisun Marsh Restoration Opportunity Areas (ROAs) in Conservation Zones 1, 2, 4, 5 and 11 (see Figures 3-1 and 3-2). The initial focus on these locations reflects the anticipated productivity benefits that may be achieved in the near-term prior to changes to the existing through Delta conveyance system. These near-term elements of the habitat program will parallel adjustments in water management and flow regimes that are designed together to realize substantial improvements in aquatic productivity and function for covered species while the structural long-term improvements are constructed. Following commencement of dual water conveyance operations (i.e., the long-term BDCP implementation period), restoration of tidal and riparian habitat would continue in these Conservation Zones and would be expanded significantly into Conservation Zone 7.

Table 4-3. Extent of BDCP Natural Communities and Habitat Types Conserved Over the Term of the BDCP

*[**Note to reviewers:** Acreages provided are subject to change based on results of Effects Analysis and revisions to Conservation Strategy]*

Conserved Natural Community/Habitat Type	***Extent of Natural Community and Habitat Type Conserved***[1]		
	Protected[2]	**Enhanced**	**Restored**
Seasonally Inundated Floodplain	0	Increased frequency and duration of Yolo Bypass flooding[3]	10,000
Freshwater and Brackish Tidal, Subtidal, and Transition Habitats	0	0	65,000
Channel Margin	0	0	20 linear miles[7]
Riparian	0[4]	0	5,000[6]
Grassland	8,000[4]	0	2,000[5]
Nontidal Perennial Emergent Wetland and Nontidal Perennial Aquatic	0[4]	0	400
Alkali Seasonal Wetland Complex	400	0	0
Vernal Pool Complex	300	0	200
Managed Seasonal Wetland	0	TBD	TBD
Agricultural Habitat	16,620-32,640	0	0

[1]All values are in acres unless otherwise noted.
[2]Though not included in the *Enhanced* column, all protected natural communities/habitat types will also be managed to maintain or increase their habitat functions for covered species.
[3]Enhancement of the existing Yolo Bypass floodplain would be provided with operation of a modified Fremont Weir to increase the duration and frequency of seasonally inundated floodplain habitat. The conditions under which this increased inflow would be provided are described in conservation measure *CM2, Yolo Bypass Fisheries Enhancement.*
[4]An undefined additional extent of these natural communities/habitat types are likely to be protected in small patches where they occur within larger patches of other protected natural communities/habitat types (e.g., existing patches of riparian habitat within preserved agricultural lands would be protected).
[5]Some of the restored grassland may be restored within the transitional component of restored tidal habitat and thus the total land base required for grassland restoration may be less than shown.
[6]Riparian habitat restoration will all occur within the restoration lands for seasonally inundated floodplain, channel margin, and freshwater tidal areas.
[7]This could be up to 40 linear miles through the adaptive management process.

[7] Portions of the 5,000 acres of riparian would be included within the 10,000 acres of floodplain and 65,000 acres of tidal habitat.

[8] The 10,000 acre target for new floodplain restoration does not include floodplain habitat enhanced in the Yolo Bypass under a separate conservation measure.

4.2.5 Activities to Reduce Contaminants

Activities to reduce contaminants that could result in incidental take are covered activities under BDCP. A more detailed discussion of these activities is provided in Chapter 3. These activities include the following:

- **Control of Methylmercury Load in BDCP Restoration Sites -** The purpose of this measure is to minimize the methylation of inorganic mercury in BDCP habitat restoration areas caused by BDCP restoration actions. The BDCP Implementation Office will minimize to the extent practicable any increase in mercury methylation associated with habitat restoration conservation measures through the design and implementation of restoration projects. The BDCP Implementation Office will work with DWR and the Central Valley Regional Water Quality Control Board (CVRWQCB) to identify and implement methods for minimizing the methylation of mercury in BDCP restoration areas.

4.2.6 Activities to Reduce Predators and Other Sources of Direct Mortality

Activities to reduce predators and other sources of direct mortality that could result in incidental take are covered activities under BDCP. A more detailed discussion of these activities is provided in Chapter 3. These activities include the following:

- **Reduce Effects of Predators -** Reduce local effects of predators on covered fish species by conducting focused predator control in high predator density locations. The BDCP Implementation Office will reduce the local effects of predators on covered fish species by conducting focused predator control using a variety of methods in locations in the Delta that are known to have high densities of predators ("predator hot spots").
- **Non-physical Barriers -** The purpose of this conservation measure is to improve the survival of outmigrating juvenile salmonids by using non-physical barriers to re-direct them away from channels in which survival is lower. The BDCP Implementation Office will install non-physical barriers at the junction of channels with low survival of outmigrating juvenile salmonids to deter fish from entering these channels.
- **Control Nonnative Submerged and Floating Aquatic Vegetation in BDCP Tidal Habitat Restoration Areas -** The BDCP Implementation Office will control the growth of Brazilian waterweed (*Egeria densa*), water hyacinth (*Eichhornia crassipes*), and other nonnative submerged and floating aquatic vegetation (SAV and FAV) in BDCP tidal habitat restoration areas.

4.2.7 Monitoring and Research Programs

As described in Chapter 3, various types of monitoring activities will be conducted during BDCP implementation including preconstruction surveys, construction monitoring, compliance monitoring, effectiveness monitoring, and system monitoring. In addition, focused research will be undertaken or contracted to develop information necessary to better inform BDCP implementation. Such monitoring and research activities could result in incidental take and these activities are covered activities under BDCP. Though individual instances of take are expected to be minor, there are likely to be many such instances over a long period of time.

4.2.8 Other Conservation Actions

All other conservation actions included in Chapter 3, *Conservation Strategy*, that could result in incidental take, not described above, are covered activities. Although take levels are expected to be low, other conservation actions that could result in take of covered species and therefore require authorization as covered activities are included. Examples of actions include:

- **Dissolved Oxygen -** The purpose of this conservation measure is to maintain dissolved oxygen concentrations above levels that impair covered fish species in the Stockton Deep Water Ship Channel during periods when covered fish species are present. The BDCP Implementation Office will operate and maintain an oxygen aeration facility in the Stockton Deep Water Ship Channel to increase dissolved oxygen concentrations.
- **Conservation Hatcheries** - The purpose of this conservation measure is to establish new and expand existing conservation propagation programs for delta and longfin smelt. The BDCP Implementation Office will support: (1) the development of a delta and longfin smelt conservation hatchery by the USFWS to house a delta smelt refugial population and provide a source of delta and longfin smelt for supplementation or reintroduction, if deemed necessary by Fishery Agencies, and (2) the expansion of the refugial population of delta smelt and establishment of a refugial population of longfin smelt at the University of California, Davis Fish Conservation and Culture Laboratory to serve as a population safeguard in case of a catastrophic event in the wild.

4.2.9 Emergency Actions

The Plan covers emergency activities related to facilities constructed and operated under the BDCP and emergency activities within BDCP habitat conservation lands (including both restored and protected habitats) necessary to prevent and minimize the loss of human life, property, critical infrastructure, and sensitive natural resources. Emergency activities are the immediate response actions that may occur in response to such events as failure of water operations infrastructure, levee failure, fire, toxic or hazardous materials spills, or other natural disasters and accident response. By their nature, these events and the response actions to them cannot be planned for or directed to areas with less sensitive resources.

Emergency actions include, but are not limited to: initial temporary repair of water operations infrastructure; initial repair of structures damaged by flooding associated with levee failure where such repairs cannot be delayed due to the imminent loss of life or property; initial repair, replacement, and/or removal of damaged or failed structures and associated facilities; emergency fire fighting actions; temporary shoring-up of levees; emergency cleanup of spilled hazardous materials and/or waste; evacuation of injured persons or livestock; and use of motorized vehicles for conducting emergency activities.

Once an emergency has been addressed, the BDCP includes planned responses to deal with the aftermath of the emergency. Planned responses following emergency actions that have substantial effects on covered species or natural communities (e.g., vegetation rehabilitation after a major fire) are considered remedial actions to changed circumstances or adaptive management. Section 6.3.2 *Changed Circumstances* describes the required planned responses to levee failures, fires, failure of water operations infrastructure, toxic or hazardous spills, and other such events. Other planned responses may be conducted as part of the adaptive management process (Section 3.7, *Adaptive Management Program*).

4.3 Federal Actions Associated with the BDCP

The activities described in this section have been designated as "federal actions associated with the BDCP." These actions consist of CVP-related activities within the Delta that are authorized, funded, or carried out by Reclamation. These federal actions differ from "covered activities," which encompass those BDCP actions that are the responsibility of non-federal entities. The federal actions associated with the BDCP are subject to the ESA Section 7 consultation process; and as such, Reclamation will consult with USFWS and NMFS regarding the effect of these actions on listed species and designated critical habitat. For the federal actions set out in this section, the BDCP is intended to provide the basis for a biological assessment (BA) to support Section 7 consultations with the federal fish and wildlife agencies. Reclamation's actions that are outside the scope of the BDCP will be addressed as part of a consultation that covers the totality of CVP-related operations.

4.3.1 CVP Operations and Maintenance

This section describes actions by Reclamation related to the operations and maintenance of existing CVP facilities in the Delta that will be addressed in the BDCP.

The CVP's Delta Division[9] facilities within the Plan Area consist of the Delta Cross Channel (DCC); the eastern portion of the Contra Costa Canal, including the Contra Costa Water District's (CCWD) diversion facility at Rock Slough; the Jones Pumping Plant (formerly Tracy Pumping Plant); the Tracy Fish Collection Facility (TFCF); and the northern portion of the Delta Mendota Canal (DMC) (Figures 4-1 and 4-2). These CVP facilities are used to convey water

[9] The Delta Division is one of several CVP divisions covering various geographical areas and facilities of the CVP including the American River, Friant, East Side, Sacramento River, San Felipe, West San Joaquin, and Shasta/Trinity River divisions. The CVP Delta Division includes facilities within the Plan Area (described in this chapter) and facilities outside the Plan Area (not included in this chapter).

from the Sacramento River in the north Delta to the south Delta and to export that water from the Delta into canals and pipelines that carry it to agricultural and municipal and industrial (M&I) contractors to the south and west of the Delta. These facilities are integral components of the CVP and contribute to the functional capacity of the overall system. This section describes these facilities, their operational requirements, and the actions necessary to maintain their viability. The operation and maintenance of these facilities are not only integral to the water supply system, but are also important to the BDCP Conservation Strategy and the protection and conservation of the aquatic ecosystem and covered fish species.

The existing CVP facilities described in this section would be operated under both the BDCP near-term and long-term implementation, but with differing operating criteria following completion of new facilities. The BDCP near- and long-term operational criteria and adaptive operational range are described in Chapter 3, *Conservation Strategy*, and include descriptions of operations of CVP facilities in the Plan Area.

All operations and maintenance of CVP facilities described in this section are federal actions associated with the BDCP and the effects of those actions are addressed by the BDCP Conservation Strategy (see Chapter 3, *Conservation Strategy* and Chapter 5, *Effects Analysis*) and will be covered in the BDCP Section 7 consultation.

4.3.1.1 Delta Cross Channel

4.3.1.1.1 Background

The DCC is a gated diversion channel between the Sacramento River, near Walnut Grove, and Snodgrass Slough (Figure 4-1). Flows into the DCC from the Sacramento River are controlled by two 60-foot by 30-foot radial gates. When the gates are open, water flows from the Sacramento River through the cross channel to Snodgrass Slough and from there to channels of the lower Mokelumne River and into the central Delta. Once in the central Delta, the water is conveyed primarily via Old and Middle rivers to the Jones Pumping Plant by the draw of the pumps. The DCC operation improves water quality in the interior Delta by improving circulation patterns of good quality water from the Sacramento River towards Delta diversion facilities.

Reclamation operates the DCC in the open position to (1) improve the transfer of water from the Sacramento River to the export facilities at the SWP Banks (see description of SWP facilities) and CVP Jones pumping plants; (2) improve water quality in the southern Delta; and (3) reduce salt water intrusion rates in the western Delta. During the late fall, winter, and spring, the gates are often periodically closed to protect out-migrating salmonids from entering the interior Delta where they are subject to higher levels of predation and greater potential for entrainment at the CVP and SWP south Delta export facilities. When flows in the Sacramento River at Sacramento reach 20,000 to 25,000 cfs (on a sustained basis) the gates are closed to reduce potential scouring and flooding that might occur in the channels on the downstream side of the gates.

4.3.1.1.2 Action

See Chapter 3, *Conservation Strategy*, for a description of operations of the DCC gates under the BDCP to provide for protection of salmon in conjunction with water conveyance. Reclamation is seeking ESA Section 7 authorization for all operations and maintenance of the DCC consistent with BDCP operations conservation measures.

4.3.1.2 C.W. Jones Pumping Plant

4.3.1.2.1 Background

The CVP and SWP use the Sacramento River, San Joaquin River, and Delta channels to transport water to pumping plants located in the south Delta (Figures 4-1 and 4-2). The CVP's Jones Pumping Plant, about five miles northwest of Tracy, consists of six available pumps. The Jones Pumping Plant is located at the end of an earth-lined intake channel about 2.5 miles in length. Jones Pumping Plant has a physical capacity of 5,100 cfs and State Water Resources Control Board (Water Board) permitted diversion capacity of 4,600 cfs with maximum pumping rates typically ranging from 4,500 to 4,300 cfs during the peak of the irrigation season and approximately 4,200 cfs during the winter non-irrigation season until construction and full operation of the proposed DMC/California Aqueduct Intertie. The winter-time physical constraints on the Jones Pumping Plant operations are the result of a DMC freeboard constriction near O'Neill Forebay, O'Neill Pumping Plant capacity, and the current water demand in the upper sections of the DMC.

4.3.1.2.2 Action

See Chapter 3, *Conservation Strategy*, for description of south Delta operations of CVP and SWP under the BDCP to provide for protection of covered fish species in conjunction with water conveyance and diversion. Reclamation is seeking ESA Section 7 authorization on all operations and maintenance of the Jones Pumping Facility not otherwise restricted by the BDCP operating criteria.

4.3.1.3 Tracy Fish Collection Facility

4.3.1.3.1 Background

At the head of the intake channel leading to the Jones Pumping Plant, TFCF louver screens intercept fish that are then collected, held, and transported by tanker truck to Delta release sites away from the south Delta facilities. The TFCF uses behavioral barriers consisting of primary and secondary louvers to guide entrained fish into holding tanks. The primary louvers are located in the primary channel just downstream of the trashrack structure. The secondary louvers are located in the secondary channel just downstream of the traveling water screen. The louvers allow water to pass through onto the Jones Pumping Plant but the openings between the slats are tight enough and angled against the flow of water in such a way as to prevent most fish from passing between them and instead enter one of four bypass entrances along the louver arrays. The holding tanks on hauling trucks used to transport salvaged fish to release sites are injected with oxygen and contain an eight parts per thousand salt solution to reduce stress on fish. The CVP uses two release sites, one on the Sacramento River near Horseshoe Bend and the other on the San Joaquin River immediately upstream of the Antioch Bridge.

4.3.1.3.2 Action

See Chapter 5, *Effects Analysis*, for a description of the level of take associated with the operations of the TFCF. Reclamation is seeking ESA Section 7 authorization for all operations and maintenance of the TFCF consistent with the BDCP operating criteria.

4.3.1.4 Contra Costa Water District Diversion Facilities

4.3.1.4.1 Background

Contra Costa Water District (CCWD) diverts water from the Delta for irrigation and municipal and industrial (M&I) uses under CVP contract and under its own water rights. Under its CVP contract, CCWD can divert water at Rock Slough for direct use and divert water at its intake on Old River near State Route 4 (designated CCWD's Old River Intake) and its new intake on Victoria Canal near Middle River (designated CCWD's Middle River Intake) for either direct use or for storage. Under its own State Water Board permit and license, CCWD can divert water for direct use at Mallard Slough, and under its own Los Vaqueros water right permit, CCWD can divert water at its Old River and Middle River intakes for storage in Los Vaqueros Reservoir.

CCWD's water system includes intake facilities at Mallard Slough, Rock Slough, Old River, and Victoria Canal near Middle River (Middle River intake); the Contra Costa Canal and shortcut pipeline; Contra Loma Reservoir; the Martinez Terminal Reservoir; and the Los Vaqueros Reservoir. The Rock Slough intake facilities, the Contra Costa Canal, the shortcut pipeline, the Contra Loma Reservoir, and the Martinez Terminal Reservoir are owned by Reclamation, and operated and maintained by CCWD under contract with Reclamation. Mallard Slough Intake, Old River Intake, Middle River Intake (on Victoria Canal), and Los Vaqueros Reservoir are owned and operated by CCWD.

CCWD's operations are governed by Biological Opinions issued to Reclamation under separate Section 7 consultations (hereafter, "CCWD-specific BOs"). CCWD's operations are included in the project description and modeling for the long-term CVP/SWP operations Biological Assessment, which resulted in the current Biological Opinions on CVP/SWP operations (USFWS 2008; NMFS 2009). CCWD also has California Endangered Species Act take authorization for all its operations under a 2081 permit issued in 2009 by the California Department of Fish and Game.

Reclamation and CCWD are currently planning two projects to modify facilities: addition of a fish screen to the Rock Slough Intake and expansion of the Los Vaqueros Reservoir. For each of these projects, Reclamation, in coordination with CCWD, consulted with the USFWS and NMFS under Section 7, and CCWD, in coordination with Reclamation, has consulted with DFG.[10]

Rock Slough Fish Screen

The Rock Slough Intake is located about four miles southeast of Oakley, where water flows into the earth-lined portion of the Contra Costa Canal. This section of the canal is open to tidal influence and continues for four miles to Pumping Plant 1, which has capacity to pump up to 350 cfs into the concrete-lined portion of the canal. Prior to completion of the Los Vaqueros Project in 1997, this was CCWD's primary diversion point. Consistent with Central Valley Project Improvement Act (CVPIA) and as required by the USFWS Biological Opinion for the Los Vaqueros Project (USFWS 1993), Reclamation, in collaboration with CCWD, is in the process of constructing a fish screen at the Rock Slough intake. This project is covered by a separate ESA Section 7 consultation. With the completion of this project, all of CCWD's Delta intakes will include positive barrier fish screens. CCWD's other intakes (Mallard Slough, Old River and the new Middle River intake on Victoria Canal) are screened.

Los Vaqueros Reservoir Expansion Project

CCWD has certified the environmental documents for an expansion of Los Vaqueros Reservoir from its current 100,000 acre-feet to 160,000 acre-feet. CCWD is in the process of completing permits and final design, and expects to begin construction in 2011, with completion of the expansion in 2012. The expansion will improve CCWD water quality, water supply reliability and emergency storage, and will have the effect of shifting CCWD diversions from drier periods to wetter periods. The expansion will not increase CCWD overall diversions from the Delta or modify any Delta facilities; operation of the expanded reservoir will continue to be governed by existing CCWD-specific biological opinions. The expansion will impact terrestrial habitat and species within the Los Vaqueros watershed, which is outside of the Delta; CCWD and Reclamation are currently consulting with USFWS (under Section 7) to develop a biological opinion covering the terrestrial impacts, mitigation, and adaptive management, separate and independent from the BDCP Section 7 consultation.

4.3.1.4.2 Action

Reclamation would include CCWD's operations described above in the BDCP ESA Section 7 Biological Assessment as part of the existing operations. CCWD is not an ESA Section 10 permit applicant under BDCP, and operation of CCWD facilities will not change under the BDCP. However, all operations and maintenance of CCWD facilities described in this section that could affect species or modify designated critical habitat protected under ESA will be included in the analysis of Delta operations in the BDCP Section 7 Biological Assessment. This will ensure that existing and ongoing operations in the Delta are accurately analyzed in the consultation on the effects of the BDCP and CVP operations. If, as a result of the BDCP ESA Section 7 consultation, any of the criteria for reinitiation of consultation set forth in the CCWD-

[10] For the Los Vaqueros project, consultation has been initiated but not completed.

specific Biological Opinions are triggered, Reclamation and CCWD will reinitiate consultation under ESA Section 7.

4.3.1.5 Central Valley Project Diversions

4.3.1.5.1 Background

The volume of water delivered by the CVP is and will continue to be variable, but in any year will be equal to the amount of water that is hydrologically available and that can be diverted under current contractual rights consistent with the terms and conditions of the BDCP Conservation Strategy and then-existing permits and regulations. Reclamation delivers water transported through facilities in the Delta to senior water rights contractors, long-term CVP water service contractors, refuges and waterfowl areas, and temporary water service contractors south of the Delta. The total volume under contract, including Level 2 refuge supplies, is approximately 3.3 MAF. Additionally, the CVP provides Level 4 refuge water totaling approximately 100,000 AF. In addition, as part of the San Joaquin River Restoration Program implementation, Reclamation anticipates submitting a petition to add a point of diversion to the State Water Board to allow re-diversion of the restoration flows either upstream of or in the Delta. Moreover, in wet hydrologic conditions when CVP storage is not available, Delta is in excess conditions, water is made available under temporary contracts for direct delivery. The volume of water available for conveyance through the Delta is a result of hydrologic conditions, upstream reservoir operations, upstream demands, regulatory constraints on CVP operations, and from transfers of water from upstream water users to south of Delta water users.

4.3.1.5.2 Action

See Chapter 3, *Conservation Strategy*, for description of near-term and long-term operations and adaptive range of CVP and SWP under the BDCP to provide for protection of covered fish species in conjunction with water conveyance and diversion. All CVP diversions described in this section are federal actions associated with the BDCP, and the effects of those actions are addressed by the BDCP (see Chapter 3, *Conservation Strategy* and Chapter 5, *Effects Analysis*) and will be covered in the BDCP Section 7 consultation. Water passing through the Delta associated with water transfers (e.g., Drought Water Bank and Dry Year Water Purchase Programs) is also a covered action. Reclamation is seeking ESA Section 7 authorization for all CVP diversions consistent with the BDCP operating criteria.

4.3.1.6 Associated Maintenance and Monitoring Activities

4.3.1.6.1 Background

Maintenance and replacement means those activities that maintain the capacity and operational features of the existing CVP water diversion and conveyance facilities described above including the DCC, Jones Pumping Plant, TFCF, and Contra Costa Diversion Facilities. Maintenance activities include maintenance of electrical power supply facilities; maintenance as needed to ensure continued operations and replacement of facility or system components when necessary to maintain system capacity and operational capabilities; and upgrades and technological improvements of facilities to maintain system capacity and operational capabilities.

Monitoring activities refers to those actions necessary for monitoring water quality and fisheries as conditioned by water rights permits and biological opinions, those actions undertaken as a result of the CVPIA and agreements, and any additional monitoring under the BDCP as described in Chapter 3, *Conservation Strategy*, for which Reclamation is responsible. These actions include routine daily, annual or other periodic sampling of water quality constituents as well as trawls for various fish species in the Delta (including actions associated with the Interagency Ecological Program). Reclamation currently operates and maintains more than 20 monitoring stations in the Delta which provide near-realtime water quality data. As the BDCP Conservation Strategy is implemented, the nature of, and requirements for, monitoring would be expected to change.

4.3.1.6.2 Action

All CVP maintenance and monitoring described in this section are federal actions associated with the BDCP, and the effects of those actions are addressed by the BDCP (see Chapter 3, *Conservation Strategy* and Chapter 5, *Effects Analysis*) and will be covered in the Section 7 consultation.

4.4 JOINT FEDERAL AND NON-FEDERAL ACTIONS

This section describes activities that will be carried out jointly by DWR and Reclamation. These actions are categorized as covered activities under ESA Section 10 and NCCPA Section 2835 for DWR because of DWR's involvement in these joint actions. The activities identified in this section for federal actions by Reclamation are not "covered activities" for the purposes of the ESA Section 10(a)(1)(b) permit. These federal actions are actions that occur within the Delta which will be coordinated with DWR to support DWR's compliance with the ESA Section 10 permit. Reclamation's activities are subject to ESA Section 7, and Reclamation will consult under ESA Section 7 on those actions. The Section 7 consultation will also include other CVP operations that are not within the Plan Area.

4.4.1 Joint Point of Diversion Operations

4.4.1.1 Background

Under State Water Board Decision 1641 (D-1641) (December 1999; revised March 2002), Reclamation and DWR are authorized to use/exchange diversion capacity between the Projects to enhance the beneficial uses of both Projects. The use of one Project's diversion facility by the other Project is referred to as the Joint Points of Diversion (JPOD). There are a number of requirements in D1641 that restrict JPOD to protect water quality and fishery resources.

In general, JPOD capabilities are used to accomplish four basic CVP-SWP objectives:

- When wintertime excess pumping capacity becomes available during Delta excess conditions and total CVP-SWP San Luis storage is not projected to fill before the spring pulse flow period, the project with the deficit in San Luis storage may elect to use JPOD capabilities.
- When summertime pumping capacity is available at Banks Pumping Plant and CVP reservoir conditions can support additional releases, the CVP may elect to use JPOD capabilities to enhance annual CVP south of Delta water supplies.
- When summertime pumping capacity is available at Banks or Jones Pumping Plant to facilitate water transfers, JPOD may be used to further facilitate the water transfer.
- During certain coordinated CVP-SWP operation scenarios for fishery entrainment management, JPOD may be used to shift CVP-SWP exports to the facility with the least fishery entrainment impact while minimizing export at the facility with the most fishery entrainment impact.

4.4.1.2 Activity/Action

All in-Delta JPOD operations are included as either covered activities or federal actions associated with the BDCP and the effects of those activities/actions are addressed by the BDCP (see Chapter 3, *Conservation Strategy* and Chapter 5, *Effects Analysis*). Those actions associated with Reclamation will receive authorization through the ESA Section 7 consultation process and those actions associated with DWR will be covered under ESA Section 10 permits and Section 2835 permits issued pursuant to the NCCPA.

4.4.2 Operations of New Water Intake and Conveyance Facilities

4.4.2.1 Background

DWR would own and operate the new intake and conveyance facilities and their operations would be covered activities as described in Section 4.2.2, *New Facilities Construction, Operation, and Maintenance*. Reclamation and/or the CVP Contractors would enter into agreements to wheel CVP water through the new facilities and this action by Reclamation would be an associated federal action.

4.4.2.2 Activity/Action

All operations of new intake and conveyance facilities are included as either covered activities or federal actions associated with the BDCP and the effects of those activities/actions are addressed by the BDCP (see Chapter 3, *Conservation Strategy* and Chapter 5, *Effects Analysis*). Those actions associated with Reclamation will receive authorization through the ESA Section 7 consultation process and those actions associated with DWR will be covered under ESA Section 10 permits and Section 2835 permits issued pursuant to the NCCPA.

4.4.3 Transfers

4.4.3.1 Background

State and federal laws enacted governing water use in California promote the use of water transfers to manage water resources, particularly water shortages, provided that certain conditions of transfer are adopted to protect source areas and users. Transfers requiring export from the Delta are conducted at times when pumping and conveyance capacity at the CVP or SWP export facilities is available to move the water. Additionally, operations to accomplish these transfers must be carried out in coordination with CVP and SWP operations, such that the capabilities of the Projects to exercise their own water rights or to meet their legal and regulatory requirements are not diminished or limited in any way.

CVP and SWP contractors have independently acquired water and arranged for its pumping and conveyance through SWP facilities. State Water Code provisions grant other parties access to unused conveyance capacity, although SWP contractors have priority access to capacity not being used by DWR to meet SWP contract amounts.

4.4.3.2 Activity/Action

Delta operations involving water passing through the Delta associated with water transfers are covered activities and federal actions, however, the effects on place of origin and use are not proposed for coverage. The effects of Delta water operations, including transfers, are addressed in Chapter 5, *Effects Analysis*.

4.4.4 Suisun Marsh Facilities Operations and Maintenance

4.4.4.1 Background

The existing Suisun Marsh facilities consist of:

- Suisun Marsh Salinity Control Gates;
- Morrow Island Distribution System;
- Roaring River Distribution System;
- Goodyear Slough Outfall; and
- Various salinity monitoring and compliance stations throughout the Marsh.

Since the early 1970s, the California Legislature, State Water Board, Reclamation, DFG, Suisun Resource Conservation District (SRCD), DWR, and other agencies have engaged in efforts to preserve beneficial uses of Suisun Marsh to mitigate for potential impacts on salinity regimes associated with reduced freshwater flows to the marsh. Initially, salinity standards for Suisun Marsh were set by the State Water Board's Decision 1485 to protect alkali bulrush production, a primary waterfowl plant food. Subsequent standards set under the State Water Board's Decision-1641 reflect the intention of the State Water Board to protect multiple beneficial uses. A contractual agreement between DWR, Reclamation, DFG and SRCD includes provision for measures to mitigate the effects of SWP and CVP operations and other upstream diversions on Suisun Marsh channel water salinity. The Suisun Marsh Preservation Agreement requires DWR and Reclamation to meet specified salinity standards, sets a timeline for implementing the Plan of Protection, and delineates monitoring and mitigation requirements.

The existing operation of the Suisun Marsh Facilities is covered for ESA and CESA compliance under the OCAP biological opinions and the related consistency determination. The Suisun Marsh Facilities will be covered under the BDCP for existing operations criteria and for future criteria discussed below.

The BDCP includes conservation actions that will change land use and water operations in Suisun Marsh over time. These changes in land use and water operations are covered activities and are addressed by the BDCP. See Chapter 3, *Conservation Strategy*, for descriptions of tidal brackish marsh restoration (CM4 *Tidal Habitat Restoration*) and water operations (CM1 *Water Facilities Operation)*. The existing operation and maintenance of the Suisun Marsh Salinity Control Gates and other facilities would not change until BDCP actions require changes in their operation. Operations of the Suisun Marsh Facilities under the existing operational criteria, as well as changes to operation as described in CM1 would be covered by BDCP. Generally, as habitat restoration in Suisun Marsh is conducted with the implementation of BDCP conservation measures, and changes in land uses occur, the operation of the Suisun Marsh Salinity Control Gates will trend towards limiting the operation of the gates and increasing the period during which the gates allow tidal inflows into Montezuma Slough to provide for the conservation of covered fish species in conjunction with all other water operations under BDCP.

4.4.4.2 Activity/Action

The BDCP covers operations of the Salinity Control Gates and other Suisun Marsh facilities under the existing and future operational criteria and future construction and maintenance of tidal habitat in Suisun Marsh identified in CM 1 and CM 4 in Chapter 3, *Conservation Strategy*. These activities/actions are included as covered activities and associated federal actions and the effects of those activities/actions are addressed by the BDCP (see Chapter 3, *Conservation Strategy* and Chapter 5, *Effects Analysis*). Those actions associated with Reclamation will receive authorization through the ESA Section 7 consultation process and those actions associated with DWR will be covered under ESA Section 10 permits and Section 2835 permits issued pursuant to the NCCPA.

CHAPTER 5. OVERVIEW OF THE EFFECTS ANALYSIS

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CHAPTER 5. OVERVIEW OF THE EFFECTS ANALYSIS

*[**Note to Reviewers:** The Effects Analysis is currently underway and expected to be completed in early 2011 and is an iterative process. This chapter is a summary of an initial draft of the Effects Analysis and has not been read or reviewed by the Steering Committee. It is the consultant's work product and provides their overview of the Effects Analysis: its development and context; a brief description of the methodologies used; the current status of the Effects Analysis; and the summary of preliminary findings presented in the August 19, 2010 Working Draft and the September 9, 2010 draft enhanced habitat analysis for covered fish species. These preliminary findings are subject to modification as the revised analyses are being completed.]*

This draft is a high level summary that captures the consultant's view of where the effects analysis is as of September 9, 2010. It does not include subsequent findings of the technical "theme teams" or other comments that were developed in the weeks preceding this draft.

Notwithstanding any text to the contrary in this chapter, the Effects Analysis is a work in progress and continues to be reviewed by the technical staff of the Steering Committee representatives and will be revised. To date, several issues have been identified that may necessitate changes to the conservation strategy or initial long-term operating criteria. These include (but are not limited to):

- *North Delta intake configuration related to predation concerns (in-river vs on-bank)*
- *Spring-run salmon egg mortality on the Sacramento River in the fall*
- *Reduced Sacramento River flows downstream of the North Delta intakes*
- *Refinement of April-May south Delta operations*
- *Winter-spring X2 and outflow effects on longfin smelt*
- *Summer and fall X2 and delta smelt abiotic habitat*

The Effects Analysis process has begun to evaluate how modifications to some of the conservation measures, including initial long-term operating criteria (see CM1 Note to Reviewers) might address some of these issues in a manner that provides a refined approach to fishery protection while being sensitive to the water supply goals. This will lead to an iteration process involving the Oversight Committee and Steering Committee that will take place for the purpose of describing the final conservation strategy and the initial long-term operating criteria for complete evaluation in the effects analysis. Also, as part of this process, an adaptive range for the operational criteria will be developed.

Further, the theme teams and the Effects Analysis Oversight Team will continue to meet to address and resolve technical comments about the methods used in the analysis, as described in Section 5.3.1. The analysis will be revised once those comments are resolved.

Finally the Steering Committee will further consider whether the results can support a conservation strategy that meets the biological goals and objectives of the BDCP.]

5.1 INTRODUCTION

An effects analysis is the principal analytical component of a habitat conservation plan. It presents conclusions regarding the expected outcomes of the conservation strategy and covered activities. The analysis includes the effects of the proposed project on covered species, including federally and state listed species, and other sensitive species potentially affected by the proposed project. The effects analysis is a systematic, scientific look at the potential impacts of a proposed project on these species and how these species would benefit from conservation actions.

This effects analysis provides a description of the outcomes of the BDCP Conservation Strategy (Chapter 3) and covered activities (Chapter 4). The BDCP is being developed to promote the recovery of endangered, threatened, and sensitive fish and wildlife species and their habitats in the Sacramento-San Joaquin Delta in a way that will also protect and restore water supplies.

As described in Chapter 3, the Delta was once a vast marsh and floodplain intersected by meandering channels and sloughs that provided habitat for a rich diversity of fish, wildlife, and plants. The Delta of today is a system of artificially channeled and dredged waterways constructed into static geometries, initially designed to support farming, and later, limited urban development on Delta islands; to protect against flooding; and to convey water supplies to cities and farms in the Bay Area, San Joaquin Valley and southern California. The physical disturbances within the Delta, the introduction of nonnative species that have disrupted the foodweb, along with multiple other environmental challenges to the ecosystem have contributed to declines in fish, wildlife, and plant species and other organisms. In recent years, these factors have caused a significant drop in the population of key native fish species, which has triggered major reductions in water supply.

Developing the effects analysis is challenging because of the scale of changes to the Delta ecosystem proposed in the BDCP Conservation Strategy. The approach embodied in the conservation strategy reflects a significant departure from the manner in which at-risk Delta fish and wildlife species and their habitats have been managed in the past. The BDCP approach seeks to contribute to the restoration of the health of the ecological systems in the Delta by focusing on ecological functions and processes on a broad landscape scale. Proposed actions would result in fundamental, systemic, long-term physical changes to the Delta, such as substantial alterations to water conveyance infrastructure and water management regimes and extensive restoration of tidal, floodplain, and terrestrial habitats. Addressing such fundamental and large-scale change has necessitated the use of a broad and complex analysis that has derived new analytical tools and an expansion in ways of looking at the Delta system and its species.

The effects analysis is built on and reflects the extensive body of scientific investigation, study, and analysis of the Delta compiled over several decades (see The State of Bay-Delta Science 2008), including the results and findings of numerous studies initiated under the CALFED Bay-Delta Science Program and Ecosystem Restoration Program, the long-term monitoring programs conducted by the Interagency Ecological Program, research and monitoring conducted by state and federal resource agencies, and research contributions of academic investigators. To ensure that the BDCP would be based on the best scientific and commercial data available, the BDCP Steering Committee also undertook a rigorous process to develop new and updated information and to evaluate a wide variety of issues and approaches as it formulated a cohesive, comprehensive Conservation Strategy. This effort included an evaluation in early 2009, conducted by multiple teams of experts, of BDCP conservation options using the CALFED Bay-Delta Ecosystem Restoration Program's Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) evaluation process. Implementation of the DRERIP evaluation process pulled together a large group of scientific experts on various aspects of the Delta ecosystem and its species and the information generated from the process provided some of the most advanced thinking on the effects of conservation actions on key ecological stressors. Results of this DRERIP evaluation were used, as applicable, to add support to various parts of the BDCP effects analysis.

Over 60 species, 14 natural communities, and a broad range of ecological stressors are analyzed in this effects analysis. Some of the species evaluated spend all or most of their lives in the Delta; others spend only portions of their lives navigating their way through various parts of the Delta via the water, land, or air. It is important to consider the effects of the BDCP on each species over the whole of its life span, not just during individual life stages.

The aquatic effects analysis begins with an evaluation of how specific identified stressors could potentially affect the various components of the ecosystem. The results of this analysis are used in the analysis of individual fish species that is described in individual sections that follow and address specific covered fish species. The terrestrial effects analysis begins with an analysis of the effects of BDCP actions on natural communities in the Delta. Similar to the use of the stressors analysis in the analyses of covered fish species, the results of the analysis of natural communities is used in analyzing the effects on specific covered wildlife and plants that follow. Each wildlife and plant species is assessed individually for the effects of BDCP actions and the overall expected outcome for each species is summarized.

The analysis for each evaluation period is based on the physical and biological conditions anticipated to be present with implementation of the BDCP actions at the end of each of the timeframes described in the conservation measures in Chapter 3, *Conservation Strategy*, and the implementation schedule in Chapter 6, *Plan Implementation*. The effects of climate change (e.g., sea level rise, temperature, and hydrology) were evaluated for early and late points in time of BDCP implementation based on climate change scenarios developed by the consultant team, technical staff from the lead agencies, and outside climate change experts (see Appendix K, *Climate Change Evaluation Methods*, for a discussion of this analysis).

The remainder of this section provides descriptions of the effects analysis regulatory scope, spatial scope, actions evaluated, existing biological conditions, temporal scope, and approach to the analysis.

5.1.1 Regulatory Scope

The effects analysis is designed to address the requirements of federal Endangered Species Act (ESA) sections 10 and 7 and California Natural Community Conservation Planning Act (NCCPA). Section 10 of the ESA requires that habitat conservation plans identify the impacts likely to result from the proposed taking of federally listed threatened and endangered species. Section 7 of the ESA requires a biological assessment be prepared that identifies the effects on all federally listed threatened and endangered species likely to be affected by a federal action. Section 7 of the ESA requires the effects analysis to evaluate all direct and indirect effects, including the effects of interrelated and interdependent actions, on federal threatened and endangered species and designated critical habitat[1]. The NCCPA requires that plans provide for the conservation of covered species and natural communities.

The analysis addresses both federal and non-federal actions. Federal actions include all actions by Reclamation, USFWS, and NMFS in the Plan Area and Central Valley Project (CVP) actions upstream of the Delta that are interrelated and interdependent with BDCP actions. Chapter 4, *Covered Activities*, includes descriptions of federal actions in the Plan Area. Federal actions upstream of the Plan Area are described in the BDCP Biological Assessment *[**Note to Reviewers** – the BDCP Biological Assessment is expected to be prepared by Reclamation in 2011 and would include a description of all CVP and Joint CVP/SWP actions that change as a result of BDCP implementation]*. Non-federal actions are all actions of the permit applicants under Section 10 of the ESA permits and Section 2835 of the NCCPA permit in the Plan Area, including changes in SWP operations upstream of the Delta that result from BDCP actions.

This effects analysis may also serve as part of the foundation for state and federal permitting and approvals that will be needed from agencies such as the US Army Corps of Engineers (USACE), US Environmental Protection Agency (EPA), and State Water Resources Control Board (SWRCB) prior to implementing the conservation plan.

5.1.2 Spatial Scope

The analysis addresses the effects of BDCP implementation on covered species, designated critical habitat, and essential fish habitat in the Plan Area[2], upstream Delta tributaries, CVP and State Water Project (SWP) reservoirs, and downstream of the Plan Area. The analysis addresses the effects on NCCP natural communities for the Plan Area and upstream and downstream of the Plan Area if natural communities could be affected by changes in water operations. The Effects Analysis addresses all effects of BDCP implementation on all covered species[3] in the "action

[1] *Effects* of the action refers to the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline… *Indirect* effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur. *Interrelated actions* are those that are part of a larger action and depend on the larger action for their justification. *Interdependent actions* are those that have no independent utility apart from the action under consideration. (50 CFR 402.02)

[2] The Plan Area includes the legal Delta (as defined in California Water Code section 12220) Suisun Marsh, and the Yolo Bypass (see Chapter 1 *Introduction* for description and map location of Plan Area).

[3] The southern resident killer whale is not a BDCP proposed covered species but is evaluated in the Effects Analysis because it is a listed species that is potentially indirectly effected by BDCP actions

area" as defined under ESA regulations[4]. For information on Plan Area boundaries and the distribution of biological resources within the Plan Area and in relevant upstream and downstream locations see Chapter 2, *Existing Ecological Conditions* and Appendix A, *Covered Species Accounts*.

5.1.3 Actions Evaluated

The analysis evaluates the construction of a new water diversion, isolated conveyance and other water-related facilities, operations of current system components, dual operations of current and proposed facilities, power plant operations, physical habitat restoration, protection and enhancement of existing habitats, control of nonnative species, and other actions described in Chapter 3, *Conservation Strategy*, that address ecological stressors on the system and covered species. Assumptions used in this analysis regarding the footprint locations of new conveyance facilities and descriptions of construction-related activities (e.g., construction schedule, construction methods) and maintenance activities and schedules for new facilities have been provided by DWR. Full descriptions of conservation measures evaluated in the Effects Analysis are in Chapter 3, *Conservation Strategy*. Full descriptions of covered activities evaluated in the Effects Analysis are in Chapter 4, *Covered Activities*.

5.1.4 Existing Biological Conditions

The effects analysis evaluates how conservation measures and covered activities result in changes to the existing biological conditions of the covered species and natural communities. Existing biological conditions for natural communities are described in Chapter 2, *Existing Ecological Conditions* and for covered species in Appendix A, *Covered Species Accounts*. The Effects Analysis evaluates the aggregate effect on covered species of the environmental baseline[5] and the implementation of the BDCP.

5.1.5 Temporal Scope

Implementation of the BDCP is divided into two periods: 1) the "Near-Term" implementation period is defined as the period before the North Delta Diversion Facilities become operable (i.e., through-Delta conveyance operations only) and 2) the "Long-Term" implementation period is defined as the period after the North Delta Diversion Facilities become operable (i.e., dual conveyance operations). The effects analysis assesses the outcomes for covered species and natural communities at three timeframes over the term of the BDCP:

[4] *Action area* means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action. (50 CFR 402.02)

[5] Under ESA regulations, the *environmental baseline* includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process. (50 CFR 402.02)

1. Near-Term (NT) Evaluation Period: Effects from BDCP authorization through approximately 10 years following approval (i.e., conditions during the period prior to completion of construction of a new isolated conveyance facility and dual operations);

   *[**Note to Reviewers**: There are currently no proposed BDCP near-term water operational criteria; therefore, the analysis is based on a continuation of the SWP and CVP operations under existing authorizations. The effects of near term actions were evaluated for all covered wildlife and plant species. For covered fish species, the NT period is not called-out separately in the evaluation of operations (since operations are assumed not to change from EBC), but NT effects on fish are evaluated for facilities construction (i.e., intake structures). While overall habitat restoration effects on covered fish species are included in this document, the more limited effects on fish of NT habitat restoration will be provided in the evaluation currently underway.]*

2. Early Long-Term (ELT) Evaluation Period: Effects from approximately 10 years following BDCP authorization through approximately 15 years following authorization (approximately 5 years after initiation of dual operations); and

3. Late Long-Term (LLT) Evaluation Period: Effects from approximately 15 years following BDCP authorization through 50 years following authorization (the end of the permit terms).

The analysis for each evaluation period is based on the physical and biological conditions anticipated to be present with implementation of the BDCP actions at the end of each of the timeframes as described in the conservation measures in Chapter 3, *Conservation Strategy* and the implementation schedule in Chapter 6, *Plan Implementation*. The effects of climate change (e.g., sea level rise, temperature and hydrology) on conditions within each timeframe were evaluated for the early long-term and late long-term timeframes based on climate change scenarios developed by the consultant team, technical staff from the lead agencies, and outside climate change experts (see Appendix K, *Climate Change Evaluation Methods*).

5.1.6 Approach to the Analysis

The BDCP Effects Analysis utilized a broad range of analytical tools including hydrologic and hydrodynamic models; temperature models; biological models for different life stages of covered fish species; statistical relationships between physical conditions and covered fish species; conceptual models for ecological conditions and individual fish species; and habitat models for fish, wildlife, and plants. Some of these models were created and used for the first time in this analysis. The methods used were developed in collaboration among technical experts from USFWS, NMFS, DFG, Reclamation, and DWR and other experts on specific species addressed and analytical tools used.

The specific location of and details of implementation approaches to most of the BDCP conservation measures are not known and will not be known until BDCP is implemented through an adaptive management process. As such, the level of adverse and beneficial effects on biological resources were evaluated using reasonable assumptions regarding the potential location and implementation approaches that could be applied during BDCP implementation. Major types of assumptions used in the analysis are listed in Section 5.3.1.2.

The analysis was conducted using an ecologically scaled hierarchy. Changes to aquatic ecosystem-level functions (e.g., flow, hydrodynamics, physical habitat restoration, food web dynamics, toxic contaminants, and salinity) that are relevant to multiple fish species were evaluated first. The results of these analyses were then used in the individual covered fish species evaluations along with species-specific evaluation tools. In similar fashion, effects on natural communities (e.g., estimating the extent of effects and effects on ecological processes, gradients, and habitat function) were evaluated and the results were then used in the evaluation of covered wildlife and plant species along with species-specific evaluation tools.

Covered fish species were evaluated using a broad range of available tools and best professional judgment. Fish species were evaluated by specific life stages (e.g., egg/embryo, larvae, juvenile, adult) and then the effects on all life stages were combined to synthesize a summary conclusion of population and species level effects. In many cases, more than one tool or approach was used to assess the effect of an ecological stressor on a fish species, providing a better understanding the full range of potential outcomes and adding greater certainty to conclusions. Where there was uncertainty regarding the use of an analytical tool or approach, the strengths and weaknesses of the tool or approach were described.

Covered wildlife and plant species were evaluated mainly through the use of occurrence data and geographic information system (GIS) based models of potentially suitable habitat developed specifically for the BDCP. GIS was used extensively in spatially identifying the location of existing species habitat and of proposed BDCP actions and in calculating the extent of overlap between them. GIS proximity models were also developed and used to estimate disturbance effects of covered activities on specific wildlife and plant species.

The analysis provides an estimate of effects on:

- covered species, where possible at the individual, population, and species levels, including estimates of take;

  *[**Note to Reviewers**: Estimates of take have not been completed for covered fish species.]*

- designated critical habitat;
- natural communities;
- Essential Fish Habitat (EFH)[6].

Conclusions of the effects analysis are predictions based on current knowledge which has many gaps and uncertainties. As a result, the level of scientific uncertainty is identified throughout the methods, results, and conclusions discussions.

[6] Under the Magnuson-Stevens Act, essential fish habitat for federally managed fish species is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." Chinook salmon are the only BDCP covered species identified for management under this Act.

Climate change is an important factor in predicting the future biological conditions in the Delta ecosystem and for covered species. The evaluation includes modeling of a range of possible climate change outcomes for hydrology, sea level, and water temperature. Climate change projections are included in the analysis as part of the aggregate effect of existing biological conditions and the proposed BDCP on covered species. The analysis includes the evaluation of a future with climate change but without implementation of BDCP to separate the effect of the BDCP on ecological processes and species from the effects of climate change.

For each covered species, the summary conclusions consider the viability factors of abundance, spatial distribution, population growth, and genetic diversity, along with the level of uncertainty, in predicting the expected outcome.

5.2 STATUS OF THE EFFECTS ANALYSIS

The full effects analysis was initiated in early February 2010, after several years of discussions and evaluations culminated in a set of conservation measures and long-term water operations approved for purposes of analysis by the BDCP Steering Committee on January 29, 2010.

Discussions directly related to performance of the effects analysis were informally conducted prior to June 2009 as consultants and federal (NMFS, USFWS, and Reclamation) and state (DWR and DFG) agency staff began to formulate an approach to evaluate effects of the BDCP. The basic approach to performing the effects analysis was developed between June and November 2009. During this time, the consultants worked with federal and state agency staff to discuss an approach to a combined effects analysis that would be used in preparation of the following documents:

- BDCP HCP/NCCP;
- BDCP EIR/EIS biological resources section;
- BDCP biological assessment; and
- USFWS and NMFS biological opinions.

A “mini-effects analysis” for the covered fish species was conducted between November 2009 and January 2010 with the charge of identifying major issues in the proposed conservation strategy being considered at that time and elevating these issues to the BDCP Steering Committee. The mini-effects analysis evaluated the effects of proposed water operations and a set of proposed habitat restoration and other stressors conservation measures identified at Steering Committee meetings during summer and fall 2009. The analysis process was directly overseen by the Effects Analysis Managers, a group of policy-level individuals initially from the five federal and state agencies and PREs, and later joined by NGOs. The mini-effects analysis evaluated the effects of the BDCP only on covered fish species and was divided into three interactive groups: foodweb and water quality, anadromous fish, and pelagic fish. These groups were composed of technical experts that were selected by Effects Analysis Managers from agencies, NGOs, PREs, and consultants. The analysis process consisted primarily of weekly meetings of each group to discuss and document the effects of proposed actions on the covered fish species. Between meetings, group members conducted analyses and wrote results, and presented their findings at the next meeting. The results were documented as a set of tables for each species that were organized by lifestage and stressor.

The results of the mini-effects analysis were discussed at Steering Committee meetings in January 2010. While the mini-effects analysis concluded that the project was mostly beneficial, several areas of scientific disagreement were identified. As a result, the Steering Committee made minor revisions to the proposed conservation strategy.

Early in February 2010, the full effects analysis was initiated to evaluate the revised Conservation Strategy, with the exception of the near-term operational criteria, which were still under development. The full effects analysis includes the evaluation of the BDCP on covered fish, plant, and wildlife species as well as covered natural communities. Methodologies for the analyses were discussed with technical experts from federal and state agencies, NGOs, and PREs through June 2010. Preliminary results of these analyses were presented to Effects Analysis Managers between May and July. Preliminary results of the effects analysis for covered wildlife and plant species and natural communities were also presented at the July 15, 2010 Steering Committee meeting. The Working Draft Effects Analysis was delivered to the Effects Analysis Managers on August 19, 2010.

The five agencies (NMFS, USFWS, Reclamation, DFG, and DWR) reviewed the August 19, 2010 Effects Analysis. The consultants reviewed and are addressing comments that were provided to them in writing; and entered into extensive discussions with the agencies, PREs, and NGOs regarding areas of significant scientific disagreement. In an effort to reach resolution regarding areas of scientific disagreement, a series of “theme team” meetings occurred during September and October 2010.

Two “theme teams” were established, one for anadromous fish and one for pelagic fish species. These “theme team” meetings included technical staff from each of the agencies and the consultant team, and were joined by representatives from the PREs and NGOs. These teams were overseen by an Oversight Committee whose composition included the BDCP Management Team and managers from the each of the five agencies, PREs and NGOs. Each meeting was led by three managers, one from the federal agencies, one from the state agencies, and one from the consultant team. The three managers reported regularly to the Oversight Committee regarding the status of the scientific discussions at the “theme team” meetings.

The charge to the “theme teams” was to air and resolve major issues with the effects analysis. Issues that could not be resolved within the “theme team” process, either because of significant technical disagreement or because the issues required policy-level decisions, were to be elevated to the Oversight Committee for additional discussion and resolution by high level agency managers. In late October, a new process evolved as the Oversight Committee began to discuss possible refinements to the BDCP Conservation Strategy based on the review of the aquatic effects analysis and subsequent “theme team” discussions and efforts. The “theme team” process will continue in the future.

To date, the following six items have been identified as requiring further consideration and evaluation by the Effect Analysis Oversight Committee. These are the first six items identified and others may be identified.

1. **North Delta intake configuration**
   Near-shore, in-river intakes in the north Delta create increased predator habitat. This is predicted to have large predation effects on juvenile salmonids. An onshore intake design will greatly reduce the adverse effects of predation of the design evaluated in the effects analysis. A decision was made at the November 10, 2010 Oversight Committee meeting to analyze an on-bank configuration for the January 31, 2011 Draft Effects Analysis. Refinements to the locations and sizes of intakes are also under consideration.

2. **Increased spring-run salmon egg mortality**
   Approximately 10 percent of the spring-run Chinook salmon population spawns in the Sacramento River. Preliminary modeling results indicate that water temperatures could potentially cause a 10 percent increase in spring-run Chinook salmon egg mortality during wet, below normal, and above normal water year types for the 10 percent of the population that spawns in the Sacramento River.

3. **Reduced Sacramento River flows downstream of the intakes**
   Flows are reduced downstream of the north Delta diversion facilities during spring, summer, and fall in wet, above normal, and below normal water years. This may have an effect on migratory cues of adult anadromous fish species, and possibly increase straying into other adjacent watersheds.

4. **April-May south Delta operations potentially effecting Delta smelt**
   OMR flows in April and May would be modified by the proposed BDCP long-term operations, as compared to the operations described in the existing biological opinions.

5. **Spring X2/outflow effects on longfin smelt**
   The X2 location is higher (more easterly) in winter and spring months, which may negatively affect longfin smelt abundance according to a statistical correlation between X2 location and longfin smelt abundance.

6. **Fall X2 - Changes in hydrodynamics potentially affecting delta smelt**
   If one assumes that the Fall X2 objective is in the baseline and compares that to the proposed project without the objective, the X2 position is higher (more easterly) in fall and summer months in the above normal and wet water years.

The aforementioned issues will be the subject of further analysis after the release of the November 2010 document. Moreover, to ensure that the final effects analysis is sufficiently rigorous, comprehensive and complete, the technical discussions between the state and federal agencies, PREs and NGOs will continue throughout the development of the effects analysis and related documentation. Potential refinements are anticipated to be incorporated into the final BDCP effects analysis for the proposed project, which is expected in early 2011.

5.3 METHODOLOGY

*[**Note to Reviewer:** Comments and questions have been received on the methods used for the effects analysis. The use of specific methods are the subject of ongoing "theme team" and Oversight Committee meetings.]*

This section provides a summary of methods used to conduct the August 19, 2010 Draft Effects Analysis and the September 9, 2010 Draft Enhanced Habitat Analysis for covered fish species. It contains short descriptions of analytical tools, assumptions, and specific analytical approaches. These methods were developed largely in collaboration with technical experts from USFWS, NMFS, DFG, Reclamation, DWR and others. The effects analysis is divided into aquatic and terrestrial analyses with little overlap. Aquatic methods consist of initial physical modeling based on operating criteria agreed to at the January 29, 2010 Steering Committee meeting that fed inputs into biological models and system wide analyses, such as water quality, toxics, and the aquatic foodweb (Figure 5-1). Biological models and system-wide analyses informed species and lifestage evaluations. For terrestrial species, the effects of the BDCP on natural communities were evaluated primarily using GIS analysis with some physical model outputs. GIS, species habitat models, and output from natural community-level analyses were used to evaluate effects on individuals covered wildlife and plant species.

The BDCP was divided into three evaluation periods for the Effects Analysis, near-term, early long-term and late long-term (Section 5.1). The August 19, 2010 Draft Effects Analysis only included evaluations during the early late long-term periods because near-term water operations had not yet been agreed upon.

The proposed project was modeled with predicted future climate change for the early long-term and late long-term periods. As a result, the existing biological conditions to which the proposed project was compared also included climate change predictions for the early long-term and late long-term evaluation periods. To determine the effects of the BDCP on a specific parameter without incorporating the effects of future climate change, the results of that parameter for the existing biological conditions scenario was compared to that of the proposed project during the same evaluation period.

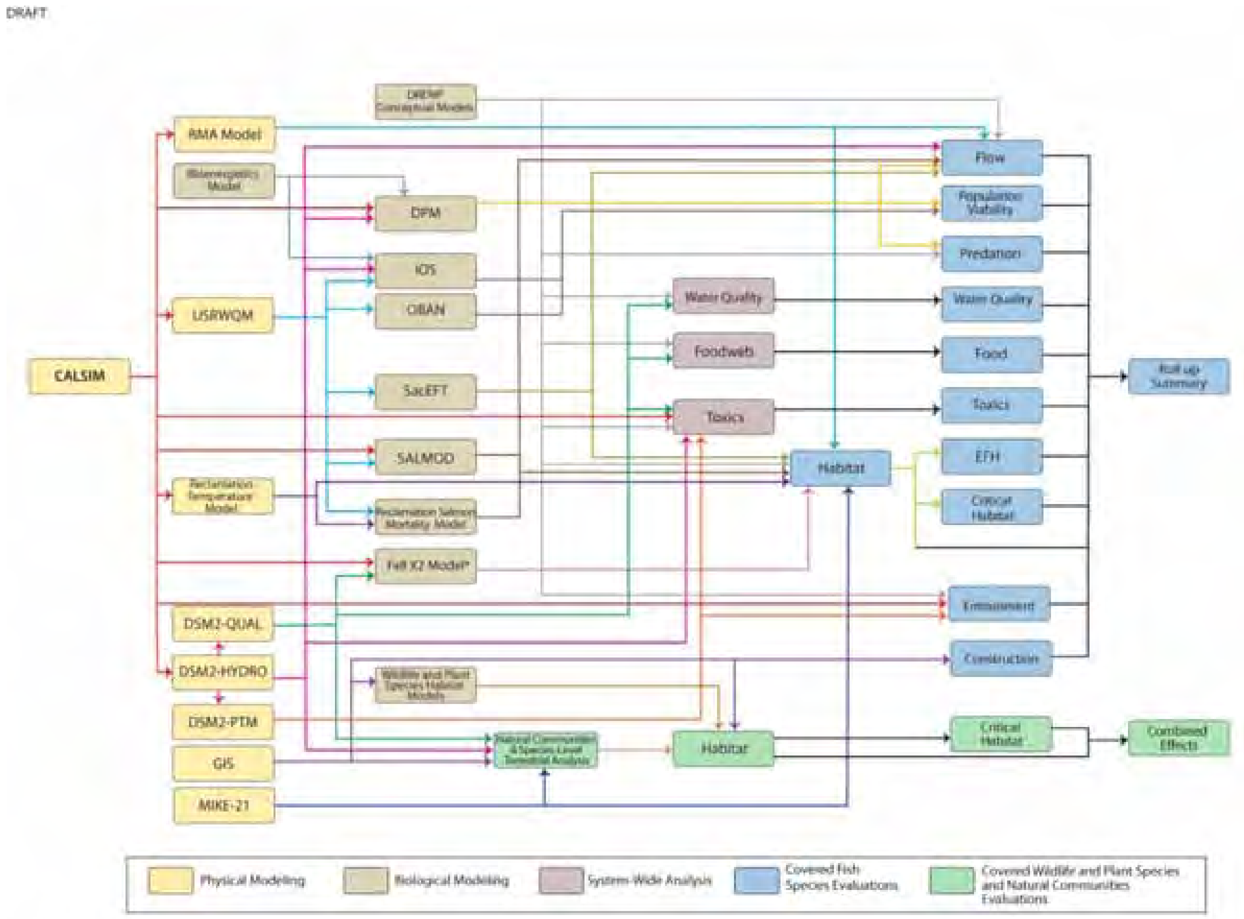

Figure 5-1. Relationships Among Physical and Biological Modeling Tools and System-Wide and Species-Level Evaluations for the BDCP Effects Analysis

5.3.1 Analytical Tools and Assumptions

5.3.1.1 Analytical Tools

Several types of analytical tools were used in performance of the aquatic effects analysis. These analytical tools can be categorized as physical and biological. Figure 5-1 summarized the relationships between the various analytical tools and biological evaluations used in the effects analysis. The following sections briefly describe the models, their outputs and use in the effects analysis.

5.3.1.1.1 CALSIM II

The CALSIM II planning model simulates the operation of the CVP and SWP over a range of hydrologic conditions. CALSIM II produces key outputs that include river flows and diversions, reservoir storage, Delta flows and exports, Delta inflow and outflow, deliveries to project and non-project users, and controls on project operations. Inputs to CALSIM II include water diversion requirements (demands), stream accretions and depletions, rim basin inflows, irrigation efficiency, return flows, non-recoverable losses, groundwater operation, and in-Delta operating criteria. In-Delta operating criteria for intake bypass flows, Sacramento River pulse flows, Delta Cross Channel operations, X2 standards, water quality standards, Yolo Bypass spills, and south Delta exports and flows that were agreed to at the January 29, 2010 Steering Committee were used as model inputs. Sacramento Valley and tributary rim basin hydrologies were developed for CALSIM II using a process designed to adjust the historical sequence of monthly stream flows over an 82-year period (1922 to 2003) to represent a sequence of flows at a future level of development. As can be seen in Figure 5-1, CALSIM II outputs were used as the basis for other physical and biological models and analyses.

5.3.1.1.2 DSM 2

DSM2 is a one-dimensional hydrodynamic and water quality simulation model used to simulate hydrodynamics, water quality, and particle tracking in the Sacramento-San Joaquin Delta (DWR 2002). The DSM2 model has three separate components, or modules: HYDRO, QUAL, and PTM.

DSM-HYDRO simulates velocities and water surface elevations and provides the flow input for QUAL and PTM. DSM2-HYDRO predicts changes in flow rates and depths as a result of the BDCP and climate change. Outputs were used to determine the effects of these hydrodynamic parameters on covered terrestrial and fish species and as inputs to other biological models.

The DSM-QUAL module simulates fate and transport of conservative and non-conservative water quality constituents, including salts, given a flow field simulated by HYDRO. Outputs were used to estimate changes in salinity and their effects on covered species as a result of the BDCP and climate change. Outputs of this model were used in the system-wide analysis of toxics.

An add-on to the DSM-QUAL module, the nutrient model, predicts the effects of changes to hydrology on temperature, dissolved oxygen, nitrogen and phosphorus concentrations (including speciation of each), and algal production. Outputs were used in the system-wide analyses for water quality, the aquatic foodweb, and toxics.

The DSM-PTM module simulates fate and transport of neutrally buoyant particles through space and time. Outputs were used to estimate the effect of hydrodynamic changes on the fate and transport of larval fish and toxics through the Delta.

5.3.1.1.3 RMA Model

The RMA model is a generalized free surface hydrodynamic model that is used to compute two-dimensional depth-averaged velocity and water surface elevation. The model uses CALSIM outputs as well as existing bathymetry and topography as inputs. The RMA model output was used to evaluate the effects tidal habitat restoration on flows throughout the Delta and the subsequent effects on covered species.

5.3.1.1.4 Upper Sacramento River Water Quality Model (USRWQM)

The USRWQM uses the HEC-5Q model to simulate mean daily (using 6-hour meteorology) reservoir and river temperatures at key locations on the Sacramento River. After being temporally downsized to daily average flows, monthly flows from CALSIM II for an 82 year period (WY 1922-2003) are used as input into the USRWQM. Output from the USRWQM was used as an input to a number of biological models for upstream lifestages of salmonids and sturgeon.

5.3.1.1.5 Reclamation Temperature Model

The Reclamation Temperature Model is a reservoir and stream temperature model that simulates monthly reservoir and stream temperatures for evaluating the effects of CVP/SWP project operations on mean monthly water temperatures in the Feather, Stanislaus, Trinity, Sacramento, and American river basins and upstream reservoirs based on hydrologic and climatic input data. The model uses CALSIM II output. The Reclamation Temperature Model was used to predict the effects of operations on water temperatures in the Feather, Stanislaus, Trinity, and American river basins, which were then used as inputs to the Reclamation Salmon Mortality Model and species-specific habitat evaluations.

5.3.1.1.6 MIKE-21

The MIKE-21 flexible mesh model is a two-dimensional hydrodynamic model that predicts changes in water surface elevation, flow, and average velocity in the Yolo Bypass as a result of inundation under CM14 Yolo Bypass Fisheries Enhancements. The model incorporates existing LiDAR and Toe Drain/Tule Canal bathymetry as well as estimated west-side tributary flows. Outputs were used to predict the potential benefits to species that use the Yolo Bypass as habitat when inundated (e.g., splittail, Chinook salmon) and to food production.

5.3.1.1.7 Delta Regional Ecosystem Restoration Implementation Plan (DRERIP)

The DRERIP conceptual models and scientific evaluation process were developed to aid in planning and decision making for potential ecosystem restoration actions in the Delta. Conceptual models contain background biological information on covered species and their stressors. The DRERIP scientific process was used twice for BDCP, once for a coarse-level evaluation of draft conservation measures in late 2008, then for a full evaluation of draft conservation measures in early 2009. Results of these previous evaluations, as well as the conceptual models themselves, were used for qualitative assessments and best professional judgment throughout the effects analysis.

5.3.1.1.8 Striped Bass Bioenergetic Model

A striped bass bioenergetic model was developed to estimate predation by striped bass based on water temperature, striped bass size, and the density and size of prey encountered. Inputs to the model include water temperature, prey density, and striped bass fork lengths taken from historical data for the Delta. This model was used to estimate predation rates of striped bass on covered fish species at the proposed North Delta diversion intakes. Results of the model were also used as inputs to the Delta Passage Model and Interactive Object-Oriented Salmon Simulation (IOS) Model.

5.3.1.1.9 Delta Passage Model

The Delta Passage Model (DPM) simulates migration and mortality of juvenile Chinook salmon entering the Delta from the Sacramento, Mokelumne, and San Joaquin rivers through a simplified Delta channel network similar to that depicted in Perry et al. (2010), and provides quantitative estimates of relative juvenile Chinook salmon survival through the Delta to Chipps Island. The DPM is based on a detailed accounting of migratory pathways and reach-specific mortality as smolts travel through a network of Delta channels. The model uses input from CALSIM II, DSM2-HYDRO, and the bioenergetics model to estimate predation pressure on juvenile salmon. The model was used to predict relative reach-specific survival estimates for winter, spring, and fall-run juvenile Chinook salmon passing through the Delta.

5.3.1.1.10 Interactive Object-Oriented Salmon Simulation (IOS) Model

The IOS model is a spatially explicit winter-run Chinook salmon life cycle model that examines environmental effects of multiple parameters on the abundance, size, and survival of winter-run Chinook salmon through successive life-stages. The IOS model uses simulated upstream daily flow and water temperatures from USRWQM and in-Delta flows from DSM2 as inputs. The model was used to evaluate the effects of multiple aspects of the BDCP on survival of winter-run Chinook salmon and population viability.

5.3.1.1.11 Oncorhynchus Bayesian Analysis (OBAN) Model

The OBAN model is a winter-run Chinook salmon life cycle analytical framework used to predict the effects of multiple actions on winter-run Chinook salmon by incorporating various sources of mortality in all phases of the life history. The model uses simulated upstream daily flow and water temperatures from USRWQM. Complementary to IOS, OBAN was used to predict the effects of multiple BDCP actions on winter-run Chinook salmon survival and population dynamics and population viability.

5.3.1.1.12 Sacramento River Ecological Flows Tool (SacEFT)

The SacEFT model is a database-centered software system for linking flow management actions to changes in the physical habitats for several focal species of concern. The model employs a set of functional relationships to generate habitat-centered performance measures for all races of Chinook salmon, steelhead, and green sturgeon that change in response to flow management scenarios. The model uses daily temperature and flow outputs from the USRWQM. SacEFT was used to predict the effects of flow changes in the Sacramento River on a set of physical (spawning area, juvenile rearing area, redd scour, and redd dewatering) and biological (egg survival, juvenile stranding, and juvenile growth) parameters for all races of Chinook salmon and steelhead. The model also predicted flow-based effects on green sturgeon egg survival.

5.3.1.1.13 SALMOD

SALMOD estimates both anadromous and resident juvenile salmonid production in freshwater, as a result of habitat. Habitat area (quantified as weighted usable area or WUA) is computed from flow versus microhabitat area functions developed empirically or by using Physical Habitat Simulation (PHABSIM) software or a similar physical habitat model. The inputs to the model include CALSIM flows, water temperature from USRWQM, spawning distribution based on aerial surveys, spawning timing depending on salmon race, and the number of spawners provided by the user (e.g., recent average escapement). SALMOD was used to predict the effects of flows in the Sacramento River on habitat quality and quantity and ultimately on juvenile production of all races of Chinook salmon.

5.3.1.1.14 Reclamation Salmon Mortality Model

This model uses temperature exposure mortality criteria resulting from changes in water operations for the three life stages, spawning distribution data, and output from the river temperature models to estimate percentages of egg and fry losses of a given brood of eggs for each run of Chinook salmon. The model uses water temperature output from the USRWQM for the Sacramento River; and the Reclamation Temperature Model for other Trinity, Feather, American, and Stanislaus rivers. The model was used to predict temperature-related proportional losses of eggs and fry for each race of Chinook salmon in the Trinity, Sacramento, Feather, American, and Stanislaus rivers.

5.3.1.1.15 Fall X2 Model

Delta smelt abiotic habitat during fall (September-December) has been calculated as surface area and related to the position of X2 (Feyrer et al. 2007). The use X2 position as an indicator of delta smelt habitat, and the technical basis for this analysis (Feyrer, et. Al. 2007), are the subject of significant scientific debate. The model was used nevertheless in the effects analysis because it was an RPA action identified by the USFWS in the current biological opinion. The statistical relationship was also modified based on BDCP proposed habitat restoration.

5.3.1.1.16 Covered Wildlife and Plant Species Habitat Models

As part of the BDCP analysis, habitat models were developed for each of the covered wildlife and plant species based on vegetation/land cover associations that support each species' habitat type and the spatial requirements (e.g., minimum habitat patch size that can support use by a species, proximity to other habitat areas that is necessary to support species use) of each species. Descriptions of the components of each species habitat model (i.e., the GIS vegetation/land cover types and other assumptions used to define each covered species habitat types) and maps of each species modeled are presented in Appendix A, *Covered Species Account*s.

5.3.1.2 Major Assumptions

The BDCP effects analysis relies on many assumptions regarding how the physical and biological processes of the Plan Area function and support natural communities and covered species; how restored habitats will develop over time; and how the physical and biological processes, natural communities, and covered species will respond to implementation of the conservation measures over time. These assumptions represent a reasonable interpretation of the best available information regarding how the Delta ecosystem functions and the life history requirement of the covered species. These assumptions are continuing to be refined and improved as new information is generated through the BDCP planning process.

Major assumptions used to conduct the effects analysis have been formulated for the following topic areas:

- The schedule for implementing conservation measures (from the implementation schedule presented in draft Chapter 6, *Implementation Plan*);
- Footprint locations and extents for habitat restoration/enhancement and other stressors conservation measures used to calculate effects on existing natural communities and habitat, effects on water quality and hydrodynamic conditions, and to model the extent of future restored tidal habitat;
- Habitat restoration and enhancement designs and the development of restored and enhanced habitat functions;
- Future effects of sea level rise;

- Types of and locations for implementing nonnative predator control actions and the effectiveness of such actions;
- Effectiveness of non-physical fish barrier and methylmercury control actions;
- Extent, frequency, and effectiveness of nonnative aquatic vegetation control actions;
- Location and effects of conveyance facilities construction and maintenance activities;
- Types and effectiveness of Yolo Bypass fisheries enhancement actions;
- Effects of restoration and construction-related noise and visual disturbances on covered wildlife species.

5.3.2 System-Level Analysis Approach to Support Assessments

5.3.2.1 Physical Modeling

To support the effects analysis, physical modeling is required to evaluate changes to conditions affecting resources within the Delta as well as effects to upstream and downstream resources. Hydrologic, operations, hydrodynamics, water quality, and particle tracking analyses are required to provide baseline and comparative information for habitat, fisheries, water supply, and water quality assessments. These analyses are also required to assess changes in the function of the Proposed Project under varying assumptions of future, non-project conditions such as climate change, future demands, and changes in Delta landforms (planned and unplanned).

The BDCP physical modeling can be separated into the following major elements:

1. Climate and Sea Level Change Scenarios;
2. Regional Hydrologic Modeling;
3. Hydrology and Systems Operations Modeling;
4. Yolo Bypass Floodplain Hydraulics;
5. Reservoir and River Temperature Modeling;
6. Delta Hydrodynamics and Water Quality Modeling; and
7. Delta Particle Transport and Fate Modeling.

Climate and sea level change analysis was conducted using a set of climate change scenarios that were spatially downscaled and entered into the regional Variable Infiltration Capacity (VIC) hydrologic model. This macro-scale model translated the effects of future climate conditions on watershed processes ultimately affecting the timing and volume of runoff. Results from this model informed hydrologic and system operations modeling, which was conducted using CALSIM II. As shown in Figure 5-1, CALSIM II formed the base of hydrologic modeling from which multiple hydrologic, hydrodynamic, and biological models and analyses received inputs. Yolo Bypass floodplain hydraulics were predicted using MIKE-21, a two-dimensional modeling for the Yolo Bypass, and CALSIM II output to better understand inundation characteristics under modifications to the Fremont Weir. For upstream out-of-Delta analyses, CALSIM II outputs were entered into the USRWQM, which calculated daily flows and water temperatures in the upper Sacramento River and the Reclamation Temperature Model, which calculates monthly averaged reservoir and river temperatures in multiple upstream rivers and reservoirs. Outputs of USRWQM were used in a number of biological models and analyses to determine the effect of flows and water temperature on anadromous fish species migration and survival. In the Delta, CALSIM II outputs informed Delta hydrodynamics and water quality modeling such as the RMA model, DSM2-HYDRO and DSM2-QUAL. These models were used to predict the effects of the BDCP on to tidal stage, velocity, flows, and salinity in the Delta. CALSIM II outputs also informed Delta particle transport and fate modeling using DSM2-PTM.

5.3.2.2 Food Web

The BDCP is predicted to affect the Bay-Delta foodweb in two primary ways: (1) changes to hydrology and hydrodynamics in Delta channels; and (2) restoration of tidal marsh, riparian, channel margin, and floodplain. To evaluate the effect of hydrology and hydrodynamics, the DSM2-QUAL nutrient model was used to estimate algal production. The effects of habitat restoration on the foodweb was estimated using existing data from within and outside the Delta, and best professional judgment was used to estimate the effects on covered fish species.

5.3.2.3 Toxics

There were six toxicants deemed important to the Delta aquatic community and, therefore, analyzed for the effects analysis: mercury, selenium, pyrethroids, endocrine disrupting compounds, copper, and ammonia/um.

The BDCP is predicted to affect mercury loads and methylmercury production as a result of three actions: (1) water operations, (2) tidal habitat restoration, and (3) enhanced Yolo Bypass inundation. The effects of the BDCP water operations on mercury were evaluated using DSM-QUAL source water fingerprinting outputs. The proportion of water predicted from DSM-QUAL from the Sacramento River and San Joaquin River at two locations in the Delta was multiplied by historical mercury loads calculated for water from each river. To determine the effects of tidal habitat restoration on methylmercury loads, average rates of methylation in wetlands and open water areas from the Delta mercury TMDL were multiplied by the area (in acres) of restored habitat and floodplain to determine estimates of overall production of methylmercury in project areas. To determine the effects of Yolo Bypass inundation on methylmercury loads, the empirical relationship between net methylmercury production in Yolo Bypass and outflow from Foe et al. (2008) was applied to the frequency duration using CALSIM II output and area of inundated land using MIKE-21 output to determine the overall change in net methylmercury production as a result of increased inundation of the Yolo Bypass.

The BDCP is predicted to affect selenium loads by changing the hydrology of the Delta such that the proportion of water entering the Delta from the San Joaquin versus the Sacramento River will be altered. This effect was analyzed using the source water fingerprinting method described for methylmercury.

The BDCP is expected to result in regional changes in pyrethroid concentrations as a result of changes in hydrodynamics. While the BDCP is not a source of increased pyrethroid loading, it may affect dilution flows both positively and negatively by changing circulation patterns. The BDCP may also reduce pyrethroid loading when land is retired from more intensive land uses and restored. The effects of water operations on pyrethroids entering Delta waterways and exposure to fish were analyzed in three ways. First, changes in loads of upstream pyrethroid sources into the Delta were estimated by calculating median application rates of multiple pesticides from Department of Pesticide Regulation (DPR) databases for each county within the Sacramento and San Joaquin River watersheds and using the source water fingerprinting techniques described for methylmercury to predict how much water from each watershed would enter the Delta. Second, effects of water operations on changes to pyrethroid concentrations from waste water treatment plants (WWTPs) were estimated using existing concentrations of pyrethroids from Weston and Lydy (2010). These concentrations, in combination with discharge estimates from WWTPs outside the Delta, as well as the Stockton and Sacramento WWTPs, were used to compare estimated annual loads of pyrethroids entering Delta waterways with and without the BDCP. Third, residence time calculations from DSM2-PTM at multiple locations within the Delta were used to predict the effect of water operations on the exposure time of an organism to pyrethroids within the Delta. The effect of changes in land use resulting primarily from BDCP habitat restoration was analyzed by using DFG land use maps to determine acreages of specific crop types on hypothetical habitat restoration sites, calculating average application rates of pyrethroids on each crop type from the DPR database, and calculating total application rate. Using the assumption that 0.11 percent of the pyrethroid application loads onto fields enters the Sacramento and San Joaquin waterways as runoff (Werner and Oram 2008), the total reduction in loads was calculated.

The analysis of the effects of the BDCP on changes to endocrine disrupting compound loads was combined with the analysis of pyrethroids because the best available data on EDC loads to the Delta consist of information on pyrethroid applications for agricultural and commercial use and in wastewater treatment plant effluent.

While the BDCP is not a source of increased copper loading, it is expected to affect copper loads as a result of four actions: water operations, nonnative aquatic vegetation control under CM9, tidal habitat restoration in the Cache Slough ROA and enhanced floodplain inundation in the Yolo Bypass, and changed land use. The effect of water operations were predicted using existing copper concentrations and the source water fingerprinting methods described for methylmercury. The effect of nonnative aquatic vegetation control on copper concentrations in Delta waterways was addressed using existing application rates used by the Department of Boating and Waterways for their existing nonnative plant removal programs and the acreage of anticipated removal under the BDCP. Due to a paucity of information, a qualitative assessment was conducted to determine the effect of restoration in Cache Slough and the Yolo Bypass, two locations with large copper deposits. The effect of changes in land use on copper pesticide use was analyzed identically to the analysis of pyrethroid pesticides.

The effect of the BDCP on ammonia/ammonium loads was estimated using the DSM2-QUAL nutrient model. The analysis did not assume future changes to ammonia/ammonium loading based on existing trends from WWTPs.

5.3.2.4 Water Quality

The effect of the BDCP on water temperature, dissolved oxygen concentration, turbidity, and salinity in the Delta and Suisun Marsh/Bay were estimated. Effects of the BDCP on Delta-wide water temperature and dissolved oxygen concentration were estimated using the DSM2-QUAL nutrient model. Additional analyses were conducted to determine the effects at smaller spatial scales. Effects on turbidity were assessed using the RMA turbidity model. Predicted changes in salinity were estimated using the DSM2-QUAL model.

5.3.3 Fish Species Assessment Methods

This section briefly describes the methods for used for each of the analyses of covered fish species. These analyses are for upstream spawning and rearing habitat (including flow and water temperature), in-Delta habitat, migration flows, entrainment, in-Delta toxics and water quality, predation, food availability, hatcheries, harvest, and construction.

5.3.3.1 Upstream Spawning and Rearing Habitat

Upstream spawning and rearing habitat was evaluated only for anadromous species: salmonids, sturgeon, and lamprey. A number of analytical tools were available to analyze multiple parameters depending on the species and the parameter. For example, the Reclamation Salmon Mortality Model and SacEFT were both used to determine the effects of flows on redd dewatering risk and other factors on Chinook salmon and steelhead eggs; SacEFT was used to determine the effect of flows on temperature related mortality of green sturgeon eggs; available literature in combination with water temperature outputs from USRWQM and the Reclamation Temperature Model were used to estimate the incidence of lethal temperatures for lamprey eggs and ammocoetes. Other upstream variables evaluated include spawning weighted usable area, redd dewatering, redd scour, juvenile stranding, and rearing weighted usable area, primarily through the use of SacEFT, SALMOD, and the Reclamation Salmon Mortality Model for salmonids. Temperature and flow-related effects for larval and adult salmonids and sturgeon were further evaluated using outputs from USRWQM, CALSIM, and the Reclamation Temperature Model in combination with known or assumed thermal tolerances for each species. Flow-related effects (redd dewatering) for lamprey were analyzed using CALSIM II and USRQWM model outputs.

5.3.3.2 In-Delta Habitat

In-Delta habitat was analyzed for all lifestages of delta smelt, longfin smelt, and splittail and the juvenile and adult phases of anadromous species using hypothetical restoration locations developed by RMA to assist in the flow analyses. The evaluation of the effects of tidal habitat, floodplain, channel margin, and riparian habitat restoration on covered fish species was mostly qualitative; used DRERIP conceptual models; and focused on changes in physical habitat restoration, food production, alternative migration pathways, juvenile growth rates, predation, stranding, water quality, and toxics.

The frequency, duration, and areal extent to which the Yolo Bypass will flood as a result of the BDCP was analyzed using daily flow data from CALSIM II coupled with flooded area data from two-dimensional hydrodynamic modeling using MIKE-21. These results were used to assess benefits of Yolo Bypass inundation to splittail spawning and juvenile rearing as well as juvenile salmonid rearing.

The fall X2 regression model was used to estimate how BDCP water operations and habitat restoration might affect the surface area of open water in the western Delta and Suisun Bay with suitable salinity and turbidity for use by delta smelt. The use of this model and interpretation of its results related to delta smelt habitat has been heavily debated by technical experts; no consensus on the direction of the effects analysis has yet been reached.

5.3.3.3 Food Availability

Food availability is expected to change as a result of the BDCP through two primary mechanisms: changes water operations and habitat restoration. The evaluation of the effects of BDCP water operations on food availability was conducted primarily using the DSM2-QUAL nutrient model. This model provides algal production estimates based on nutrient levels, light availability, and water temperature. The effects of habitat restoration on food availability were conducted using best professional judgment based on existing data within and outside the Delta. The combined effect of changes to food availability to each covered fish species foraging in the Delta was conducted using best professional judgment.

5.3.3.4 Flow

The BDCP may affect both downstream transport flows and upstream migration cues to anadromous fish species. The evaluation of downstream transport flows in the upper rivers and tributaries on salmonids, sturgeon, and lamprey used CALSIM outputs to determine flow rates in multiple upstream rivers as well as multiple channels within the Delta during periods of migration for each species. The Delta passage model, which uses known relationships between flows in the Delta and juvenile salmon survival, was used to evaluate transport flows for salmonids. The analysis of transport flows for delta and longfin smelt used daily and monthly flow data from areas of known presence within the Delta and Suisun Bay during periods of migration for each species.

The evaluation of changes to upstream migration cues on salmonids, sturgeon, and lamprey compared DSM2-QUAL source water fingerprinting data between existing biological conditions and under the proposed project to determine changes in flow splits at the confluence of the Sacramento and San Joaquin rivers during periods of migration through the Delta for each species. The evaluation also compared CALSIM II monthly flow data or USRWQM daily flow data at the confluence of larger rivers to determine changes in the amount of water coming from tributaries during periods of migration for each species. The effect of the BDCP on barriers to migration, including the Stockton Deep Water Ship Channel, Sacramento Deep Water Ship Channel, and the Yolo Bypass, were also evaluated by examining model outputs and using best professional judgment.

The effects analysis also evaluated the change in Delta outflow/X2 in December through May as an indicator of longfin smelt abundance in the DFG Fall Midwater Trawl (Kimmerer et al. 2009). This evaluation of flow effects on longfin smelt abundance will be revised for the January 31, 2011 draft to include the consensus among various BDCP Oversight Committee technical staff that other factors, such as food availability also drive longfin smelt abundance.

5.3.3.5 Entrainment

This analysis included an evaluation of BDCP effects on four sources of entrainment: SWP/CVP south Delta facilities, proposed north Delta facilities, agricultural diversions, and power plant intakes. The evaluation of entrainment at south Delta facilities varied by species and, for some species, by lifestage. The analysis of salmonids, sturgeon, splittail, and lamprey began with calculating historical expanded salvage loss and export rates. The loss density of each species or race was calculated by dividing salvage by export rate. This density was then applied to predicted future monthly export rates from CALSIM II output. Entrainment of delta smelt larvae and longfin smelt larvae and younger juveniles was assessed using particle tracking with a number of starting positions based on historical trawl data and hydrologic conditions based on DSM2-PTM scenarios. Entrainment of juvenile and adult delta smelt and older juvenile and adult longfin smelt used the loss density method that were normalized by annual fall midwater trawl indices for each species. A number of modifications will be made to these methods for the January 31, 2011 draft Effects Analysis. In addition, other methods will be used for the evaluation of some species or lifestages.

The evaluation of the north Delta facilities examined existing design features of screens, flow and sweeping velocities, and size and shape of fish to qualitatively assess effects.

The evaluation of the removal of agricultural diversions due to habitat restoration and construction used best professional judgment to assess effects to covered fish species.

The evaluation of entrainment risk on Mirant’s Pittsburg and Contra Costa power plants was qualitative and utilized recent regulations to phase out completely Mirant’s once-through cooling systems by 2017.

5.3.3.6 In-Delta Toxics and Water Quality

Best professional judgment was applied to the results of the system-level analyses to estimate the effects of the BDCP on toxics loads and water quality parameters in the Delta to qualitatively evaluate the effects of these changed loads on covered fish species health and survival.

5.3.3.7 Predation

There are two primary ways the BDCP is expected to change predation risk: installation of north Delta intakes, and CM15 *Predator control*. To evaluate the effects of the north Delta intakes for salmonids, a striped bass bioenergetics model was developed that estimates predation rates. Densities and total numbers of predators were estimated using existing density data; the zone of influence (the area in which flows are altered and predators live) was estimated using best professional judgment. Bioenergetics model outputs on predation rates were used by the DPM and IOS to evaluate population level effects to salmonids. The effects of north Delta intakes on other species were assessed by calculating estimated losses of individuals to predation. There was much discussion about the assumptions and methods used for this analysis during the "theme team" meetings. These issues are being resolved for the January 31, 2011 draft Effects Analysis.

The effects of CM15 Predator Control on covered fish species were mostly evaluated qualitatively. As with the evaluation of the north Delta intakes, the assumptions used for this evaluation have been reconsidered and will be revised for the January 31, 2011 draft.

5.3.3.8 Hatcheries

There are two hatchery-related conservation measures in the BDCP: CM17 *Hatchery and Genetic Management Plans* that proposes to assist DFG and USFWS in completing and implementing hatchery and genetic management plans; and CM19 *Conservation Hatcheries* that proposes to provide funding and support to conservation hatcheries for delta smelt and longfin smelt. Both conservation measures were analyzed using best professional judgment.

5.3.3.9 Harvest

Best professional judgment was used to evaluate the effect of CM18 *Illegal Harvest* on Chinook salmon, steelhead, sturgeon, and splittail.

5.3.3.10 Construction

Existing information on the techniques to be used for the construction and maintenance of the five north Delta intakes was obtained. A set of best management practices (e.g., work windows, protection from oil spills, use of sediment screens) was assumed based on other in-Delta construction projects. Best professional judgment was used to evaluate the effects of these practices on covered fish species.

5.3.4 Killer Whale Analysis Methods

The analysis of the effects of the BDCP on southern resident killer whale was not included in the August 19, 2010 draft Effects Analysis. This analysis will be completed for the January 2011 draft and will be based primarily on the results of the Chinook salmon evaluation because Chinook salmon are a preferred prey item of the southern resident killer whale. Fecundity and survival of the distinct population segment appear to be correlated with abundance of Chinook salmon in inland Pacific Northwest waters (Ward et al 2009, Ford et al. 2009). Methods to be used will be consistent with the NMFS Biological Opinion on the CVP and SWP (NMFS 2009).

5.3.5 Natural Community Assessment Methods

Information and analytical tools used to conduct the effects analysis on the natural communities, including ecological processes, ecological gradients, native species habitat functions supported by each of the natural communities as well as the extent of natural communities in the Plan Area, included:

- Draft Chapter 2, *Existing Ecological Conditions*, including the BDCP GIS vegetation and natural community data base;
- Descriptions of the BDCP conservation measures in Draft Chapter 3, *Conservation Strategy*;
- The conservation implementation schedule in BDCP Chapter 6, *Implementation Plan*;
- DHCCP draft conveyance facility construction schedules;
- Applicable DRERIP models;
- Assumptions regarding development of restored and enhanced habitats (see Section 5.3.1.2, *Major Assumptions*);
- Descriptions of relevant avoidance and minimization measures in Draft Chapter 3, *Conservation Strategy*;
- Results of relevant modeling (e.g., modeled changes in salinity gradients);
- GIS data layers of conveyance facility footprints; and
- BDCP hypothetical footprints of restored and enhanced tidal, seasonally inundated floodplain, channel margin, and riparian habitats.

The analysis was based on an assessment of the effects mechanisms associated with each of the covered activities that could result in an adverse or beneficial effect on the natural communities. Changes in the permanent, temporary, and periodic inundation effects on the extent of each natural community were determined using GIS by intersecting (i.e., overlaying) the footprint effect area of each of the covered activities with the GIS natural community data base layer. The combined effects of constructing conveyance facilities and restoring habitats were qualitatively evaluated to assess effects on habitat connectivity and movement of native wildlife species. The process for calculating the extent of footprint, noise, and visual effects of implementing water conveyance facility construction and habitat restoration actions on each of the natural communities is illustrated in Figure 5-2.

Effects of covered activities on aquatic ecological processes and gradients were evaluated based on results of hydrodynamic and water quality modeling and the assumptions regarding the evolution of enhanced and restored tidal, channel margin, riparian, vernal pool, seasonally inundated floodplain, and grassland habitats.

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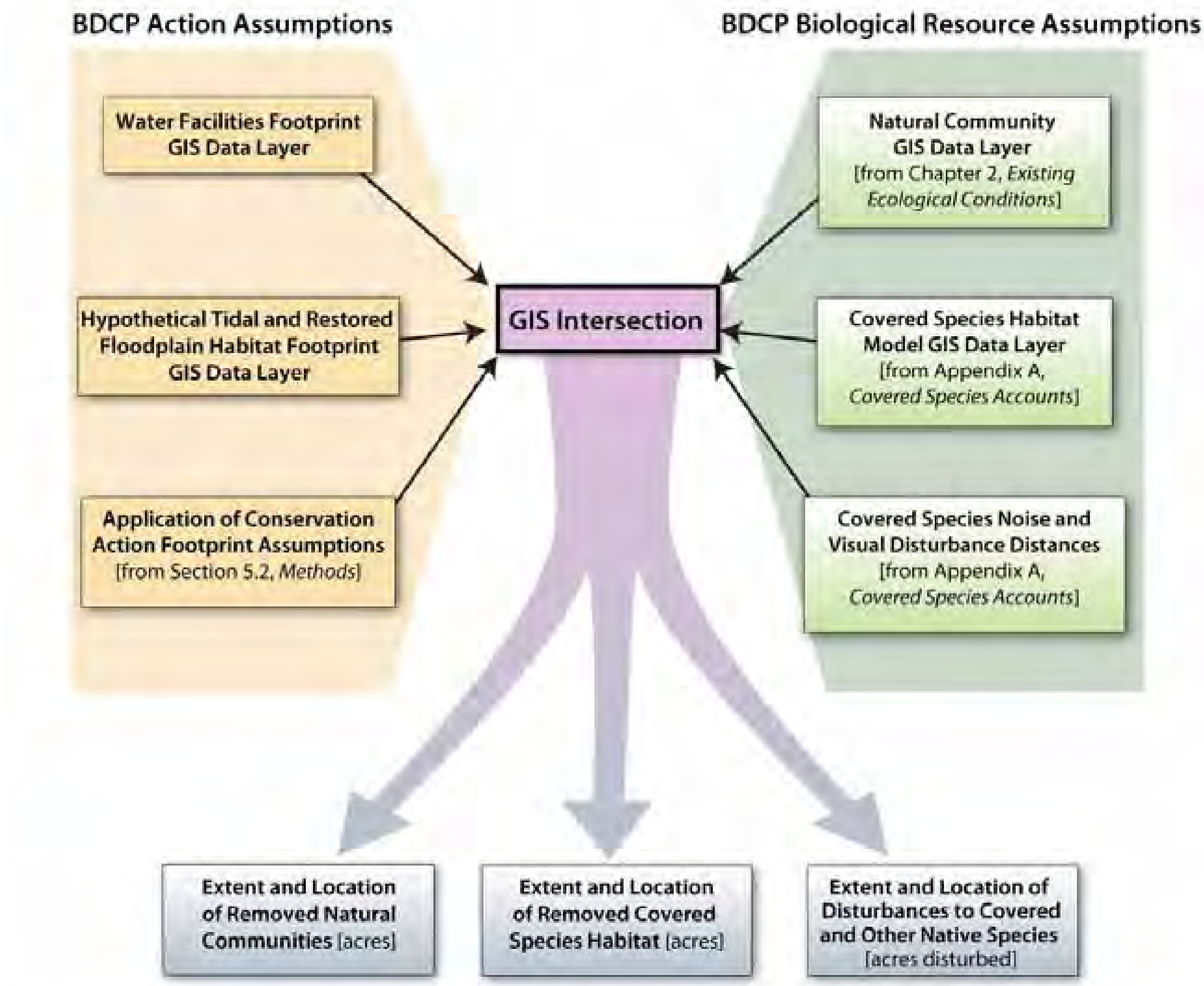

Figure 5-2. Process for Calculating Extent of BDCP Covered Activity and Conservation Action Footprint Effects on Natural Communities and Covered Species Habitats

5.3.6 Covered Wildlife and Plant Species Assessment Methods

Information and analytical tools used to conduct the effects analysis on covered wildlife and plant species included:

- The BDCP covered wildlife and plant species habitat models (Appendix A, *Covered Species Accounts*);
- Species information in BDCP Appendix A, *Covered Species Accounts*;
- Applicable DRERIP models;
- Descriptions of the BDCP conservation measures in Draft Chapter 3, *Conservation Strategy*;
- The conservation implementation schedule in Draft Chapter 6, *Implementation Plan*;
- DHCCP draft conveyance facility construction schedules;
- Draft Chapter 2, *Existing Ecological Conditions*;
- Assumptions regarding development of restored and enhanced habitats (see Section 5.3.1.2, *Major Assumptions*);
- Application of relevant avoidance and minimization measures in Draft Chapter 3, *Conservation Strategy*;
- Results of relevant modeling (e.g., modeled changes in salinity gradients);
- GIS data layers of conveyance facility footprints; and
- BDCP hypothetical footprints of restored and enhanced tidal, seasonally inundated floodplain, channel margin, and riparian habitats.

The analysis was based on an assessment of the effects mechanisms associated with each of the covered activities that could result in an adverse or beneficial effect on each of the covered wildlife and plant species. Changes in the permanent, temporary and periodic inundation effects of on the extent of each species' habitat types were determined using GIS by intersecting the footprint effect area of each covered activities with each species' habitat model data base layers. The process for calculating the extent of footprint and noise and visual effects of implementing water conveyance facility construction and habitat restoration actions on covered species and their habitats is illustrated in Figure 5-2. Effects of changes in salinity and hydrodynamic conditions were evaluated based on results of hydrodynamic and water quality modeling and the assumptions regarding the evolution of enhanced and restored tidal, channel margin, riparian, vernal pool, seasonally inundated floodplain, and grassland habitats.

5.4 Summary of Results

*[**Note to Reviewers:** This section presents draft Section 5.4,* Summary of Results*, section of Chapter 5,* Effects Analysis*, for the November 18, 2010 BDCP document.*

Section 5.4.1 summarizes the results of the effects analysis results of covered fish species from the August 19, 2010 draft for fish species and the subsequent September 9, 2010 draft enhanced habitat analysis. This section is sub-divided into a description of results for each covered fish species or groups of similar fish species. Where applicable, summaries of the effects on population viability, designated critical habitat, and essential fish habitat are included.

Sections 5.4.2 and 5.4.3 summarize the effects analysis results for the natural communities and covered wildlife and plant species. These two sections consist of the revised "summary of effects" sections from the August 19, 2010 draft for the natural communities and species for only the late long-term outcomes with full BDCP implementation. Tables presenting the extent of impacts on and the level of conservation provided for each of the natural communities and covered wildlife and plant species habitats at the late long-term evaluation point are provided at the end of this draft.]

This section summarizes the results of the August 19, 2010 draft of the BDCP effects analysis and the September 9, 2010 draft enhanced habitat analysis for covered fish species. Owing to the complexity and comprehensiveness of this effects analysis, there have been over 1,400 pages of results and over 1,900 pages of accompanying appendices generated to date. Therefore, the results section presented here is a very condensed summary of the full analysis. The August 19 draft effects analysis did not include a southern resident killer whale effects analysis or estimated levels of take and overall syntheses and conclusions for covered fish species and, therefore, are not included in this section.

5.4.1 Covered Fish Species

5.4.1.1 Delta Smelt

5.4.1.1.1 BDCP Effects on Stressors

The results of the effects analysis indicate that implementation of the BDCP conservation strategy will result in a number of major changes that will reduce the impacts of stressors on the delta smelt population and improve habitat conditions for larval, juvenile, and adult rearing. Some adverse effects were also noted. These major findings include:

Expansion of habitat through physical restoration. Habitat restoration under the BDCP will increase subtidal habitat extent in Suisun Marsh and West Delta ROAs by 11,000 acres in the LLT. Approximately 21,000 acres of subtidal habitat will be added in the other ROAs in the LLT, including 7,400 acres in the Cache Slough area, which is used extensively by delta smelt.

Approximately 11,000 acres will be created in the South Delta ROA, which is not used extensively by delta smelt currently, but was historically. Expansion of suitable delta smelt habitat to the south Delta offers the opportunity to re-establish range expansion for delta smelt, geographic diversity within the Delta population, and the potential to re-establish another independent spawning population of delta smelt that would be consistent with Population Viability Assessment (PVA) and recovery criteria for threatened and endangered fish populations. This restored habitat would provide additional spawning and rearing habitat for delta smelt if these new habitat areas were to contain suitable hydraulics and water quality, and was not extensively colonized by submerged aquatic vegetation or introduced predators. As discussed above, the BDCP monitoring, research, and adaptive management programs will address this uncertainty and provide for continual improvement in implementation design over time to ensure that newly restored habitat contains suitable features for delta smelt. Specific measures are included in the BDCP to control submerged aquatic vegetation and nonnative predators. In total, the extent of subtidal habitat in the Delta will increase by approximately 35 percent over existing subtidal habitat in the Delta and Suisun Marsh and Bay.

Increased food production. It has been postulated that food is a limiting factor for delta smelt (Feyrer et al. 2007, Baxter et al. 2008, Glibert 2010, Miller unpubl. data). Changes in operations and habitat restoration under the BDCP will increase hydraulic residence time in some areas of the Delta, which has the potential to increase food production in those areas. In other areas, residence time will decrease, which has the potential to reduce food production. The types of primary producers found in the Delta water column are determined in part by the nutrient composition of the water (Glibert 2010). The net near term effect of hydraulic changes is therefore uncertain.

Habitat restoration has substantial potential to enhance food production within and adjacent to restoration sites because of the substantial increase in intertidal and subtidal habitat in the ELT and LLT. Delta smelt are expected to receive the greatest benefits from the creation of additional habitat in the Cache Slough area. This area currently has favorable food web productivity (Lehman 2010) and has supported a relatively large delta smelt population in recent years. Although shallow intertidal habitat is not expected to be used by delta smelt for rearing, primary production in these areas is expected to be high in the future. Adjacent subtidal areas will also produce food, as well as provide delta smelt habitat as described above. The high food production from intertidal marsh areas may be carried from these areas into adjacent subtidal habitats that provide suitable habitat for delta smelt, increasing production there, which would increase growth rates, and presumably benefit the delta smelt population. There are two schools of thought regarding the amount of production expected to be exported from intertidal marsh: some experts believe that export of primary production could be moderate to high whereas other experts believe that exports would be low and sporadic.

An unknown fraction of this increased production could be consumed by the introduced overbite and Asian clams. Colonization of expanded habitat areas by the Asian clam *Corbula*, or future colonization of these habitats by nonnative clams and mussels in the future, could reduce the benefits of production in restored habitats. However, the BDCP Implementation Office will learn from monitoring and research much more about successful and unsuccessful habitat restoration design features to minimize effects of nonnative clams during the 50 year term of the BDCP and will, therefore, adaptively manage restoration design to minimize these effects.

Changes in Fall X2. In comparison with the RPAs in the existing delta smelt biological opinion, BDCP will modify the location of X2 position during fall in below normal, above normal and wet water years. However, this RPA has not yet been implemented due to lack of suitable hydrological circumstances. Moreover, it was not accepted by Reclamation and is under contention in litigation, the outcome of which cannot be predicted here. Thus it is not currently an existing condition for purposes of comparison to BDCP. In order to be conservative, however, analysis has been conducted to evaluate the change in fall X2 location that would occur under BDCP relative to the fall X2 RPA.

Under the BDCP, X2 position will move upstream in the fall months of below normal, above normal and wet years relative to its location assuming “existing biological conditions (EBC)” in the existing RPA. In fall, this would occur in the wettest 60 percent of years, although it would not be different from the EBC under the driest 40 percent of conditions. Higher X2 position will reduce the surface area of open water with salinity and turbidity levels that some consider suitable habitat for delta smelt (see e.g., Feyrer et al., 2007) by 30-40 percent, assuming the current Delta configuration. These changes are similar for the ELT and the LLT. When habitat restoration by the BDCP is included in the evaluation of effects on X2 position (based on LLT projections), the BDCP is projected to result in approximately 25 percent more habitat in the western Delta and Suisun Marsh/Bay than the EBC under the driest 50 percent of years and 20-40 percent less habitat under wetter years.

There is an ongoing discussion regarding whether or not fall X2 position is an appropriate indicator of delta smelt habitat and whether it is useful in predicting population responses. This issue has been identified as one of the remaining issues that require further evaluation and discussion amongst the scientific community. Further analysis will be completed on this issue over the next few months.

Reduced losses of adult delta smelt at south Delta SWP/CVP facilities. While entrainment in the existing project facilities has not been shown to have a population level effect, project related improvements will benefit the species. Dual export facility operations will reduce adult delta smelt losses at the south Delta export facilities by approximately 50 percent from existing conditions. This effect is especially pronounced during the earlier months of the migration season, which will protect older, larger fish that are presumed to spawn earlier and provide a disproportionately greater percentage of successful recruits in any given year. Adult losses will likely increase in April, but this effect is outweighed by reduced losses during December through March. The reduction in adult delta smelt losses is comparable between the ELT and LLT implementation periods.

Reduced losses of juvenile delta smelt in south Delta SWP/CVP facilities. While neither entrainment in the existing project facilities, nor project related changes in hydrodynamics, has ever been shown to have a population level effect; project related improvements in these areas will benefit the species. Dual export facility operations will reduce juvenile delta smelt losses at the south Delta export facilities by approximately 15 percent in the ELT and 26 percent in the LLT relative to corresponding existing biological conditions (EBC) conditions at the SWP facilities. Little difference in loss was identified between the BDCP and the EBC at the CVP facilities for juvenile delta smelt. This effect will provide a benefit for delta smelt, as well, but not as great as that achieved through reductions of adult losses. Losses were slightly reduced for larval delta smelt, based on PTM results, but this difference was quite small (less than 3 percent in many cases) and, given the high variability in the results, is not concluded to be different from that under EBC.

Negligible entrainment risk at north Delta intakes. As a result of the state-of-the-art design characteristics (i.e., 0.2 ft/sec approach velocity, screen mesh size, screen cleaning, etc.), and the northern location of the proposed intake structures relative to the geographic distribution of delta smelt, the risk of entrainment or impingement of all life stages of delta smelt at the north Delta intakes is negligible.

Entrainment in non-project diversions will be marginally reduced. The removal of non-project diversion due to changing land use in the Delta as a result of BDCP conservation measures (e.g., conversion of agricultural land use to restored natural habitat) will provide a marginal benefit to reducing entrainment risk for delta smelt.

Entrainment in Mirant power plants will be greatly reduced. The expected transition to exclusive closed cycle water use at Mirant's Contra Costa and Pittsburg power plants by 2017 is predicted to substantially reduce and avoid entrainment and impingement of delta smelt.[

Changes in toxicant levels. Toxicants (e.g., pyrethroids, copper, ammonia) have been identified as a potential stressor to delta smelt (Sommer et al. 2007, Baxter et al. 2008, Werner 2010). Much of the research on the effects of toxicants to delta smelt is preliminary. Under the BDCP, toxicant concentrations will decrease in the west Delta as a result of minor decreases in loading from upstream sources, changes in hydrodynamics, and in-Delta land use changes. Results for central Delta are more mixed. Because the bulk of the delta smelt population occurs in the northern Delta and confluence, the net effect of the project with regard to toxicants is beneficial.

Removal of submerged aquatic vegetation (SAV). SAV removal is an important secondary action to habitat restoration. SAV has the potential to make habitat unsuitable for delta smelt by encroaching on areas used by smelt for spawning and rearing, providing habitat for introduced predators, and reducing turbidity both within SAV beds and in nearby areas. Without SAV removal, some portion of the intertidal and subtidal restored habitat will be colonized by SAV and become unsuitable for delta smelt. This action would be beneficial to delta smelt by keeping newly created habitat available for smelt.

Predator removal. Localized removal of predators (e.g., striped bass, largemouth bass, smallmouth bass) is expected to provide only negligible benefits to delta smelt. Currently, there are few studies evaluating the effect of predation on delta smelt. After further study, more information regarding the importance of predation on the delta smelt population will be known, and effective predator management programs can be developed.

Establishment of a conservation hatchery. Establishing viable refuge populations of delta smelt in a conservation hatchery will provide insurance against the potential extinction of the wild populations and is an important consideration, given the low numbers of wild delta smelt. It also will provide a stock of fish that could be used to assess the effects of various stressors on the species without impacting wild stocks. There would be more risk and uncertainty associated with increasing the scale of the facility to enhance the natural population. Long-term benefits would outweigh these risks if program managers develop and maintain populations whose genetic diversity and fitness are comparable to those of wild populations.

5.4.1.1.2 BDCP Effects on Delta Smelt Designated Critical Habitat

The U.S. Fish and Wildlife Service has identified the important physical and biological features, or primary constituent elements (PCEs), essential for the conservation of delta smelt as: "…physical habitat, water, river flow, and salinity concentrations required to maintain delta smelt habitat for spawning, larval and juvenile transport, rearing, and adult migration" (59 FR 65256). Results of the effects analysis led to the following conclusions regarding the effects of BDCP actions on designated critical habitat for delta smelt spawning, larval and juvenile transport, rearing and adult migration.

Effects on Physical Habitat. The BDCP will result in increased spawning habitat availability through habitat restoration and the removal of nonnative aquatic vegetation. With respect to habitat restoration, it is unknown whether restored areas will provide suitable spawning substrate, although there is evidence from recent BREACH III sampling suggesting that delta smelt spawn in or near Liberty Island (P. Hrodey, pers. comm.). However, the projected increases in intertidal and subtidal habitat are expected to result in substantial increases in the availability of suitable rearing habitat. In addition to increasing spawning and rearing habitat area, increased local food production and export to adjacent pelagic habitats may occur where the frequency and duration of inundation would be increased relative to existing biological conditions as a result of habitat restoration (Jassby and Cloern 2000, Kneib et al. 2008, Opperman 2008).

There is uncertainty associated with the projected benefits of habitat restoration (based on delta smelt use of restored areas, proximity to population sources for native vs. exotic plants and animals, etc.). The biological benefits of expanded aquatic habitat will depend, in part, on the location of the habitat feature with respect to the geographic distribution of the species and their lifestages, compatibility of physical habitat features with species- and life-stage specific habitat requirements and preferences, the specifics of the habitat design, physical processes, and configuration that would serve to reduce and avoid colonization by nonnative filter-feeding macroinvertebrates and predatory fish. As discussed above, the design and implementation of the BDCP conservation measures include specific design characteristics (e.g., habitat diversity and complexity, water depths and velocities, hydraulic flushing and residence times, wind and wave induced turbidity, etc.) that work in concert with phased implementation of habitat restoration, coupled with integrated monitoring and evaluation, to assess habitat performance, improve performance of the habitat restoration projects, and reduce uncertainty. Through careful phased implementation of habitat features developed in accordance with physical and biological design characteristics, the net effect is expected to be an increase in suitable physical habitat for delta smelt.

Effects on Water. The BDCP would have little effect on water temperature relative to the effects of climate change. Water temperatures will increase in the future primarily as a result of climate change, and are not expected to be intensified as a result of the BDCP. In fact, during small periods during summer months, tidal marsh restoration is predicted to reduce water temperature in and near marshes, which would offset some of the increases due to climate change. The projected reductions in contaminant concentrations in the vicinity of the confluence will decrease delta smelt contaminant exposure. These changes will range from relatively minor (in the NT and ELT) to substantial (in the LLT). Finally, increases in turbidity associated with floodplain, channel margin, subtidal and intertidal habitat enhancement and restoration in particular, will provide a benefit to delta smelt critical habitat. These benefits will accrue during spawning, larval and juvenile transport, rearing, as well as adult migration.

Effects on River Flows. Transport flows for larval delta smelt would decrease under the proposed project during the late winter and spring in the tidal reaches of the lower Sacramento River downstream of the north Delta diversions. The greatest flow reductions are expected in wet, above normal, and below normal hydrologic conditions. These transport flows are likely to be unimportant if temperatures are suitable and food supply is sufficient to provide adequate nourishment (Nobriga pers. comm.) further upstream in the lower Sacramento River, as will likely be the case in wetter periods. The project will have little effect on transport flows in drier years. Consequently, changes in transport flows are expected to have little to no effect on larval delta smelt critical habitat. Investigation of the potential effects of changes in Sacramento River flows on delta smelt is continuing.

River flow rates and hydrologic conditions within the Delta may have some effect on the potential for larval and juvenile delta smelt to be entrained at water diversion facilities. With BDCP implementation, entrainment losses of delta smelt at the north and south Delta export facilities combined are projected to decrease for larval, juvenile, and adult delta smelt. The reduction in entrainment risk for delta smelt reflects the combined effects of increased exports from the north Delta intakes which would be located near the upstream boundary of the delta smelt geographic distribution as well as reductions in south Delta diversions and an associated reduction in reverse flows in Old and Middle Rivers and other south and central Delta channels. Although there will be a minor adverse effect with regard to larval transport flows within the tidal reach of the Sacramento River downstream of the north Delta diversions, the improvements in Delta hydrologic conditions, including both reduction in Old and Middle River reverse flows as well as improvements in the net downstream flow of water through the Delta and associated improvements in aquatic habitat and production of food organisms within tidal habitats and Delta channels, is expected to be such that no net adverse effect on critical habitat will result. The net effect will be a benefit to the species.

Effects on Salinity (X2 Position). There is significant scientific disagreement regarding the biological importance of X2 in the fall and summer. This issue has been identified as requiring further research, analysis, and discussion amongst the scientific community. Further analysis will be undertaken.

To the extent that X2 is an indicator of delta smelt distribution, it is expected that the proposed habitat projects will increase the availability of physical habitat. Under the various distribution scenarios based on the potential future locations of X2, delta smelt will benefit from the newly restored physical habitat in the Cache Slough complex, western Delta and/or Suisun Marsh.

5.4.1.1.3 BDCP Effects on Delta Smelt Population Viability

This section addresses the population viability of delta smelt, although a formal population viability analysis has not been developed. The analysis is based on the results of the effects analysis and focuses on how the BDCP will affect the following criteria (based on those described for salmonids):

- Population abundance (population size) as reflected in the numbers of adult delta smelt returning the Delta to spawn;
- Population growth rates (productivity) as reflected in survival rates for each life stage and increasing population abundance trends (positive cohort replacement);
- Population spatial structure (habitat and population distribution) as reflected in the geographic distribution of suitable habitat, habitat heterogeneity and complexity; and
- Diversity (variation in behavioral and genetic traits) as reflected in diversity and complexity of habitat types, variation in life history timing, and access to suitable upstream spawning and rearing habitat and migration pathways.

Additional considerations include reducing and avoiding threats and stressors on the delta smelt population associated with actions such as changes in instream flows, water diversion effects, increased vulnerability to predation, and other factors.

Results of the BDCP effects analysis indicate that the BDCP conservation strategy and actions are consistent with the principles of delta smelt recovery planning and will address many of the stressors for delta smelt as identified in the Recovery Plan for the Sacramento/San Joaquin Delta

Native Fishes (USFWS 1996). The BDCP conservation actions are expected to result in the following outcomes related to delta smelt population viability:

Protection and expansion of habitat will increase abundance, growth rate, spatial structure, and diversity. The BDCP will contribute to increased abundance of delta smelt through protection and enhancement of suitable habitat conditions in existing areas utilized by delta smelt and through habitat restoration actions that increase the amount of suitable habitat available to smelt and, potentially increase smelt geographic distribution. In the south Delta, which smelt used historically but do so only occasionally now, conditions will be improved through decreased entrainment, increased residence time, and increased San Joaquin River flow at Verona. Increased residence time and reduced entrainment losses of phytoplankton, zooplankton, and nutrients from the central and southern Delta are projected to result in increased phytoplankton and zooplankton densities in the Delta and contribute to increased turbidity, which will increase habitat value for delta smelt. These beneficial effects could be reduced by increased water temperature resulting from climate change, but this effect may be offset by the effects of BDCP habitat restoration actions. Overall, these factors are expected to increase larval and juvenile growth and survival, contributing to increased adult abundance. These increases in habitat and abundance will contribute to increased diversity within the delta smelt population, increasing the resilience of the population to extinction risk and the ability to adapt to a changing environment.

Increased habitat will enhance food availability. The expanded floodplain, tidal wetland, and channel margin habitat restoration implemented as part of BDCP will provide an increase in intertidal habitat of approximately 14,360 acres and an increase in subtidal habitat of 31,320 acres over existing habitat. These habitats will be maintained by natural processes and will offer a wide range of residence times, water depths, water velocities, tidal mixing, and habitat conditions. These expanded habitats will substantially contribute to improved juvenile rearing by contributing to food production and availability. The expanded area and diversity of juvenile delta smelt rearing habitat and adult spawning habitat resulting from the BDCP will provide a broader range of habitats within the Delta for delta smelt and increased population abundance. These increases in habitat and abundance will likely contribute to increased diversity within the delta smelt population, increasing the resilience of the population to extinction risk and the ability to adapt to a changing environment.

Reduction in SWP/CVP losses will increase survival. While entrainment in the existing project facilities has ever been shown to have a population level effect, the BDCP will substantially reduce entrainment of juvenile and adult delta smelt at south Delta facilities by approximately one fourth and one half, respectively. This effect will increase survival of spawners and increase recruitment of juveniles to the adult lifestage.

5.4.1.1.4 Overall Conclusions for Delta Smelt

The following overall conclusions were made based on the results of the effects analysis for delta smelt.

Contribution to Recovery. *[**Note to Reviewers:** The Steering Committee has not completed discussion on the sufficiency of the BDCP to contribute to recovery of covered species]* As a comprehensive package of conservation measures, BDCP will contribute to the survival and recovery of the delta smelt population through cumulative reduction in stressors and improvements in habitat that together contribute to increase population abundance. The BDCP conservation strategy and actions are consistent with the principles of delta smelt recovery planning and will address many the stressors of delta smelt as identified in the Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes (USFWS 1996). Habitat conditions and water operations resulting from implementation of BDCP conservation measures will allow for increased individual growth and survival, and consequently, increased delta smelt population abundance within the Delta. There are no actions proposed as part of BDCP that are inconsistent or incompatible with long-term delta smelt recovery plan implementation.

Net Beneficial Effects on Designated Critical Habitat. The BDCP implementation is expected to improve critical habitat for delta smelt. The PCEs for delta smelt critical habitat include physical habitat, water quality and food availability, to support delta smelt spawning, larval and juvenile transport, rearing habitat, and adult migration. It will result in a substantial increase in available habitat area, although the utility of this habitat cannot be fully known from existing information. This increase in habitat extends beyond the rearing space that delta smelt occupy and incorporates areas that are likely to experience increased food production. BDCP habitat restoration will likely increase turbidity, which would increase feeding success for delta smelt and assist in the avoidance of predators. The proposed project will reduce the concentration of toxic compounds in the areas most used by delta smelt, although changes in concentration are variable.

Need for Adaptive Management. Due to a limitation of available analytical tools, the magnitude of the effects of BDCP actions on delta smelt could not be quantified. There are a number of uncertainties described in the analyses of the effects of the project on delta smelt. Many of these uncertainties result from substantial scientific uncertainties regarding the factors affecting current trends in species abundance, basic life history requirements, and how the Delta may respond to large-scale changes in its habitat area and hydrology. To address this uncertainty, the BDCP includes an extensive monitoring program to evaluate the effectiveness of BDCP actions, a research program to expand the knowledge base, and an adaptive management program that provides the flexibility to adjust water operations criteria for certain parameters within specified adaptive ranges (see CM1 *Water Facilities and Operations* in Chapter 3, *Conservation Strategy*). The habitat restoration program will be adaptively managed as habitat is restored in phases over time. This phasing of restoration will provide an opportunity to learn which restoration strategies work and which do not, and to employ that knowledge to subsequent project planning to maximize their success. Because these monitoring, research and adaptive management programs are integral components of the project, there is the opportunity and flexibility to adaptively change the conservation measures, within prescribed bounds, reduce uncertainty, and improve outcomes.

5.4.1.2 Longfin Smelt

5.4.1.2.1 BDCP Effects on Stressors

The results of the effects analysis indicate that implementation of the BDCP conservation strategy will result in a number of major changes that will reduce the impacts of stressors on the longfin smelt population and improve habitat conditions for larval, juvenile, and adult rearing, although some adverse effects were also noted. These major findings include:

Expansion of habitat through physical restoration. Habitat restoration under the BDCP will increase subtidal habitat extent in Suisun Marsh and West Delta ROAs by 11,000 acres in the LLT , which are used extensively by longfin smelt. Approximately 11,000 acres will be created in the South Delta ROA, which is not used extensively by longfin smelt currently, but was historically. These restored subtidal areas may provide additional spawning and rearing habitat for longfin smelt if these areas are constructed to have appropriate hydraulics and water quality, and are not extensively colonized by SAV or introduced predators (BDCP includes specific measures to control SAV and predators). In total, the extent of subtidal habitat in the Delta will increase by approximately 35 percent over existing subtidal habitat in the Delta and Suisun Marsh and Bay.

Increased food production. It has been postulated that food is a limiting factor for longfin smelt (Baxter et al. 2008). Changes in operations and habitat restoration under the BDCP will increase hydraulic residence time in some areas of the Delta, which has the potential to increase food production in those areas. The types of primary producers found in the Delta water column are determined, in part, by the nutrient composition of the water (Glibert 2010). The net near term effect of hydraulic changes is therefore uncertain.

Habitat restoration has substantial potential to enhance food production within and adjacent to restoration sites because of the substantial increase in intertidal and subtidal habitat in the ELT and LLT. Although shallow intertidal habitat is not expected to be used by longfin smelt for rearing, primary production in these areas is expected to be high in the future. Adjacent subtidal areas will also produce food, as well as provide longfin smelt habitat as described above. The high food production from intertidal marsh areas may be carried from these areas into adjacent subtidal habitats that provide suitable habitat for longfin smelt, increasing production there, which would increase growth rates, and presumably benefit the longfin smelt population. There are two schools of thought regarding the amount of production expected to be exported from intertidal marsh: some experts believe that export of primary production could be moderate to high whereas other experts believe that exports would be low and sporadic.

An unknown fraction of this increased production could be consumed by the introduced overbite and Asian clams. Colonization of expanded habitat areas by the Asian clam *Corbula*, or future colonization of these habitats by nonnative clams and mussels in the future, could reduce the benefits of production in restored habitats. This potential effect could be off-set by concentrating early habitat actions in areas like Suisun Marsh, which have not been colonized by *Corbula* and where brackish conditions are inhospitable to freshwater SAV such as *Egeria*. The BDCP Implementation Office will learn from monitoring and research much more about successful and unsuccessful habitat restoration design features to minimize effects of nonnative clams during the 50 year term of the BDCP and will, therefore, adaptively manage restoration design to minimize these effects.

Reduced losses of longfin smelt at south Delta SWP/CVP facilities. Dual export facility operations under the BDCP will reduce adult longfin smelt losses by approximately 60 percent at both south Delta export facilities relative to existing biological conditions during both the ELT and LLT. While adult entrainment in the south Delta project facilities has been negligible in all but a few very dry years, the further reduction in proportional entrainment under the BDCP will benefit the species. Dual operations will likely increase juvenile longfin smelt losses in the ELT by approximately 20 percent at the south Delta SWP facility and 4-7 percent at the CVP facility. In the LLT, no difference was detected in juvenile longfin smelt losses between the BDCP and EBC at either facility. Dual operations will likely result in negligible reductions (less than 2 percent in many cases) in larval entrainment under the BDCP relative to the EBC. Based on the relative magnitude of differences in predicted losses under the BDCP and the EBC for each of these lifestages, and the relative importance of each lifestage to the overall population, reductions in adult losses are expected to outweigh increases in entrainment projected for juveniles, resulting in a net benefit to longfin smelt.

Negligible entrainment risk at north Delta intakes. As a result of the state-of-the-art design characteristics (i.e., 0.2 ft/sec approach velocity, screen mesh size, screen cleaning, etc.), and the northern location of the proposed intake structures relative to the geographic distribution of longfin smelt, the risk of entrainment or impingement of all life stages of longfin smelt at the north Delta intakes is negligible.

Entrainment in non-project diversions will be marginally reduced. The removal of non-project diversion due to changing land use in the Delta as a result of BDCP conservation measures (e.g., conversion of agricultural land use to restored natural habitat) will provide a marginal benefit to reducing entrainment risk for longfin smelt.

Entrainment in Mirant power plants will be greatly reduced. The expected transition to exclusive closed cycle water use at Mirant's Contra Costa and Pittsburg power plants by 2017 is predicted to substantially reduce and avoid entrainment and impingement of longfin smelt.

Changes in Delta hydrodynamics. There is significant disagreement regarding the biological importance of the location of X2. While the y-intercept of the statistical relationship between

Delta outflow and longfin smelt abundance reported by Kimmerer (2002) and Rosenfield and Baxter (2007) has decreased in recent years, the relationship is still present (Sommer et al. 2007, Rosenfield and Baxter 2007). At the same time, the response of longfin smelt abundance to levels of flow has dramatically declined, with the same magnitude of flows expected to produce less and less smelt over time.

Documented decreases in abundance between Age 1 and Age 2 fish (Rosenfeld and Baxter 2009) also suggest that a population bottleneck occurs after the recruitment from larvae to juvenile, suggesting that potential reductions in larval abundance based on reduced transport flows occurring prior to this bottleneck may not have significant population level effects.

Due to the scientific uncertainty regarding how to interpret any potential changes in the location of X2, this issue has been identified as requiring further research, analysis, and discussion amongst the scientific community. Further analysis will be undertaken.

Changes in toxicant levels. Toxicants (e.g., pyrethroids, copper, ammonia) have been identified as a potential stressor to longfin smelt (Sommer et al. 2007, Baxter et al. 2008, Werner 2010). Although studies focusing on the effects of toxics on longfin smelt have not yet been conducted, research on delta smelt should provide an indication of the magnitude of the impact on longfin smelt. Much of this research, however, is preliminary. Under the BDCP, toxicant concentrations will decrease in the west Delta as a result of minor decreases in loading from upstream sources, changes in hydrodynamics, and in-Delta land use changes. Results for the central Delta are more mixed. Because the bulk of the longfin smelt population occurs in the northern Delta and confluence, the net effect of the project with regard to toxicants is beneficial.

Removal of submerged aquatic vegetation (SAV). SAV removal is an important secondary action to habitat restoration. SAV has the potential to make habitat unsuitable for longfin smelt by encroaching on areas used by smelt for spawning and rearing, providing habitat for introduced predators, and reducing turbidity both within beds and in nearby areas. Without SAV removal, some portion of the intertidal and subtidal restored habitat will be colonized by SAV and become unsuitable for longfin smelt. This action would be beneficial to longfin smelt by keeping newly created habitat available for smelt.

Predator removal. Localized removal of predators (e.g., striped bass, largemouth bass, smallmouth bass) is expected to provide only negligible benefits to longfin smelt. Currently, there are few studies evaluating the effect of predation on longfin smelt. After further study, more information regarding the importance of predation on the longfin smelt population will be known, and effective predator management programs can be developed.

Establishment of a conservation hatchery. Establishing a viable refugial population of longfin smelt in a conservation hatchery will provide insurance against the potential extinction of the wild population and is an important consideration, given the low numbers of wild longfin smelt. It also will provide a stock of fish that could be used to assess the effects of various stressors on the species without impacting the wild stock. There would be more risks and uncertainty associated with increasing the scale of the facility to enhance the natural population. Long-term benefits would outweigh these risks if program managers develop and maintain populations whose genetic diversity and fitness are comparable to those of wild populations.

5.4.1.2.2 BDCP Effects on Longfin Smelt Population Viability

This section addresses the population viability of longfin smelt, although a formal population viability analysis has not been developed. The analysis is based on the results of the effects analysis and focuses on how the BDCP will affect the following criteria (based on those described for salmonids):

- Population abundance (population size) as reflected in the numbers of adult longfin smelt returning to the Delta to spawn;
- Population growth rates (productivity) as reflected in survival rates for each life stage and increasing population abundance trends (positive cohort replacement);
- Population spatial structure (habitat and population distribution) as reflected in the geographic distribution of suitable habitat, habitat heterogeneity and complexity; and
- Diversity (variation in behavioral and genetic traits) as reflected in diversity and complexity of habitat types, variation in life history timing, and access to suitable upstream spawning and rearing habitat and migration pathways.

Additional considerations include reducing and avoiding threats and stressors on the longfin smelt population associated with actions such as changes in instream flows, water diversion effects, increased vulnerability to predation, and other factors.

Results of the BDCP effects analysis show that the BDCP conservation strategy and actions are consistent with the principles of longfin smelt recovery planning and will address many of the stressors for longfin smelt as identified in the Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes (USFWS 1996). The BDCP conservation actions are expected to result in the following outcomes related to longfin smelt population viability:

Protection and expansion of habitat will increase abundance, growth rate, spatial structure, and diversity. The BDCP will contribute to increased abundance of longfin smelt through protection and enhancement of suitable habitat conditions such as food availability and turbidity within upstream spawning and juvenile rearing habitats, as well as contribute to an increased smelt geographic distribution of adult spawning and juvenile rearing habitat within the Delta. Increased access to, and extent of suitable rearing habitat, as well as increased food resources, from habitat restoration will contribute to increased juvenile growth and survival, thereby contributing to increased adult abundance.

Long-term implementation of BDCP conservation measures will reduce the adverse effects of a number of current stressors and improve longfin smelt survival that will result in improved population growth rates (a greater probability of maintaining positive cohort replacement) over a wide range of hydrologic and environmental conditions that occur within the Central Valley.

Increased habitat will enhance food availability. The expanded floodplain, tidal wetland, and channel margin habitat restoration implemented as part of the BDCP will provide an increase in intertidal habitat of approximately 14,360 acres and an increase in subtidal habitat of 31,320 acres over existing habitat. These habitats will be maintained by natural processes and will offer a wide range of residence times, water depths, water velocities, tidal mixing, and habitat conditions. These expanded habitats will contribute to improved juvenile rearing by contributing to food production and availability. The expanded area and diversity of juvenile rearing habitat and adult spawning habitat resulting from the BDCP will provide a broader range of habitats within the Delta for longfin smelt which is expected to contribute to increased population abundance. These increases in habitat and abundance will likely contribute to increased diversity within the longfin smelt population, increasing the resilience of the population to extinction risk and the ability to adapt to a changing environment.

Reduction in SWP/CVP losses will increase survival. Adult entrainment in the south Delta project facilities has been negligible in all but a few very dry years. Nevertheless, as the BDCP would further reduce proportional entrainment, the species will benefit. The BDCP will reduce losses of adult longfin smelt at south Delta facilities by approximately 60 percent. This effect will contribute to an increased production of eggs and greater larval abundance. Losses of juvenile longfin smelt will be higher by approximately 15 to 26 percent, although this increase is outweighed by reduced losses to adults, due to differences in magnitude, and the relative importance of adults compared to juveniles to the population (an adult has already survived to the age of reproduction, whereas a juvenile has not).

5.4.1.2.3 Overall Conclusions for Longfin Smelt

The following overall conclusions were made based on the results of the effects analysis for longfin smelt.

Contribution to Recovery. *[**Note to Reviewers:** The Steering Committee has not completed discussion on the sufficiency of the BDCP to contribute to recovery of covered species]* As a comprehensive package of conservation measures, BDCP will contribute to the survival and recovery of the longfin smelt population through cumulative reduction in stressors and improvements in habitat that together contribute to increase population abundance. The BDCP conservation strategy and actions are consistent with the principles of longfin smelt recovery planning and will address many the stressors of longfin smelt as identified in the Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes (USFWS 1996). Habitat conditions and water operations resulting from implementation of BDCP conservation measures will allow for increased individual growth and survival, and consequently, increased longfin smelt population abundance within the Delta. There are no actions proposed as part of BDCP that are inconsistent or incompatible with long-term longfin smelt recovery plan implementation.

Need for Adaptive Management. Due to a limitation of available analytical tools, the magnitude of the effects of BDCP actions on longfin smelt could not be quantified. There are a number of uncertainties described in the analyses of the effects of the project on longfin smelt. Many of these uncertainties result from substantial scientific uncertainties regarding the factors affecting current trends in species abundance, basic life history requirements, and how the Delta may respond to large-scale changes in its habitat area and hydrology. To address this uncertainty, the BDCP includes an extensive monitoring program to evaluate the effectiveness of BDCP actions, a research program to expand the knowledge base, and an adaptive management program that provides the flexibility to adjust water operations criteria for certain parameters within specified adaptive ranges (see CM1 *Water Facilities and Operations* in Chapter 3, *Conservation Strategy*). The habitat restoration program will be adaptively managed as habitat is restored in phases over time. This phasing of restoration will provide an opportunity to learn which restoration strategies work and which do not, and to employ that knowledge to subsequent project planning to maximize their success. Because these monitoring, research and adaptive management programs are integral components of the project, there is the opportunity and flexibility to adaptively change the conservation measures, within prescribed bounds, reduce uncertainty, and potentially improve outcomes.

5.4.1.3 Salmonids

5.4.1.3.1 BDCP Effects on Stressors

The results of the effects analysis indicate that implementation of the BDCP conservation strategy will result in a number of major changes that will reduce the impacts of stressors on the Chinook salmon and Central Valley steelhead populations and improve habitat conditions for juvenile rearing and migration within the Delta, and adult upstream migration to natal spawning areas, although some adverse effects were also noted. These major findings include:

Greater access to habitats used by juvenile salmonids. BDCP conservation measures will result in substantially increased access to expanded seasonal floodplain, tidal wetland, and channel margin habitat, geographically distributed throughout the Delta. This restoration will benefit juvenile salmon and steelhead produced in the Sacramento River Basin, east side tributaries, and the San Joaquin River Basin. Intertidal habitat could be expanded by approximately 6,040 acres in the near-term with an additional 7,250 acres in subtidal habitat. During the early long-term intertidal habitat could be expanded by 10,990 acres and subtidal habitat could be expanded by 9,350 areas. During the late long-term intertidal habitat could be expanded by 14,360 acres and subtidal habitat could be expanded by 31,320 acres. The Yolo Bypass floodplain rearing habitat would be enhanced by increased frequency and duration of flood flows. Up to 10,000 acres of new floodplain habitat would be restored across the Delta, mostly in the south Delta along the San Joaquin, Old, and Middle Rivers.

Among the salmonids winter-run and fall-run Chinook salmon are expected to receive the greatest benefit from expanded juvenile rearing habitat within the Delta. Both of these species have fry that rear within the Delta for several months before migrating into the ocean. During the juvenile rearing and emigration period (late winter and spring months) these juveniles would benefit from increased access to seasonally inundated floodplain habitat as well as shallow-water, low-velocity juvenile rearing habitat located throughout the various regions of the Delta. Late fall-run and spring-run Chinook salmon and steelhead primarily rear in upstream riverine habitats and typically their juveniles do not spend a prolonged period rearing within the Delta. The older juveniles and smolt stages of these and other salmonids would, however, gain benefits from increased availability of channel margin habitat and food production in tidally inundated wetland habitat during their emigration from the Sacramento and San Joaquin River systems. The increased access to suitable habitat for foraging and rearing, and the increased availability of prey, are expected to contribute directly to increased growth, juvenile health, and survival.

Habitat benefits for Sacramento River salmonids. Major expansion in access to floodplain habitat (Yolo Bypass), tidal habitat (Cache Slough complex, Suisun Marsh, West Delta ROAs), and channel margin habitat (e.g., along the mainstem Sacramento River and Sutter and Steamboat sloughs) will occur in the northern and western Delta, and will serve to benefit juvenile steelhead, spring-run, winter-run, fall-run, and late fall-run Chinook salmon produced in the Sacramento River Basin. Intertidal habitat could be expanded by approximately 2,950 acres in Cache Slough in the near-term with an additional 1,210 acres in subtidal habitat. During the early long-term intertidal habitat in Cache Slough could be expanded by 5,750 acres and subtidal habitat could be expanded by 2,320 areas. During the late long-term intertidal habitat could be expanded by 6,710 acres from existing conditions and subtidal habitat could be expanded by 7,400 acres. Additional substantial tidal and subtidal habitat expansion in the western Delta and Suisun Marsh, and channel margin habitat enhancement on the Sacramento River (at least 5 miles) and on Sutter and Steamboat sloughs, would also be available on the migration pathway for juvenile steelhead, winter-run, spring-run, fall-run, and late fall-run Chinook salmon.

Rearing habitat function for Sacramento River Basin salmonids of the existing floodplain in the Yolo Bypass will be enhanced through an increase in the frequency and duration of inundation with an approximately a 2- to -3 fold increase in frequency of short duration flood events (>30 days), as much as a 2- to 6-fold increase in frequency of intermediate duration flood events (between 30-45 days), and as much as a 3- to 9-fold increase in frequency of long duration flood events (>45 days). Extended rearing opportunities within the floodplain habitat have been shown to result in increased growth and survival of juvenile Chinook salmon (Sommer et al. 2001). Results of bioenergetic modeling suggested that feeding success was greater on the floodplain than in the Sacramento River (Sommer et al. 2001). Survival rates of marked salmon were found to be overall greater for those fish rearing in the floodplain, likely due to increased feeding success, increased prey availability, increased seasonal water temperatures, and availability of shallow-water low-velocity rearing habitat, although there was variation in the data showing equal or reduced survival in some years. The factors that contributed to increased and decreased juvenile survival and growth within the Yolo Bypass are continuing to be analyzed.

The benefits of rearing on seasonally inundated floodplain habitat within the Yolo Bypass would be available for all salmonids produced in the Sacramento River watershed with the exception of those from the lower American River. Rearing by juvenile winter-run, spring-run, fall-/late fall-run Chinook and steelhead within the floodplain and the interconnected Cache Slough tidal complex also offers the opportunity for greater life history diversity, such as extended fry rearing, and a wider range of ocean entry times that reduce the risk of adverse population-level effects in response to poor seasonal habitat conditions. Expanding opportunities for life history diversity for salmonids and other Central Valley fish is consistent with conservation principles and recovery planning.

Habitat Benefits for Eastside Tributary salmonids. Intertidal habitat will be expanded in the lower regions of the Mokelumne and Cosumnes rivers by approximately 850 acres in the near-term and subtidal habitat will be expanded by 1,970 acres. These expanded intertidal and subtidal habitats will then continue to function during the ELT and LLT to benefit east side steelhead and fall-run Chinook salmon, as well as other aquatic species. Mokelumne and Cosumnes river basin salmonids will also benefit from habitat expansion in the western Delta and Suisun Marsh and channel margin enhancements along distributaries of the Mokelumne and Cosumnes rivers.

Habitat benefits for San Joaquin River salmonids. Expansion of intertidal and subtidal habitat in the south Delta along the migratory pathway for juvenile steelhead and Chinook salmon produced in the San Joaquin River basin will occur in the LLT. Approximately 1,850 acres of intertidal and 10,950 acres of subtidal habitat will be restored in the LLT. Restoration floodplain habitat along the San Joaquin, Old, and Middle rivers will periodically (in years of flood events) provide rearing habitat for San Joaquin River salmonids. San Joaquin River salmonids will also benefit from habitat expansion in the western Delta and Suisun Marsh and channel margin enhancements along the mainstem and distributaries of the San Joaquin River.

BDCP creates alternative migratory routes. Juvenile Sacramento River basin salmonid survival will improve as a result of expanded access to seasonal floodplain within the Yolo Bypass, which will provide opportunities for juvenile Chinook salmon and steelhead to access alternative migration pathways that will circumvent the new north Delta intake structures as well as the existing Delta Cross Channel and Georgiana Slough. This is expected to lead to improved survival of Sacramento River basin juveniles.

BDCP creates conditions of enhanced food production, with potential to offset survival risk from stranding, predation, and water quality. Expanded access to seasonal floodplain, tidal wetland, and improved channel margin habitat will provide shallow water, low-velocity, habitat areas with increased food production. Expanded access to suitable habitat is expected to benefit juvenile salmon and steelhead rearing through access to alternative migration pathways, access to improved juvenile rearing habitat, and access to increased food production, all of which are collectively expected to result in increased juvenile growth rates and survival.

The magnitude of these benefits on the population abundance of Chinook salmon and steelhead from BDCP expanded habitat has not been quantified. The potential to improve juvenile salmonid rearing, and reduce risks associated with stranding, predation and exposure to potential toxics and adverse water quality conditions is unknown relative to existing biological conditions. Rigorous monitoring, adaptive management, and expanded habitat design serve to reduce uncertainty and the risk of adverse effects resulting from habitat expansion.

Potential benefits to all Central Valley salmonid populations. Distributing expanded access to suitable habitat for juvenile salmonid rearing throughout the Delta would offer potential net biological benefits to all populations of Central Valley salmonids.

Potential but unquantified benefits from habitat modifications along levees. Currently, habitat conditions within the Delta are characterized by large areas of riprap stabilized channel margin with little shallow water or low velocity habitat for fry and juvenile rearing. Expanded access to habitat areas characterized by shallow-water, low velocities, increased hydraulic residence time, and increased food availability, as well as providing a wider geographic distribution of diverse and complex habitats within the Delta, is consistent with salmonid conservation principles and increases opportunities for a broader range of life history expression including extended fry and juvenile rearing within the Delta.

Expanding life history diversity through expanded diverse habitat conditions is thought to improve rearing and growth, increase survival, and increase the range of life histories. This increased range of life histories includes varying juvenile rearing strategies and an expanded range of ocean entry dates that serve to reduce the risk of adverse habitat conditions on a single area of the species range (e.g., upstream habitat, or ocean conditions), which then contribute to reduced population-level declines in survival and abundance. The benefits of increased access to expanded habitat for fry and juvenile rearing on the population dynamics, resiliency, and robustness of Central Valley salmonids exposed to a wide range of environmental conditions, however, has not been quantified.

Reduced losses of salmonids at SWP/CVP facilities. While entrainment in the south Delta project facilities has never been found to have a population level effect, the project is expected to provide some benefits through reduced entrainment. Dual export facility operations would result in a reduction in juvenile steelhead losses, including pre-screen losses, at the south Delta export facilities by 40-60 percent relative to existing conditions. Dual export facility operations will reduce juvenile winter-run Chinook salmon losses at the south Delta export facilities by 50-60 percent relative to existing conditions. Dual export facility operations will result in small changes (a reduction of 1 percent to an increase of 12 percent) in juvenile spring-run salmon entrainment and salvage losses at the south Delta export facilities relative to existing conditions**.** The estimated reduction in fall-run Chinook salmon losses is 3-15 percent.

Negligible entrainment risk at north Delta intakes. As a result of the state-of-the-art design characteristics (i.e., 0.2 ft/sec approach velocity, screen mesh size, screen cleaning, etc.), the risk of entrainment or impingement of juvenile Sacramento River Basin salmonids at the north Delta intakes is negligible.

Entrainment in non-project diversions will be marginally reduced. The removal of non-project diversions due to changing land use in the Delta as a result of BDCP conservation measures (e.g., conversion of agricultural land use to restored natural habitat) will provide a marginal benefit to reducing entrainment risk for juvenile steelhead and salmon.

Entrainment in Mirant power plants will be greatly reduced. The expected transition to exclusive closed cycle water use at Mirant's Contra Costa and Pittsburg power plants by 2017 is predicted to substantially reduce and avoid entrainment and impingement of juvenile steelhead and Chinook salmon.

Increased predation resulting from north Delta in-river intakes. The use of five in-river intake structures located in the north Delta would create conditions that attract predatory fish such as striped bass, and thus increase the risk of Sacramento River juvenile steelhead and salmon to predation losses. No increase in predation risk is expected for salmonids produced in east side tributaries or San Joaquin River basin. Actions that could reduce the predation risk include reconfiguration of the intakes to an on-bank design that reduces predator habitat, although additional analyses must be conducted to verify this conclusion, and implementation of an aggressive and sustained local and regional predator removal and control program under CM6 *Predator Control*.

Improved survival of juvenile steelhead and salmon is expected from re-operation of the Delta Cross Channel (DCC) gates and installation of non-physical barriers. Closure of the DCC gates and installation and operation of non-physical barriers at key locations such as the confluence between Georgiana Slough and the Sacramento River and at the head of Old River will serve to improve survival of juvenile Sacramento River and San Joaquin River runs of steelhead and salmon migrating downstream in the rivers and through the Delta. DCC gate closure in the fall may also improve attraction flows, and thus improve olfactory cues, for upstream migrating adult Sacramento River Basin salmonids and reduce inter-basin straying. It should be noted that the effectiveness of non-physical barriers and their interaction with predators is based on limited testing; thus outcomes for salmonids remain uncertain.

Reduced reverse flow conditions. BDCP dual facility operations will result in substantial improvements in Old and Middle River (OMR) reverse flows within the south and central Delta and a net improvement in downstream flows through the Delta, particularly from the San Joaquin, Mokelumne, and Consumes river systems. These improvements in Delta hydrodynamics are expected to result in improvements in habitat conditions for juvenile steelhead and salmon rearing and survival during emigration.

No adverse upstream impacts of BDCP operations measures on steelhead, winter-run, fall-run, and late fall-run salmon. No major adverse effects were detected on upstream habitat conditions (e.g., reservoir storage, instream flows, and water temperatures during egg incubation) for steelhead, winter-run, fall-run, and late fall-run Chinook salmon in the Sacramento, Feather, and American rivers. Small positive and negative changes were detected in the Sacramento and

Feather rivers, such as reduced summer and fall flows in the Sacramento River relative to existing conditions. None of these changes would be expected to have a substantial effect on salmonid life history (i.e., migration, spawning, and juvenile rearing). No changes in habitat (i.e., instream flows and seasonal water temperatures) were detected in other rivers including the Trinity, San Joaquin, and Stanislaus or Clear Creek. BDCP operations would have no effect on habitat in non-CVP/SWP rivers including the Mokelumne, Consumes, Tuolumne, and Merced rivers, or Deer, Mill, Butte, Battle, and other tributary creeks.

Uncertainty regarding potential egg mortality for Sacramento River spring-run salmon. Results of egg mortality estimates for spring-run Chinook salmon on the Sacramento River downstream of Keswick Dam showed an increase in egg mortality of approximately 5 percent during early long term and 10 percent during late long term under BDCP operations in wet, above normal, and below normal water years relative to existing conditions. Refinement in reservoir operations and coldwater pool management may reduce this effect, but potential operational changes have not been evaluated using the hydrologic and water temperature simulation models. Spring-run Chinook salmon primarily inhabit tributaries to the Sacramento River, such as Clear Creek, Butte Creek, Mill Creek, Deer Creek, and others. Therefore, the effects of increased egg mortality on the Sacramento River would potentially adversely affect only a small proportion of the spring-run Chinook salmon spawning in the Sacramento River Basin. Results of the effects analysis detected no BDCP-related adverse effects to upstream habitat conditions (e.g., instream flows, water temperatures during egg incubation) for spring-run Chinook salmon in the Trinity River, Clear Creek, or Feather River low flow channel. BDCP operations will have no effect on instream flows, temperatures, or other habitat conditions affecting spring-run Chinook salmon spawning or egg incubation in other Sacramento River tributaries such as Mill, Butte, Deer, or Battle Creeks.

Spring-run Chinook salmon are sensitive to drought and climate change. Spring-run Chinook salmon egg mortality in the mainstem Sacramento River is extremely sensitive to effects of dry and critically dry hydrologic conditions and future climate change. Increased egg mortality under these conditions reflects natural seasonal and inter-annual variation in rivers flows, coldwater storage, and temperature effects on incubating eggs that were independent of BDCP operations.

Due to the scientific uncertainty regarding the nature and magnitude of this effect, particularly after mitigation, this issue has been identified as requiring additional analysis. Further review will be undertaken.

Uncertain effects related to operation of north Delta intake. Sacramento River flows downstream of the north Delta intakes will be reduced under BDCP operations relative to existing conditions. Flows will be reduced less during the winter than during the other seasons. Flows will be reduced most in the wetter years. The effects of flow reduction within the lower reach of the Sacramento River on the attraction and olfactory cues for upstream migrating adult salmonids and survival of downstream migrating juvenile salmonids are uncertain. Flows in the lower Sacramento River are influenced by tidal hydrodynamics, which also affect adult salmonid attraction and juvenile migration. Increased flows in drier years offer a benefit of increased attraction and olfactory cues that will contribute to reduced adult straying among watersheds.

Interannual and long-term hydrologic changes occur with or without BDCP operations. The greatest changes in habitat conditions result from natural variation in inter-annual hydrology (e.g., between wet and dry years) and future climate changes. These major effects on habitat were largely independent of differences between existing conditions and BDCP operations. Spring-run Chinook salmon were found to have the greatest risk among the salmonids of high egg mortality resulting from exposure to elevated water temperatures, particularly in critically dry water years, because of the effects of projected climate change independently, whether from existing conditions or conditions with BDCP implementation;

Net benefits of other stressor conservation measures. Collectively, other stressor conservation measures provide additional benefits to salmonids relative to existing conditions. Benefits of conservation actions such as removing structures that create habitat for and attract predators, reducing illegal harvest, and implementing hatchery and genetic management plans, although small, contribute to the cumulative biological benefits to salmonids of BDCP.

5.4.1.3.2 BDCP Effects on Salmonid Designated Critical Habitat

Critical habitat for salmonids was designated in 2005 for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and the distinct population segment of Central Valley steelhead (70FR170: 52488-52627). Habitat for these species is further characterized in the Federal Register Final Rule for each listed species (steelhead: 70 FR 52488; winter-run Chinook: 58 FR 33212; Spring-run Chinook: 70 FR 52488). The effects analysis for salmonids addressed how changes in SWP and CVP water operations and other BDCP conservation actions would affect, beneficially or adversely, the primary constituent elements (PCEs) of steelhead and Chinook salmon critical habitat.[7] The PCEs used in the effects analysis were:

- Freshwater spawning sites (i.e., providing suitable water temperatures and instream flows for successful spawning in the upstream reaches of the tributary rivers);
- Freshwater rearing sites (i.e., providing suitable water quality for juvenile rearing, instream flows to support physical habitat, connectivity with floodplains, tidal habitat, channel margin habitat, and other juvenile rearing areas, and providing suitable food resources for juvenile rearing);
- Freshwater migration corridors (i.e., reducing and avoiding passage barriers and impediments, providing suitable water quality and instream flows to support access and

[7] Other important habitats for salmonids include nearshore and offshore marine coastal habitats, which will not be affected by BDCP conservation actions.

connectivity for migration within the tributary rivers, seasonally inundated floodplains and tidal habitats, and migration pathways through the Delta);

- Estuarine areas (i.e., providing unobstructed migration and rearing opportunities, suitable water quality with salinity conditions that support juvenile and adult physiological transitions between freshwater and saltwater, and providing food resources to support juvenile growth and survival).

The effects analysis examined, through hydrologic and water quality simulation modeling, predicted changes in habitat conditions that would potentially affect the quality and availability of suitable habitat for each of the freshwater lifestages of Chinook salmon and steelhead.

Effects on Freshwater Spawning Sites. Although minor adverse and beneficial changes in habitat conditions (instream flow, water temperature, and the risk of redd dewatering) were detected for salmonid spawning and egg incubation in some locations, these changes will not have a substantive effect on habitat conditions for steelhead or winter-run Chinook salmon. Based on results of the egg mortality analysis for spring-run Chinook salmon in the mainstem Sacramento River, additional analyses are underway to assess the significance of increased egg mortality on spring-run salmon population dynamics, recognizing that only a small fraction of the population spawns in the Sacramento River, and potential refinements to Shasta Reservoir operations to reduce adverse effects. For a majority of the Central Valley rivers there was no effect of the BDCP on habitat conditions for spawning relative to the EBC. The greatest observed changes in habitat quality or availability are in response to interannual variation in Central Valley hydrologic conditions (e.g., wet years and dry years) and in response to long-term changes in Central Valley climate. Therefore, the BDCP would not affect critical habitat or the success of steelhead and Chinook salmon spawning within Central Valley rivers.

Effects on Freshwater Rearing Sites. Although minor adverse and beneficial changes in habitat conditions (flow and water temperature) were detected for salmonid rearing in some locations, these changes will not have a substantive effect on habitat conditions for Chinook salmon or steelhead. For a majority of the Central Valley rivers, there was no effect of the BDCP on habitat conditions for juvenile rearing relative to the EBC. The greatest observed changes in habitat quality or availability are in response to interannual variation in Central Valley hydrologic conditions (e.g., wet years and dry years) and in response to long-term changes in Central Valley climate.

Restoration of additional floodplain, tidal, and channel margin habitat that is geographically distributed throughout the Delta will provide substantial benefits to all Central Valley salmonids. The predicted magnitude of these benefits to increased juvenile growth and survival, and the contribution of these conservation measures to increased adult salmonid abundance have not been quantified, although positive trends towards recovery are anticipated based on salmonid recovery plans. Floodplain enhancement actions designed to increase the frequency and duration of access for juvenile Sacramento River basin Chinook salmon and steelhead to seasonally inundated floodplain habitat in Yolo Bypass will be a significant environmental benefit of

BDCP. Similarly, the BDCP will substantially increase the availability of, and access to, shallow water, low velocity tidal and channel margin habitat that is geographically distributed along the Sacramento River and within the eastern and southern Delta and Suisun Marsh, which will increase rearing habitat for juvenile Chinook salmon and steelhead from all Central Valley rivers relative to existing conditions. The increased tidal and seasonal floodplain habitat proposed under BDCP will contribute to improved ecological functions related to increased food production and availability of prey for juvenile salmon and steelhead. Uncertainty in expanded habitat performance and ecological functions will be addressed through a rigorous monitoring, research, and adaptive management programs.

Overall, BDCP will not adversely modify habitat conditions for freshwater rearing in upstream habitats within rivers tributary to the Delta. Instead, BDCP conservation actions will improve habitat access, quality, and availability for juvenile Chinook salmon and steelhead rearing within the lower reaches of the Sacramento and San Joaquin rivers and within the Delta and Suisun Marsh. Implementation of BDCP conservation measures will contribute to a substantial increase in suitable habitat for juvenile Chinook salmon and steelhead rearing.

Effects on Freshwater Migration Corridors. The BDCP conservation strategy includes measures specifically designed to improve migratory corridors and reduce the effects of obstructions that impede salmonid passage under existing conditions. Proposed actions include increasing fish passage opportunities for juvenile salmon and steelhead migration into the seasonally inundated Yolo Bypass floodplain, improving passage at the Fremont Weir, using non-physical barriers to guide downstream migrating salmon and steelhead, improving dissolved oxygen concentrations in the lower San Joaquin River, and modifying operation of the Suisun Marsh Salinity Control Structure to improve fish passage. Operations under BDCP will also improve hydrologic conditions as reflected by an increase in positive flows in Old and Middle Rivers, as well as maintenance of instream flows within the tributaries to the Delta. These conditions are intended to improve the survival of juvenile Chinook salmon and steelhead migrating downstream through the Delta, in part by reducing their vulnerability to entrainment losses at the existing south Delta water export facilities. Implementation of additional floodplain and tidal habitat has been identified as being beneficial for all Central Valley salmonids. There is a high degree of uncertainty, however, in the quantification of the magnitude of net benefits to the salmonid populations, although positive trends towards recovery are anticipated based on salmonid recovery plans. Reductions in instream flow in the lower reaches of the Sacramento River have the potential to reduce olfactory cues and attraction flows for upstream migrating adult Chinook salmon and steelhead, and river flows for downstream migrating juveniles in the reach downstream of Walnut Grove. Upstream of the north Delta intakes, river flows are similar between the BDCP and existing conditions. In the downstream estuarine region of the Delta, tidal flows are dominant. No information is available to quantitatively assess the potential effects of local flow reductions on migration and survival of Chinook salmon or steelhead.

Construction of five north Delta intake structures would modify local hydrodynamic conditions as well as obstruct a portion of the river channel by the footprint of each intake structure. These effects of the north Delta intakes would occur whether or not the intake is actually diverting water. Although these physical structures and their effects on local instream flow patterns and turbulence would adversely affect critical and essential habitat for salmonids in the lower reaches of the Sacramento River, these effects are expected to be localized and relatively small in comparison to the large areas of subtidal and intertidal aquatic habitat that would be restored and available for salmonid foraging, rearing, and migration.

Overall, the BDCP will not adversely affect habitat conditions for Chinook salmon or steelhead in migration corridors within the tributaries of the Delta and would improve passage conditions for salmonids migrating through the Delta. BDCP conservation actions will reduce obstructions to salmon and steelhead passage within the lower reaches of the Sacramento and San Joaquin rivers and within the Delta and Suisun Marsh. Implementation of BDCP conservation measures is expected to contribute to an increase in habitat conditions for juvenile Chinook salmon and steelhead migration.

Effects on Estuarine Areas. The BDCP conservation strategy will contribute to a substantial increase in access to suitable juvenile salmonid rearing habitat within the estuarine regions of the Delta through channel margin habitat enhancements in the western Delta, as well as substantial increases in aquatic habitat within Suisun Marsh adjacent to Suisun Bay (approximately 24,570 acres in the LLT). The increased access of shallow water, lower velocity juvenile rearing habitat within the estuarine region of the Delta will contribute to an increase in ecological functions of aquatic habitat including increased habitat diversity and complexity, foraging habitat and food resources for migrating juvenile Chinook salmon and steelhead. Implementation of additional tidal habitat will be beneficial to salmonids. Although positive trends towards recovery are anticipated based on salmonid recovery plans, there is a high degree of uncertainty in the magnitude of net population level benefits to the salmonid populations.

Operations under BDCP will also improve hydrologic conditions as reflected by an increase in positive flows in Old and Middle rivers and maintenance of instream flows within the rivers tributary to the Delta. These conditions will improve the survival of juvenile Chinook salmon and steelhead migrating downstream through the Delta and improve estuarine rearing habitat conditions. These improvements will benefit juvenile salmon and steelhead by providing a potential for increased growth, which should contribute to increased survival. Improvements in central Delta habitat and hydrodynamics will provide the greatest benefits for salmon and steelhead produced in the Mokelumne, Cosumnes, and San Joaquin river basins.

Operations under BDCP during the late winter and spring months when juvenile salmon and steelhead are migrating downstream through the estuarine region of the Delta provide outflow and salinity conditions that are comparable to those under existing conditions.

Overall, the BDCP will not adversely affect habitat conditions for Chinook salmon and steelhead within the estuarine region of the Delta. BDCP conservation actions will reduce obstructions to salmon and steelhead passage within Suisun Marsh. The BDCP will contribute to an increase in habitat for juvenile Chinook salmon and steelhead migration within the estuarine region of the Delta.

5.4.1.3.3 BDCP Effects on Essential Fish Habitat for Pacific Salmon

The Bay-Delta system has been identified as Essential Fish Habitat (EFH) under the Magnuson-Stevens Act for several groups of fish species including Pacific salmon, Coastal Pelagic Species, and West Coast Groundfish. EFH includes those waters and substrate necessary for fish production needed to support a long-term sustainable fishery and contributions to a healthy ecosystem. The BDCP effects analysis included an assessment of EFH for Pacific salmon which includes winter-run, spring-run, fall-run, and late fall-run Chinook salmon from all Central Valley river systems.

The BDCP conservation measures and operations will result in localized temporary effects on EFH. These effects would be reduced through implementation of BMPs during construction and other actions. The BDCP actions would result in small changes in local habitat conditions in some areas of the upstream rivers and Delta, but would also result in improvements in aquatic habitat conditions through changes in local hydrodynamics such as reductions in Old and Middle River reverse flows and significant expansion of aquatic habitat within a variety of regions distributed throughout the Delta and within Suisun Marsh. Operations will not result in substantial or detectable changes in habitat conditions for EFH species inhabiting regions of the Bay-Delta downstream of Suisun Bay. Based on these factors, it was concluded that implementation of BDCP will not result in adverse effects to EFH that would impact Chinook salmon at a population level. Instead, many of the proposed conservation actions will contribute to enhanced EFH conditions within the Delta.

5.4.1.3.4 BDCP Effects on Salmonid Population Viability

The long-term recovery of Central Valley Chinook salmon and steelhead is measured by four fundamental viable salmonid population (VSP) criteria as described in the NMFS (2009) draft Central Valley salmonid recovery plan and Lindley et al. (2007):

- Population abundance (population size) as reflected in the numbers of adult Chinook salmon and steelhead returning to Central Valley rivers to spawn;
- Population growth rates (productivity) as reflected in survival rates for each life stage and increasing population abundance trends (positive cohort replacement);
- Population spatial structure (habitat and population distribution) as reflected in the geographic distribution of suitable habitat, habitat heterogeneity and complexity, abundance of juvenile smolts produced in different watersheds, and dispersal of distinct population segments among watersheds; and
- Diversity (variation in behavioral and genetic traits) as reflected in diversity and complexity of habitat types, reduced percentage of hatchery produced Chinook salmon

and steelhead, variation in life history and run timing, and access to suitable upstream spawning and rearing habitat and migration pathways.

Additional considerations include reducing and avoiding threats and stressors on the populations associated with actions such as changes in instream flows, water diversion effects, increased vulnerability to predation, and other factors.

Results of the BDCP effects analysis indicate that changes predicted to occur as a direct result of implementation of the conservation strategy are consistent with the principles of recovery planning for Central Valley salmonids. The BDCP conservation actions will contribute to recovery for salmonids because they will result in the following:

Restoration of habitat will increase abundance, growth rate, spatial structure, and diversity. The BDCP will contribute to increased abundance of Central Valley Chinook salmon and steelhead through protection and enhancement of suitable habitat conditions such as instream flows and water temperatures within the upstream spawning and juvenile rearing habitats, as well as contribute to increased geographically distributed and complex juvenile rearing habitat within the Delta. Increased access to expanded seasonal floodplain, tidal wetlands, and improved channel margin habitat will contribute to increased juvenile growth and survival, thereby improving survival and contributing to increased adult abundance. Long term implementation of BDCP conservation measures will reduce the adverse effects of a number of current stressors and improve juvenile and adult Chinook salmon and steelhead survival that will result in improved population growth rates (a greater probability of maintaining positive cohort replacement) over a wide range of hydrologic and environmental conditions that occur within the Central Valley.

Salmonid independent populations. Conservation measures included as part of BDCP would not result in the expansion of winter-run or spring-run Chinook salmon or Central Valley steelhead populations into additional upstream habitats or result in the formation of additional independent spawning populations. Habitat conditions and water operations within the Sacramento River and Delta, however, would be complementary to the formation of additional winter-run or spring-run Chinook salmon or steelhead populations within the Central Valley if that should occur in the future.

Reduction in SWP/CVP losses will increase survival. While entrainment in the south Delta SWP and CVP project facilities has never been determined to have a population level effect, reduced entrainment would provide some increases in survival thereby benefiting the species. Reduction in south Delta SWP and CVP exports through dual facility operations would contribute to: (1) increased juvenile winter-run and fall-run Chinook salmon and steelhead survival through a reduction in losses resulting from reductions in south Delta SWP and CVP export operations; (2) increased juvenile rearing habitat and survival, particularly for juvenile Chinook salmon and steelhead produced in the San Joaquin, Mokelumne, and Consumes river watersheds as a result of reductions in Old and Middle river reverse flows and associated increases in net downstream flows through the Delta; and (3) reduced risk of indirect mortality for juvenile salmonids migrating through the Delta and improvements in net downstream flows through the Delta channels. Actions such as expanded closure times of the Delta Cross Channel gates and installation and operation of non-physical barriers at key locations (Georgiana Slough, head of Old River) will further contribute to increased juvenile survival, improved attraction, and reduced straying for adult Chinook salmon and steelhead returning to the San Joaquin River system and east side tributaries.

5.4.1.3.5 Overall Conclusions for Chinook Salmon and Steelhead

The following overall conclusions were made based on the results of the effects analysis for Chinook salmon and steelhead.

Net Beneficial Effects on San Joaquin River Salmonids. Steelhead, fall-run Chinook, and future re-introduced spring-run Chinook salmon runs in the San Joaquin River Basin would benefit from BDCP implementation by a reduction in south Delta exports and the associated reduced risk of entrainment at the export facilities, reduction in the magnitude of Old and Middle rivers reverse flows and improvement in the net downstream flow of water from the San Joaquin River through the Delta. Reduction in potential indirect effects on the survival of juvenile salmonids. Expansion of aquatic habitat in the south Delta in the LLT and habitat expansion in the west Delta and Suisun Marsh in the ELT and LLT will provide opportunities for juvenile salmonids emigrating from the San Joaquin River system to rear and contribute to increased juvenile growth rates and survival. BDCP would have no effect on instream flows, water temperatures, or other habitat conditions within the mainstem San Joaquin River or its tributaries relative to existing biological conditions. Increased flow from the San Joaquin River passing through the Delta will improve adult salmonid attraction and olfactory cues and contribute to improved survival of emigrating juveniles. Application of a non-physical barrier at the head of Old River and the effects of reductions in other stressors would contribute to the cumulative benefits of BDCP conservation measures on the growth, survival, and abundance of San Joaquin River salmonids.

Net Beneficial Effects on Mokelumne and Cosumnes River Salmonids. Steelhead and fall-run Chinook runs in the Mokelumne and Cosumnes rivers would benefit under BDCP by a reduction in south Delta exports and the associated risk of entrainment at the export facilities, reduction in the magnitude of Old and Middle River reverse flows and improvement in the net downstream flow of water from the Mokelumne and Cosumnes rivers through the Delta. Expansion of aquatic habitat in the lower reaches of the Mokelumne and Cosumnes rivers and habitat expansion in the west Delta and Suisun Marsh would provide opportunities for juvenile salmonids emigrating from the Mokelumne and Cosumnes rivers to rear and contribute to increased juvenile growth rates and survival. BDCP would have no effect on instream flows, water temperatures, or other habitat conditions within either the Mokelumne or Cosumnes rivers relative to existing biological conditions. Closure of the Delta Cross Channel gates during the fall would potentially improve attraction to the Mokelumne and Cosumnes rivers and reduce straying to other Central Valley rivers. The effects of reductions in other stressors would contribute to the cumulative benefits of BDCP conservation measures on the growth, survival, and abundance of steelhead and fall-run Chinook salmon produced in the two rivers.

Net Beneficial Effects on Sacramento River Salmonids. Steelhead, winter-run, spring-run, fall-run and late fall-run Chinook runs in the Sacramento River Basin would benefit from BDCP implementation by a reduction in south Delta exports and the associated risk of entrainment at the export facilities. Diversions from the north Delta would make use of state-of-the-art positive barrier fish screens designed and operated to avoid entrainment and impingement of juvenile salmonids. An increased risk of predation associated with the north Delta intake structures was identified in the effects analysis, but can be substantially reduced by intake re-design in combination with predator management. Reduction in the magnitude of Old and Middle rivers reverse flows and improvement in Delta habitat available for juvenile salmonid rearing will provide an improvement in hydrologic conditions affecting habitat and survival of juvenile salmonids in the central and south Delta. Reduction in reverse flows and reductions in south Delta exports results in a reduction in potential indirect effects on the survival of juvenile salmonids. Expansion of aquatic habitat in the north Delta through substantial increases in the frequency and duration of access to expanded seasonal floodplain rearing habitat within the Yolo Bypass, that is interconnected to substantially increased tidal habitat within the Cache Slough complex, will increase juvenile growth and survival, contribute to increased habitat diversity and complexity, and provide opportunities for expanded diversity of life history characteristics. In combination, these changes would result in greater juvenile survival and increased adult salmonid abundance. Habitat expansion in the west Delta and Suisun Marsh would provide opportunities for juvenile salmonids emigrating from the Sacramento River and its tributaries to rear and contribute to increased juvenile growth rates and survival. BDCP would have no effect on instream flows, water temperatures, or other habitat conditions in many of the Sacramento River tributaries. Relatively small beneficial and adverse changes in upstream habitat within the mainstem Sacramento River and Feather River were identified. Refinements in Shasta Reservoir operations may help reduce a projected increase in spring-run Chinook salmon egg mortality in wetter years in the mainstem Sacramento River. Reduced flows in the lower reach of the Sacramento River downstream of the north Delta intakes in wetter years may affect adult salmonid attraction and juvenile survival, however, the potential for adverse effects within the tidal reach of the river are uncertain. Installation of a non-physical barrier at Georgiana Slough and the effects of reductions in other stressors would contribute to the cumulative benefits of BDCP conservation measures on the growth, survival, and abundance of Sacramento River salmonids.

Contribution to Recovery. [**Note to Reviewers:** The Steering Committee has not completed discussion on the sufficiency of the BDCP to contribute to recovery of covered species] BDCP conservation measures are consistent with and complementary to salmonid recovery within the Central Valley as identified in the NMFS draft recovery plan (NMFS 2009). BDCP conservation measures would not result in the establishment of new independent salmonid populations within the Central Valley. Habitat conditions and water operations within the Sacramento River and Delta would, however, be complementary to the formation of additional winter-run or spring-run Chinook salmon or steelhead populations within the Central Valley if that should occur in the future. There are no actions proposed as part of BDCP that are inconsistent or incompatible with long-term salmonid recovery plan implementation.

Net Beneficial Effects on Designated Critical Habitat. BDCP conservation actions would contribute substantially to improved habitat availability and diversity that would benefit juvenile salmonids and reduce stressors that currently adversely affect Chinook salmon and steelhead growth, survival, and population abundance. Substantial reductions in Old and Middle River reverse flows and expanded intertidal, subtidal, and seasonal floodplain habitat represent major contributions toward improved critical habitat for winter-run and spring-run Chinook salmon and steelhead within the Delta. These improvements in critical habitat conditions for listed salmonids would contribute to increased juvenile growth and survival, greater life history and habitat diversity, and are expected to result in increased adult salmonid abundance. Effects of BDCP operations on critical habitat upstream of the Delta has been evaluated and results show relatively small adverse and beneficial effects on habitat conditions for spawning and juvenile rearing on the mainstem Sacramento River and Feather River, but no incremental changes in habitat conditions on other Central Valley river systems. The magnitude of beneficial effects associated with changes in water operations, expanded aquatic habitat, improved hydrologic conditions within the Delta, and reduction in other stressors have not been quantified. Uncertainties regarding the ecological functions and net biological response of salmonids to expanded diverse habitats geographically distributed in various regions of the Delta, and changes in water operations and hydrologic conditions within the rivers and Delta will be addressed through the BDCP monitoring, research, and adaptive management programs.

Net Beneficial Effects on Essential Fish Habitat. Based on results of the effects analysis it was concluded that implementation of BDCP conservation measures and operations would result in localized temporary effects on EFH. These effects would be reduced through implementation of BMPs during facilities construction and other actions. The BDCP actions would result in small changes in local habitat conditions in some areas of the upstream rivers and Delta but would also result in substantial improvements in aquatic habitat conditions through changes in local hydrodynamics such as reductions in Old and Middle River reverse flows and significant expansion of aquatic habitat within a variety of regions distributed throughout the Delta and within Suisun Marsh as a result of BDCP habitat restoration actions. Operations would not be expected to result in substantial or detectable changes in habitat conditions for EFH species inhabiting regions downstream of Suisun Bay. Based on these factors, it was concluded that implementation of BDCP would not result in adverse effects to EFH that would impact species at a population level and that many of the proposed conservation actions would contribute to enhanced EFH conditions within the Delta.

Need for Adaptive Management. As a comprehensive package of conservation measures, BDCP will contribute to the survival and recovery of Central Valley Chinook salmon and steelhead populations through cumulative reduction in stressors and improvements in habitat that together contribute to increase population abundance. The magnitude of the effects of BDCP actions on Chinook salmon and steelhead recovery, however, has not been quantified. There remain areas of uncertainty regarding the effectiveness of various individual conservation actions that will be addressed as part of BDCP implementation through the BDCP monitoring, research, and adaptive management programs.

5.4.1.4 Sacramento Splittail

5.4.1.4.1 BDCP Effects on Stressors

Based on results of the effects analysis, the BDCP will produce a number of major changes within the Delta that will reduce the impacts of ecological stressors on the Sacramento splittail population and improve habitat conditions for adult reproduction and larval and juvenile rearing. These major effects analysis findings include:

Increased Yolo Bypass inundation creates more spawning and rearing habitat. Limited availability of spawning habitat and rearing habitat for the larval and early juvenile life stages is a primary stressor on the splittail population, especially in dry years when floodplains are not inundated. Implementation of CM2, *Yolo Bypass Fishery Enhancement*, will increase the frequency and duration of Yolo Bypass inundation, resulting in substantial increases in spawning and rearing habitat availability. The increased duration of flooding events will reduce the risk of stranding. Rates of predation on splittail larvae will not be affected by CM2. Increases in habitat surface area are predicted to be especially large (on a percentage basis) in dry years, when Sacramento River flow is low. Predicted habitat increases are somewhat larger with the combined effects of the proposed project and climate change in the ELT and LLT. There is some uncertainty regarding the level of flow from the Bypass that is sufficient to trigger spawning migration by the splittail adults, although the BDCP includes monitoring, research, and adaptive management to identify refinements in operations to further increase spawning habitat availability.

Restored inundated floodplain habitat in other parts of the Delta would increase habitat availability. Restoration of 10,000 acres of new seasonally inundated floodplain under the BDCP will provide substantial new splittail rearing and spawning habitat in different areas of the Delta in the LLT. Increases in the ELT will be 1,000 acres. Benefits to splittail will occur only with flood events which will be more frequent in wet years, when inundated floodplain habitat is currently most available. The main benefit of this conservation action will be to increase habitat diversity, as discussed below.

Enhance channel margin habitat expected to benefit emigrating young of the year (YOY). Currently, channel margin habitat conditions within the Delta are characterized by large areas of riprap stabilized channel margin with little shallow water or low velocity habitat for fry and juvenile rearing. Under the proposed project expansion of access to habitat areas characterized by shallow-water, low-velocities, increased hydraulic residence time, and increased food availability will enhance growth and survival of YOY juvenile splittail during their downstream migrations. Availability of rearing habitat for juveniles during their downstream migration is an important stressor, but less so than the availability of inundated floodplain habitat. Enhancement of channel margin habitat under the proposed project will increase rearing habitat availability and geographic distribution. Channel margin habitat may be used for spawning in dry years, when spawning habitat is limited, but the degree to which splittail spawn in channel margin habitats in the Delta, and conditions required for successful egg/embryo and larval development, are not well known.

Restored tidal habitat would provide additional rearing and foraging habitat. Restoration of tidal and subtidal habitats under the proposed project will substantially increase the availability of rearing and foraging habitat for splittail. Availability of rearing habitat for juveniles following completion of their downstream migration is an important stressor, but less so than availability of inundated floodplain habitat. Restoration in the Cache Slough and Suisun Marsh ROAs will be especially beneficial. The Cache Slough area receives most of the YOY splittail emigrating from the Yolo Bypass, resulting in heavy use, whereas Suisun Marsh is the most important rearing habitat destination for juvenile splittail. The benefits of the restored tidal habitats will increase progressively from the NT to the ELT and to the LLT, as areas of restored habitat increase. These benefits could be substantially reduced, however, if nonnative vegetation and predatory fish colonize newly restored habitats. Conservation measures to control SAV and nonnative predators and the BDCP adaptive management program will be aimed at maintaining high habitat function by addressing these stressors. Tidal habitat may be used for spawning in dry years, when spawning habitat is limited, but the degree to which splittail spawn in tidal habitats in the Delta and the conditions required for successful egg/embryo and larval development are not well understood.

Increased Yolo Bypass inundation and channel margin and tidal habitat restoration would result in greater local food production and increased export of production to other areas of the Delta. The increases in Yolo Bypass inundated floodplain habitat and other habitat improvement measures will result in greater food web resources for splittail larvae and juveniles rearing on the floodplain and adults preparing to spawn and for rearing juveniles and foraging adults in channel margin and tidal habitats. More food for splittail will contribute to higher growth rates, survival, and fecundity of splittail. Export of food web resources produced on the floodplain and other restored habitats is expected, which would benefit splittail in other areas, but the degree to which food is exported is uncertain.

Habitat restoration over a wide geographic range will have several potential benefits. Restoration of tidal, floodplain, and channel margin habitats under the proposed project will increase the geographic distribution of spawning and rearing habitat for splittail, which will: 1) increase the range of available habitat conditions, thereby improving the likelihood of providing suitable conditions for spawning, eggs/embryo development, larval and juvenile rearing, and adult foraging; and 2) buffer against unforeseen future adverse environmental effects (including catastrophic events).

Uncertain effects on exposure to methylmercury. Enhanced frequency and duration of flooding of the Yolo Bypass has the potential to increase exposure of splittail to methylmercury because: 1) the Yolo Bypass experiences high levels of methylmercury loading, particularly from

Cache Creek, 2) splittail use of the Yolo Bypass would increase, and 3) the inundation regime on the Bypass will be altered, increasing the rate of mercury methylation. These effects, however, may be mitigated by dilution and advection effects of increased Sacramento River inflows. The thresholds of toxicity of methylmercury concentrations are unknown. The BDCP conservation measure to control methylmercury, implemented with adaptive management, is expected to reduce methylmercury loading. Splittail in Delta habitats are expected to receive increased exposure to methylmercury because habitat restoration activities increase methylmercury production. Splittail are expected to be especially at risk in the Cache Slough ROA because methylmercury concentrations in this area are already high. The BDCP will have a low, but relatively uncertain, negative outcome with regard to methylmercury exposure.

Uncertain effects on exposure to pyrethroids. Pyrethroid concentrations in the Delta will decrease under the proposed project during most of the April to July period of juvenile emigration. Residence time also affects exposure to pyrethroids. Residence time, as determined by flow, will increase in some areas of the Delta and decrease in other areas, depending on hydrologic conditions, with no net effect on splittail expected. Habitat restoration under the BDCP will result in reduced pyrethroid loading because agricultural land will be taken out of production. On balance, the BDCP will provide a low, but uncertain, benefit with respect to splittail exposure to pyrethroids.

Increased exposure to selenium. The BDCP will result in increased exposure of splittail to toxic levels of selenium. The adult life stage is the most important with regard to selenium because of its relatively long duration and a diet including overbite clams, which contain high concentrations of selenium. Selenium bioaccumulates with age, although eggs and embryos, which receive high levels of selenium in maternal transfer, are the most susceptible to selenium toxicity. The BDCP will result in increased exposure of adults to selenium because it is predicted to cause increased selenium concentrations in the west Delta during the summer and fall. The west Delta is the primary foraging habitat of adult splittail and summer and fall are the principal seasons for grazing by the overbite clam. The effects will be similar in the ELT and LLT relative to EBC, independent of projected climate change. These increases will likely result in increased reproductive failure in splittail, but the magnitude of the effect is uncertain, particularly at the population level.

Reduced losses at south Delta SWP/CVP facilities. While it has never been determined that entrainment has a population level effect, reductions in entrainment will increase survival and benefit the species. Dual export facility operations under the proposed project will result in a reduction in juvenile and adult splittail losses at the south Delta export facilities relative to EBC**.** Juvenile splittail are at risk of losses primarily during May through July, as they migrate to downstream rearing habitats, whereas adult splittail are at risk of loss primarily between December and March, during their upstream spawning migration. The BDCP will result in a substantial reduction in losses of both life stages because exports at the south Delta export facilities, which currently entrain large numbers of splittail, will be reduced, while entrainment of splittail at the new screened north Delta intakes will be negligible. In both the ELT and LLT, the reductions in entrainment of juveniles are predicted to exceed 65 percent at both the CVP and SWP south Delta facilities relative to EBC. For scenarios that take into account projected climate change conditions, the reductions are 75 percent or greater. For adults, the reductions in entrainment at both the CVP and SWP facilities, for all the analysis scenarios, will be between 60 and 66 percent relative to EBC. The benefits of these reductions are limited because past studies have found no evidence that entrainment of splittail significantly affects population abundance. The removal of non-project diversions due to changing land use in the Delta as a result of the BDCP will provide a marginal benefit to reducing entrainment risk for larval and juvenile splittail.

Effects of BDCP on predation uncertain. Many BDCP conservation actions have the potential to affect predation on splittail, including habitat restoration, changes in lower Sacramento River flow, and north Delta intake structures. Habitat restoration will result in increased numbers of predators and increased numbers of splittail. If predation rates do not change significantly, the net effect will be an increase in the total population of splittail. Diversions of Sacramento River flow at the new north Delta intakes will result in reduced flow rates downstream. Studies on juvenile salmon indicate that flow reductions reduce rates of downstream migration, which increases time of exposure to predators. During May and June, the peak months of juvenile splittail emigration, BDCP operations will reduce average flows by 2 to 3 percent in drier years and 35 to 42 percent in wetter years. When climate change is included, average flows will be negligibly reduced in drier years and reduced by approximately 25 percent in wetter years. The flow reductions will result in little change on predation on juvenile splittail in drier years, but could result in a substantial increase in predation in wetter years. The north Delta intakes will provide new habitat for piscivorous fish such as striped bass, resulting in increased predation on the emigrating juveniles. The increases could be substantial for both the ELT and LLT, exceeding numbers currently entrained at the south Delta facilities. This conclusion is highly uncertain because the actual predation rates by striped bass and other Delta piscivores on splittail are unknown. The BDCP conservation measures to control nonnative predators and removal of SAV will result in minor reductions in predation in the Delta. Overall, the BDCP will have moderately negative but uncertain effects with respect to predation on splittail in both the ELT and LLT.

Entrainment in Mirant power plants will be greatly reduced. The expected transition to exclusive closed cycle water use at Mirant's Contra Costa and Pittsburg power plants by 2017 will substantially reduce and avoid entrainment and impingement of juvenile splittail.

5.4.1.4.2 Overall Conclusions for Splittail

The following overall conclusions were made based on the results of the effects analysis for Sacramento splittail.

Contribution to Increased Reproduction. Overall, the BDCP will contribute to increased reproduction of Sacramento splittail. The most important component of the BDCP for splittail is the increase in seasonally inundated floodplain habitat, including expected increases in food web resources. Several studies have concluded that the Sacramento splittail population is largely limited by the availability of floodplain habitat. Splittail year classes are nearly always high in wet years, when large areas of floodplain are inundated, and low in dry years. The BDCP Yolo Bypass floodplain enhancement will substantially increase the acreage of inundated floodplain, particularly in dry years. Restoration of new floodplain under BDCP will provide additional seasonally inundated floodplain habitat, primarily in wet years, and will increase the geographic distribution and diversity of the available habitat for splittail. Restoration of tidal, subtidal, and channel margin habitats under the proposed project will provide additional spawning habitat in all water year types.

Need for Adaptive Management. Results of the effects analysis indicate that the BDCP will reduce adverse effects of major stressors and is consistent with, supportive of, and complementary to recovery planning for splittail (USFWS 1996). Uncertainties remain, however, regarding the magnitude of population-level effects on the dynamics and recovery of the population. The BDCP includes adaptive management based on extensive monitoring and research that will be used to address areas of uncertainty and to refine the conservation measures to improve the overall net environmental benefits of the program, in combination with other recovery actions, in contributing to the long-term recovery of splittail. The adaptive ranges for a number of water operations parameters allow for adjustments such that, if initial operations do not support the outcomes expected for splittail, there is the opportunity and flexibility to adaptively change operations and potentially improve biological outcomes.

5.4.1.5 Sturgeon

5.4.1.5.1 BDCP Effects on Stressors

Results of the effects analysis indicate that the BDCP conservation strategy will result in a number of major changes within the Delta that will reduce the impacts of stressors on green and white sturgeon populations and improve habitat conditions for juvenile sturgeon rearing and adult and juvenile sturgeon migration. These major effects analysis findings for stressors on sturgeon are described below.

Greater access to rearing habitats potentially used by juvenile sturgeon. BDCP conservation measures will result in substantially increased access to expanded subtidal, tidal wetland and channel margin habitat, geographically located throughout the Delta, which will potentially benefit juvenile sturgeon that utilize the Sacramento River and the San Joaquin River basins, Suisun Marsh and Bay, and the Delta. As noted for salmonids, intertidal habitat will be expanded by approximately 7,900 acres in the NT with an additional 7,300 acres in subtidal habitat. During the ELT, intertidal habitat will be expanded to 13,000 acres and subtidal habitat will be expanded by 9,400 areas. During the LLT intertidal habitat will be expanded by 16,400 acres and subtidal habitat will be expanded by 32,300 acres.

Habitat benefits for sturgeon. Major expansion in access to tidal habitat and channel margin habitat will result from the proposed project in the northern Delta (Yolo Bypass and Cache Slough complex) as well as channel margin habitat along the mainstem Sacramento River, Sutter and Steamboat sloughs, and western Delta, and tidal habitat expansion within Suisun Marsh that would serve to benefit juvenile sturgeon produced in the Delta. As noted for salmonids, intertidal habitat will be expanded by approximately 3,000 acres in Cache Slough in the NT with an additional 1,200 acres in subtidal habitat. During the ELT, intertidal habitat in Cache Slough will be expanded to 5,900 acres and subtidal habitat will be expanded by 2,300 areas. During the LLT intertidal habitat will be expanded by 6,900 acres from existing conditions and subtidal habitat will be expanded by 7,400 acres. Additional habitat expansion in the western Delta, five miles of channel margin habitat enhancement on the Sacramento River, and substantial increases in habitat in the western Delta and Suisun Marsh will also be made available by the proposed project on the migration pathway for juvenile sturgeon.

Expansion of intertidal and subtidal habitat in the south Delta along the migratory pathway for juvenile white sturgeon produced in the San Joaquin River basin will result from the proposed project in the LLT. San Joaquin River white sturgeon will also benefit from subtidal and tidal habitat expansion in the western Delta and Suisun Marsh.

Creation of alternative migratory routes and access to more habitat. Juvenile Sacramento River basin sturgeon survival may improve as a result of the potential use of expanded access to seasonal floodplain within the Yolo Bypass, which would provide opportunities for juvenile sturgeon to access alternative migration pathways that would circumvent the north Delta intake structures, the Delta Cross Channel, and Georgiana Slough;

BDCP implementation will create conditions of enhanced food production, with potential to offset survival risk from stranding, predation, and water-quality. Expanded access to tidal wetland and improved channel margin habitat will provide shallow water, low-velocity habitat areas with increased food production. Expanded access to suitable habitat will benefit juvenile sturgeon rearing through access to alternative migration pathways, access to improved juvenile rearing habitat, and access to increased food production that collectively are expected to result in increased juvenile growth rates and survival.

The magnitude of these benefits on the population abundance of sturgeon from BDCP expanded habitat is uncertain. The potential to improve juvenile sturgeon rearing; and risks associated with predation and exposure to potential toxics and adverse water quality conditions is unknown relative to existing biological conditions. Rigorous monitoring, adaptive management, and continual improvements to habitat restoration design will serve to reduce uncertainty and the risk of adverse effects resulting from habitat expansion.

Potential, but unquantified, benefits from habitat modifications along levees. Currently, habitat conditions within the Delta are characterized by large areas of riprap stabilized channel margin with little shallow water or low velocity habitat for juvenile sturgeon rearing. Expanded access under the proposed project to habitat areas characterized by shallow-water, low-velocities, increased hydraulic residence time, and increased food availability, as well as the provision of a wider geographic distribution of diverse and complex habitats within the Delta is consistent with sturgeon conservation, and increases the opportunities for a broader range of life history expression including extended juvenile rearing within the Delta. Expanding opportunities for a wide range of life histories is consistent with sturgeon conservation and recovery principles.

Improved survival of juvenile sturgeon from re-operation of the Delta Cross Channel (DCC) gates. Expanded closure of the DCC gates and installation and operation of non-physical barriers at key locations such as the confluence between Georgiana Slough and the Sacramento River and at the head of Old River will improve survival of juvenile sturgeon migrating downstream in the rivers and through the Delta. Extended DCC gate closure may also improve attraction flows and thus improve olfactory cues for upstream migrating adult sturgeon and reduce inter-basin straying.

Reduced reverse flow conditions. BDCP dual facility operations will result in substantial improvements in Old and Middle River (OMR) reverse flows within the south and central Delta and a net improvement in downstream flows through the Delta, particularly from the San Joaquin River system. These improvements in Delta hydrodynamics will result in substantial improvements in habitat conditions for juvenile sturgeon rearing and survival in these habitats.

Reduced losses of sturgeon in SWP/CVP facilities. While it has never been determined that entrainment has a population level effect, reductions in entrainment will increase survival and benefit the species. Dual export facility operations will result in a reduction in juvenile sturgeon entrainment and salvage losses at the south Delta export facilities by 30-60 percent for white sturgeon and 25-70 percent for green sturgeon relative to existing conditions;

Negligible entrainment risk at north Delta intakes. As a result of the state-of-the-art design characteristics (i.e., 0.2 ft/sec approach velocity, screen mesh size, screen cleaning, etc.), and the demersal behavior of post-larval sturgeon, the risk of entrainment of age-0 sturgeon at the north Delta intakes will be negligible, but is currently not quantifiable.

Entrainment in non-project diversions will be marginally reduced. The removal of non-project diversions due to changing land use in the Delta as a result of the BDCP will provide a marginal benefit to reducing entrainment risk for age-0 sturgeon.

Entrainment in Mirant power plants will be reduced. The expected transition to exclusive closed cycle water use at Mirant's Contra Costa and Pittsburg power plants by 2017 will substantially reduce and avoid entrainment and impingement of juvenile sturgeon.

No adverse upstream impacts on sturgeon. No major adverse effects were detected in the effects analysis on upstream habitat conditions (e.g., reservoir storage, instream flows, and water temperatures during egg incubation) for sturgeon in the Sacramento or San Joaquin rivers. Small positive and negative changes were detected in the Sacramento and Feather rivers, such as reduced summer and fall flows in the Sacramento River relative to existing conditions. None of these changes will have a substantial effect on sturgeon life history (i.e., migration, spawning, and juvenile rearing). No significant changes in upstream habitat (i.e., instream flows and seasonal water temperatures) were detected in the San Joaquin and Stanislaus rivers. BDCP operations will have no effect on habitat in rivers not controlled by the CVP or SWP operations.

No increase in egg mortality for Sacramento River or San Joaquin River sturgeon. Results of the SacEFT model for green sturgeon on the Sacramento River indicate an adverse effect on temperature conditions for sturgeon as a result of climate change, but with no apparent effect attributable to the proposed project. Results of the effects analysis detected no BDCP-related adverse effects to upstream habitat conditions (e.g., instream flows, water temperatures during egg incubation) for sturgeon in the Sacramento or San Joaquin rivers.

Late summer flow decreases in the Feather River. Within the Feather River, small decreases in July flows under the proposed project, most significant in below normal and dry years in the upper river, may adversely affect green sturgeon egg/embryo; however the adverse affects may be offset by the larger increases in April-June flows under the proposed project, relative to EBC. However, large decreases in late summer flows (Aug-Sept) related to BDCP water operations may adversely affect the downstream migration of green sturgeon larvae.

Uncertain Effect of Decrease in Sacramento River flows on adult cue detection. Adult green sturgeon attraction flows from November-July will decrease in the Sacramento River downstream at Rio Vista under proposed project operations. The large decreases in flows at Rio Vista in November were affected not only by north Delta diversions, and the operations of upstream dams, as indicated by the reduced mean monthly flows at Keswick and Verona, but the requirements for cold water pool storage necessary to support upstream salmonid spawning habitat. A good portion of the November-July attraction flow period (December–April) occurs during periods of greatest Sacramento River flows at this portion of the river. Proposed north Delta operations are designed to divert additional waters during the highest flows, to maintain flows during drier periods of the year for threatened and endangered salmonids. However, in the absence of data investigating minimum flow requirements for adult green sturgeon attraction and migratory cues, the certainty at which flow reductions will result in reduced cue detection is low.

Uncertain effects related to operation of north Delta intake. Sacramento River flows downstream of the north Delta intakes will be reduced under BDCP operations relative to existing conditions. Flows will be reduced less during the winter than during other seasons. Flows will be reduced most in wet, above normal, and below normal water years; flows are projected to increase under BDCP operations in dry and critical years. The effects of flow reduction within the lower reach of the Sacramento River, on the attraction and olfactory cues for upstream migrating adult sturgeon and survival of downstream migrating juvenile sturgeon are uncertain.

Interannual and long-term hydrologic changes occur with or without BDCP operations. The greatest changes in habitat conditions result from natural variation in interannual hydrology (e.g., between wet and dry years) and the effects on hydrology from future climate change. These major effects on habitat were largely independent of differences between existing conditions and BDCP operations. Sturgeon are sensitive to the risk of exposure to elevated water temperatures and decreased flow in the Feather River, potentially decreasing habitat suitability, particularly in drier water years under both existing conditions and proposed BDCP operations.

Net benefits of other stressor reduction measures. Collectively, other stressor conservation measures provide additional benefits to sturgeon relative to existing conditions. Benefits of conservation actions such as removing unscreened water diversions and structures that attract predators, although incrementally small, contribute to the cumulative biological benefits of BDCP. Conservation measures with the greatest benefit to sturgeon include the revised operations of Fremont Weir, the installation of 1-3 sturgeon ramps facilitating upstream migration and eliminating the stress of the bottleneck, and the increased game enforcement to significantly reduce the poaching of sturgeon that occurs in the Delta. BDCP will, through the installation of an aeration facility in the Stockton Deep Water Ship Channel (SDWSC), effectively raising dissolved oxygen in much of the channel above levels that cause stress in adult sturgeon. The outcome of this conservation measures will be to reduce the upstream passage impediment of adult sturgeon in the vicinity of the SDWSC and facilitate the migration to suitable upstream spawning habitats in the San Joaquin basin. These other stressors measures, in combination with habitat restoration, will provide the greatest benefit to sturgeon from the proposed project.

5.4.1.5.2 BDCP Effects on Green Sturgeon Designated Critical Habitat

Critical habitat for green sturgeon was designated in 2009 (74 FR 52300). The effects analysis for green sturgeon addressed how the BDCP would beneficially or adversely affect the primary constituent elements (PCEs) of green sturgeon critical habitat. PCEs in the upstream reaches not affected by BDCP actions and, therefore, not addressed in the effects analysis include substrate type or size and water depth. The green sturgeon PCEs addressed in the effects analysis were:

- Freshwater spawning sites (i.e., providing suitable water temperatures, and instream flows for successful spawning in the upstream reaches of the Sacramento River and tributaries);
- Freshwater rearing sites (i.e., providing suitable water quality for juvenile rearing, instream flows for downstream migration, sediment quality, tidal habitat and other juvenile rearing areas, and the effect of suitable quantity of food resources for juvenile growth and rearing);
- Freshwater migration corridors (i.e., the allowance for safe and timely passage by reducing and avoiding passage barriers and impediments for both juveniles and adults, providing suitable water quality and instream flows to support access and connectivity for migration, both within tidal habitats and through the Delta);

- Estuarine areas (i.e., providing safe and timely passage via unobstructed migration and rearing opportunities, suitable water quality with salinity conditions that support juvenile and adult physiological transitions between freshwater and saltwater, sediment quality, and providing food resources to support juvenile, subadult, and adult growth, survival, and facilitate the access to upstream spawning habitats).

The effects analysis included a number of analytical approaches, including modeling analyses (i.e. hydrologic and water quality), to predict changes in habitat physical and biological conditions that would potentially affect the quality and availability of suitable habitat influenced by proposed BDCP actions.

Effects on Freshwater Spawning Sites. Although minor adverse and beneficial changes in habitat conditions (instream flow, water temperature) were detected for upstream green sturgeon spawning and egg incubation in some locations, these changes will not have a substantive effect on habitat conditions for green sturgeon. The greatest change was noticeable in the reduction of late summer flows in the Feather River. However, as flows are greater in late spring/early summer, it is unknown if these changes will have a substantive effect on habitat conditions in the Feather River. Within the Sacramento and Feather rivers there was little or no cumulative adverse effect of the BDCP on habitat conditions for spawning relative to the EBC. The greatest observed changes in habitat quality or availability are in response to interannual variation in Central Valley hydrologic conditions (e.g., wet years and dry years) and in response to long-term changes in Central Valley climate. Therefore, the proposed project would not affect critical habitat or the success of green sturgeon spawning within the Sacramento or Feather rivers.

Effects on Freshwater Rearing Sites. Minor adverse and beneficial changes in habitat conditions (flow and water temperature) were detected for sturgeon rearing. In general, within the Sacramento and Feather rivers, there was no effect of the proposed project on habitat conditions for juvenile rearing relative to the EBC. The greatest observed changes in habitat quality or availability are in response to interannual variation in Central Valley hydrologic conditions (e.g., wet years and dry years) and in response to long-term changes in Central Valley climate.

Restoration of additional floodplain, tidal, and channel margin habitat that is geographically distributed throughout the Delta will provide substantial benefits to green sturgeon, with the greatest potential coming through benefits to the foodweb. The predicted magnitude of these benefits to increased juvenile growth and survival, and the contribution of these conservation measures to increased adult sturgeon abundance have not been quantified. Floodplain enhancement actions designed to increase the frequency and duration of seasonally inundated floodplain habitat in Yolo Bypass will be a significant environmental benefit of BDCP. Similarly, BDCP implementation will substantially improve ecological functions and increase the availability of, and access to, intertidal and subtidal habitat that is geographically distributed along the Sacramento River and within the eastern and southern Delta and Suisun Marsh, that will increase rearing habitat and food production for juvenile, subadult, and adult sturgeon, relative to existing conditions. Uncertainty in expanded habitat performance and ecological functions will be addressed through a rigorous BDCP monitoring, research, and adaptive management programs.

Overall, the proposed project will not adversely modify habitat conditions for freshwater rearing in upstream habitats within rivers tributary to the Delta. Instead, BDCP conservation actions will improve habitat access, quality, and availability for juvenile green sturgeon in the lower reaches of the Sacramento and Feather rivers and within the Delta and Suisun Marsh. Implementation of BDCP conservation measures will contribute to a substantial increase in suitable habitat for juvenile and subadult rearing.

Effects on Freshwater Migration Corridors. The BDCP conservation strategy includes measures specifically designed to improve migratory corridors and reduce the effects of obstructions that impede both juvenile and adult sturgeon passage under existing conditions. Proposed actions include improving passage at the Fremont Weir through the installation of sturgeon ramps, notching the weir, increasing game enforcement to reduce the poaching of adult sturgeon, increasing closure of the Delta Cross Channel gates to improve migration and upstream cue detection. Operations under BDCP will also improve hydrologic conditions as reflected by an increase in positive flows in Old and Middle rivers, as well as maintenance of instream flows within the tributaries to the Delta. These conditions are intended to improve the survival of juvenile sturgeon migrating downstream through the Delta, in part by reducing their vulnerability to entrainment losses at the existing south Delta water export facilities. Restoration of additional floodplain and tidal habitat would be beneficial for sturgeon. There is a high degree of uncertainty, however, in the quantification of the magnitude of net benefits to sturgeon populations. Reductions in instream flow in the lower reaches of the Sacramento River have the potential to reduce olfactory cues and attraction flows for upstream migrating adult sturgeon, and river flows for downstream migrating juveniles. Upstream of the north Delta intakes, river flows are similar between the proposed project and existing conditions. In the vicinity of Rio Vista, flows would be reduced during the period for upstream cue detection. The effect of this reduction on population dynamics is currently unknown. In the downstream estuarine region of the Delta, tidal flows are dominant. No information is available to quantitatively assess the potential effects of local flow reductions on migration and survival of green sturgeon.

Overall, the BDCP will not adversely modify habitat conditions for green sturgeon migration corridors within the tributaries of the Delta and would improve passage conditions for green sturgeon migrating through the Delta. BDCP conservation actions will reduce obstruction to juvenile and adult sturgeon passage within the lower reaches of the Sacramento River and throughout the Delta and Suisun Marsh. Implementation of BDCP conservation measures is expected to contribute to an increase in habitat conditions for juvenile and adult sturgeon migration.

Effects on Estuarine Areas. The BDCP conservation strategy will contribute to a substantial increase in access to suitable juvenile and subadult green sturgeon rearing habitat within the estuarine regions of the Delta through channel margin habitat enhancements in the western Delta, as well as substantial increases in aquatic habitat within Suisun Marsh adjacent to Suisun Bay (approximately 24,570 acres in the LLT). The increased access of intertidal and shallow subtidal rearing habitat within the estuarine region of the Delta will contribute to an increase in ecological functions of aquatic habitat including increased habitat diversity and complexity, foraging habitat and food resources for juvenile green sturgeon. Restoration of additional tidal habitat will be beneficial to green sturgeon. Although positive trends towards recovery are anticipated, there is a high degree of uncertainty in the magnitude of net population level benefits to green sturgeon.

Water operations under the proposed project will improve hydrologic conditions as reflected by an increase in positive flows in Old and Middle rivers and maintenance of instream flows within the rivers tributary to the Delta. These conditions will improve the survival of juvenile sturgeon migrating downstream through the Delta and improve estuarine rearing habitat conditions. These improvements will benefit juvenile green sturgeon by providing a potential for increased growth conditions, which should contribute to increased survival. Improvements in central Delta habitat and hydrodynamics will provide the greatest benefits for green sturgeon rearing in estuarine habitats.

Overall, the BDCP will not adversely modify habitat essential for green sturgeon within the estuarine region of the Delta. The BDCP will contribute to an increase in habitat for juvenile and subadult green sturgeon migration within the estuarine region of the Delta.

5.4.1.5.3 Overall Conclusions for Sturgeon

The following overall conclusions were made based on the results of the effects analysis for green and white sturgeon.

Contribution to Recovery. *[**Note to Reviewers:** The Steering Committee has not completed discussion on the sufficiency of the BDCP to contribute to recovery of covered species]* BDCP conservation measures are consistent with and complementary to sturgeon recovery within the Central Valley. In addition to habitat benefits provided by BDCP conservation measures, additional measures to reduce poaching and facilitate upstream migration will increase the protection and survival of reproducing members of the populations. There are no actions proposed as part of BDCP that are inconsistent or incompatible with long-term sturgeon recovery;

Net Beneficial Effects on Designated Critical Habitat. BDCP conservation actions would contribute substantially to improved habitat availability and diversity that would benefit green sturgeon by reducing stressors that currently affect growth, survival, migration, and population abundance. These improvements in critical habitat conditions for green sturgeon would contribute to increased juvenile growth and survival, greater life history and habitat diversity, and are expected to result in increased green sturgeon abundance. Effects of BDCP operations on critical habitat upstream of the Delta has been evaluated and results show relatively small adverse and beneficial effects on habitat conditions for spawning and juvenile rearing on the mainstem Sacramento River and Feather River. The magnitude of beneficial effects associated with changes in water operations, expanded aquatic habitat, improved hydrologic conditions in the Delta, and reduction in other stressors such as poaching and migration barriers have not been quantified. Uncertainties regarding the ecological functions and net biological response of green sturgeon to expanded diverse habitats geographically distributed in various regions of the Delta, and changes in water operations and hydrologic conditions within the rivers and Delta, will be addressed through the monitoring, research, and adaptive management programs. Therefore, the construction and operation of the proposed project, including adaptive management actions, would not be expected to adversely modify green sturgeon critical habitat.

Need for Adaptive Management. As a comprehensive package of conservation measures, BDCP will contribute to the survival and recovery of white and green sturgeon through cumulative reduction in stressors and improvements in habitat, that together contribute to increased population abundance. The magnitude of the effects of BDCP actions on green sturgeon recovery, however, has not been quantified. There remain areas of uncertainty regarding the effectiveness of various individual conservation actions that will be addressed as part of BDCP implementation through the BDCP monitoring, research, and adaptive management programs.

5.4.1.6 Lamprey

5.4.1.6.1 BDCP Effects on Stressors

Based on results of the effects analysis, implementation of the BDCP conservation strategy will result in a number of changes that will reduce the impacts of stressors on Pacific and river lamprey. Some adverse effects were also noted. These effects analysis findings include:

No major effects on downstream migration flows in most rivers. There are no measurable predicted effects of BDCP on downstream macropthalmia migration of changes in flows in the Sacramento, San Joaquin, or Stanislaus rivers. Flow effects on downstream macropthalmia migration during December through May in the Feather River will improve by 5 to 25 percent as a result of the proposed project. There is a 3-15 percent predicted reduction in flows in the Sacramento River in the Delta. Climate change will generally increase flows during January through March and decreases flows during May. There is moderate certainty regarding these conclusions because they are based entirely upon model output.

Within the Delta, upstream migration conditions will greatly improve in the San Joaquin River but decline slightly in the Sacramento River. As a result of changes in diversion points and dual operations under the proposed project, there will be large benefits to San Joaquin River attraction flows for both Pacific lamprey (mean increases during December through May of 36-146 percent) and river lamprey (mean increases during September through November of 374-733 percent) under the proposed project. In addition, passage impediments such as the Stockton Deep Water Ship Channel low dissolved oxygen barrier will be reduced significantly as a result of the proposed project. There will be small reductions in attraction flows for Pacific lamprey adults in the Sacramento River (predicted 4-12 percent reduction in mean in-Delta attraction flows) and moderate reductions for river lamprey in the Sacramento River (predicted 11-17 percent in mean in-Delta attraction flows). Climate change is predicted to have variable effects on Sacramento River contributions and marginal benefits in the San Joaquin River to lamprey attraction flows. There is low certainty in these conclusions because of limited understanding of the use of upstream migration cues by lamprey.

Upstream of the Delta, there are small benefits or no changes in predicted adult Pacific lamprey attraction flows and highly variable, but predominantly adverse predicted effects on river lamprey attraction flows. There will be no effects of the proposed project on Pacific lamprey adult attraction flows during December through May in the Sacramento, San Joaquin, or Stanislaus rivers. There will be small benefits to Pacific lamprey in the Feather and American rivers due to changes in upstream reservoir operations. For river lamprey, there will be highly variable, but predominantly reduced, adult attraction flows during September through November upstream of the Delta in the Sacramento, Feather, Trinity, and American rivers. There will be no effects in the Stanislaus or San Joaquin rivers to river lamprey. There are minimal and inconsistent effects of climate change on these upstream flows during January through June (Pacific) and September through November (river). There is low certainty in these conclusions due to limited understanding of the use of upstream migration cues by Pacific and river lamprey.

No major effects on upstream water temperatures. Upstream water temperatures during egg, embryo, and ammocoete occurrence for both Pacific and river lamprey will not change in a measurable or consistent way as a result of the proposed project. Climate change is predicted to moderately increase water temperature and this effect far outweighs effects of the proposed project. There is moderate certainty regarding these conclusions because multiple models were used to derive temperature outputs.

No major effects on redd dewatering incidence in most rivers. Predicted changes in redd dewatering incidence for both Pacific and river lamprey will be small and inconsistent among all evaluated locations except for the Feather River. The incidence of redd dewatering in the Feather River will increase moderately in both the ELT and LLT. Climate change has small and variable effects on redd dewatering. However, due to the lack of instream models available for lamprey redds, there is low certainty that the metric used in this analysis (50 percent reduction month-over-month instream flows) represents actual redd dewatering, although they are likely correlated.

Entrainment in SWP and CVP intakes will be moderately reduced. While it has never been determined that entrainment has a population level effect, small reductions in entrainment will increase survival and benefit the species. Entrainment and impingement of both Pacific and river lamprey at the north Delta diversions will be minimal because of the size and swimming ability of macropthalmia at the time of passage past the intakes compared to the slot size of screens and approach velocity. In the south Delta, entrainment will decline by approximately 40-50 percent due to reduced diversions and the change in seasonal timing of diversions in the south Delta. Climate change effects will be small relative to the reductions by the BDCP and inconsistent among months and between SWP and CVP facilities. The certainty regarding these results is limited due to high temporal variability in salvage numbers.

Entrainment in non-project diversions will be marginally reduced. The removal of non-project diversions due to changing land use in the Delta as a result of the implementation of BDCP habitat restoration will provide a marginal benefit to both Pacific and river lamprey macropthalmia. Climate change is not expected to affect these results. There is relatively low certainty in these results due to the lack of rigorous sampling of agricultural diversions to date.

Entrainment in Mirant power plants will be greatly reduced. The transition to exclusive closed cycle water use at Mirant's Contra Costa and Pittsburg power plants by 2017 will greatly reduce entrainment of both Pacific and river lamprey macropthalmia. Climate change is not expected to affect these results. Because the effect of entrainment at power plants under existing biological conditions is not well understood, the magnitude of this benefit is uncertain.

Upstream predation will not change; Delta predation will increase. Changes to potential upstream predator abundance and consumption rates of both Pacific and river lamprey eggs, embryos, and ammocoetes as measured by water temperature will not change due to the proposed project because temperatures would increase only 1-2 °F. However, there are slightly greater predicted temperature increases (1-4 °F) due to climate change. There is low certainty of these conclusions due to lack of understanding of predation pressure on Pacific and river lamprey and lack of direct analysis on predator abundance and consumption rates.

Predation rates of both Pacific and river lamprey macropthalmia at the north Delta diversion intake will increase from background predation rates. Some of this increase will be offset by predator reduction actions under the proposed project at the intake facilities and other predator hotspots in the Delta, although these actions are predicted to provide short-term, small scale benefits. Climate change may increase predation rates because predators will need to consume more to keep up with their increased temperature-dependent metabolism. There is low certainty regarding these results due to a lack of understanding of predation rates of lamprey fish predators that would be attracted to the north Delta intakes.

5.4.1.6.2 Overall Conclusions for Lamprey

The following overall conclusions were made based on the results of the effects analysis for Pacific and river lamprey.

Contribution to Reduction in Stressors. Overall, the BDCP will contribute to the net reduction in adverse stressors on both Pacific and river lamprey. Positive upstream effects on flow and water temperatures at some locations and during some months will outweigh adverse effects, even though most of the upstream effects are small. The reduction in attraction flows in the Sacramento River below the new intakes will be partially offset by improved Yolo Bypass flows and large improvements in the San Joaquin River. Predation effects on lamprey at the north Delta intakes will be greater than the reduction in entrainment effects in the south Delta. The collective benefits of additional BDCP actions, including predator control, non-project entrainment reductions, and power plant entrainment reductions will add to the benefits to lamprey populations.

Need for Adaptive Management. The results of the effects analysis indicate that the proposed water project operations would avoid and minimize adverse effects on lamprey and, in combination with other conservation measures, contribute to recovery of the two lamprey species. There are many uncertainties regarding the magnitude of population-level effects of the BDCP on the dynamics and recovery of the species. The BDCP includes adaptive management based on extensive monitoring and research that will be used to address areas of uncertainty and to refine the conservation measures to improve the overall net environmental benefits of the program, in combination with other recovery actions, in contributing to the long-term recovery of lamprey. The adaptive ranges for a number of water operations parameters allow for adjustments such that, if initial operations do not support the outcomes expected for lamprey, there is the opportunity and flexibility to adaptively change operations and potentially improve biological outcomes.

*[**Note to Reviewers:** the following are the draft natural communities and covered wildlife and plant species sections of Chapter 5, Effects Analysis, for the November 18, 2010 BDCP document. These sections consist of revised "summary of effects" sections from the August 19, 2010 draft for the natural communities and species for only the late long-term outcomes with full BDCP implementation. The text has been modified to indicate whether or not restoration/ protection of natural communities and habitats will keep pace with the expected rate of impacts. The results include the "population-level" effects section for each of the covered species and the assessment of effects on critical habitat for applicable species. The "estimated level of take" sections from that document are not included. Tables presenting the extent of impacts on and the level conservation provided for each of the natural communities and covered wildlife and plant species habitats at the late long-term evaluation point are provided at the end of this draft.]*

5.4.2 Natural Communities

The following summarizes the overall effects of implementing the BDCP actions on each of the natural communities. The extent of each natural community that would be permanently and temporarily removed and periodically affected by BDCP at the late long-term evaluation point is presented in Table 5-1. The table also indicates the total extent of each natural community that will be present in the Plan Area following full implementation of the BDCP. The extent of the contribution to conservation of each natural community following full BDCP implementation through implementation is presented in Table 5-2. The complete effects analysis will describe the combined effects of implementing all BDCP actions for each of the natural communities at the near-term, early long-term, and late long-term evaluation periods.

The complete effects analysis will present the permanent, temporary, and periodic effects on each natural community for each of the evaluation periods for the entire Plan Area and each of the 11 Plan Area Conservation Zones (see Figure 3-1) and will describe the combined effects of implementing all BDCP actions for each of the natural communities at the near-term, early long-term, and late long-term evaluation periods. The mechanisms associated with each of the BDCP actions that can result in a permanent or temporary direct or indirect effect, or periodic effect on each of the natural communities will also be described and evaluated in the full effects analysis.

5.4.2.1 Tidal Perennial Aquatic Natural Community

The implementation of all BDCP actions would result in overall benefits for the tidal perennial aquatic community, including the restoration and ongoing management of subtidal aquatic habitats and a return to more-natural channel water salinity in habitats restored in Suisun Marsh. Based on RMA modeling of hypothetical tidal habitat restorations (see Appendix N.3), approximately 25,000 to 32,000 acres of tidal perennial aquatic natural community would be restored, resulting in a 29 to 37 percent increase in subtidal aquatic habitat in the Plan Area (see Table 5-1). The export of nutrients and food restored tidal marsh plains, floodplain, and channel margin habitats would improve the habitat functions of the tidal perennial aquatic community for covered fish species and other aquatic species. Improvements in the habitat function of the tidal perennial aquatic community for covered fish species and other aquatic species would result from BDCP actions specifically designed for or incidentally resulting in the reduction of stressors such as nonnative predators, nonnative invasive plant species, and agricultural pesticides and herbicides. BDCP actions are estimated to remove 46 acres of the tidal perennial aquatic community, amounting to less than 2 percent of the extent of BDCP restored tidal perennial aquatic community (Table 5-2). There are no temporal losses of the community because the extent that would be removed by the covered activities at each evaluation point is exceeded by the extent of tidal perennial aquatic community that would be restored.

5.4.2.2 Tidal Mudflat

The implementation of the BDCP would result in overall benefits for the tidal mudflat community through the restoration of at least 20 linear miles of tidal mudflat edge as a component of the 65,000 acres of BDCP restored tidal and channel margin habitats. This increase in the extent of tidal mudflat is expected to provide foraging habitat for shorebirds, wading birds, and other native wildlife species as well as substrates suitable for the establishment of covered and other tidal mudflat plant species. Implementation of the covered activities is expected to affect an indeterminable extent of tidal mudflat through construction of new intake facilities and restoration of tidal, floodplain, and channel margin habitats. Restoration of tidal, floodplain, and channel margin habitats, however, are expected to result in an overall increase in the extent of tidal mudflat. Changes in water operations may also affect the long-term distribution of tidal mudflat if those changes alter the current patterns of erosion and deposition in tidal channels. No temporal losses of tidal mudflats are expected because the extent that would be removed by the covered activities at each evaluation point is expected to be exceeded by the extent of tidal mudflat that would be restored.

5.4.2.3 Tidal Brackish Emergent Wetland

Implementation of the BDCP would result in overall benefits for the tidal brackish emergent wetland community, including the restoration and ongoing management of tidal brackish emergent wetlands and a return to more-natural channel water salinity. Based on RMA modeling of hypothetical tidal habitat restorations (see Appendix N.3), between 3,600 and 4,800 acres of tidal brackish emergent wetland community would be restored in Suisun Marsh (Conservation Zone 11), resulting in a 37 to 51 percent increase in the tidal brackish emergent wetland community in the Plan Area (see Table 5-1). There are no temporal losses of the community because the extent of tidal brackish emergent wetland that would be removed by the covered activities at each evaluation point is exceeded by the extent of tidal brackish emergent wetland that would be restored. Restoration and subsequent management of this community to maintain its ecological functions is expected to benefit aquatic food web processes in support of the covered and other native fish species and covered and other native wildlife and plant species dependent on Suisun Marsh tidal habitats.

5.4.2.4 Tidal Freshwater Emergent Wetland Natural Community

The implementation of the BDCP would result in overall benefits for the tidal freshwater emergent wetland community through restoration and ongoing management of the community. Based on RMA modeling of hypothetical marsh restorations, between 13,200 to 21,600 acres of tidal freshwater emergent wetland community would be restored in the Cache Slough Complex, the South Delta, the Cosumnes/Mokelumne, and the West Delta ROAs (Conservation Zones 1, 2, and 4-7), more than doubling the total extent of tidal freshwater emergent wetland community in the Plan Area (Table 5-1). The restored areas of tidal freshwater emergent wetland community are expected to support higher habitat functions for associated-covered and other native wildlife species because they are expected to be much larger than the existing tidal freshwater emergent wetlands that primarily occur in small and isolated patches. There are no temporal losses of the community because the extent of tidal brackish emergent wetland that would be removed by the covered activities at each evaluation point is exceeded by the extent of tidal brackish emergent wetland that would be restored. Restoration and subsequent management of this community to maintain its ecological functions is expected to benefit aquatic food web processes in support of the covered and other native fish species and covered and other native wildlife and plant species associated with tidal habitats of the Delta.

5.4.2.5 Valley/Foothill Riparian Natural Community

Implementation of the BDCP would result in overall benefits for the valley/foothill riparian natural community through restoration and ongoing management of 5,000 acres of riparian communities. BDCP actions are expected to permanently and temporarily remove and periodically inundate 1,114 acres, 165 acres, and 589 acres of riparian habitats, respectively (Table 5-1). Following implementation of riparian restoration actions, there would be a 22 percent increase in the total extent of riparian habitats in the Plan Area and an 80 percent increase in the amount of protected riparian habitat in the Plan Area (Tables 5-1 and 5-2). Restored riparian natural community is expected to support higher habitat functions for associated covered and other native wildlife species because restoration would occur in large patches within floodplains and along channel margins compared with the small, narrow, isolated patches of existing riparian habitat in the Plan Area. Restored sites would also provide more structural and species diversity than most existing patches with an increase in ecological function. There is a temporal loss of riparian habitat because most of the affected riparian vegetation is removed in the near-term implementation period, while large quantities of riparian habitat will not be restored until the early and late long-term implementation periods (Figure 5-3).

Each mapped polygon of riparian vegetation that would be removed by BDCP actions were categorized as supporting low, moderate, or high habitat functions for the riparian-associated and other native wildlife based on the following criteria:

- Type of vegetation (woodland, scrub, or herbaceous),
- Extent and structural qualities of riparian vegetation (dense multistoried vegetation versus a few trees with no understory) within the polygon,
- Hydrology and connectivity (along an active natural stream, man-made canal, irrigation ditch, or isolated patch with no riparian function), and
- Polygon size.

Based on this assessment, Figure 5-3 illustrates the extent of affected riparian vegetation that support low, moderate, and high wildlife habitat values, and Figure 5-4 depicts the size distribution of affected riparian vegetation polygons as an indicator of habitat patch size.

Effects of this temporal loss of riparian communities on associated covered and other native wildlife species is expected to be minimal because most of the affected community is comprised of small patches of riparian scrub and herbaceous vegetation that are fragmented and distributed across the agricultural landscape of the Plan Area. Consequently, much of the affected valley/foothill riparian natural community supports relatively low-functioning habitat for associated covered species and other native species and is not expected to result in a measurable change in the abundance or distribution of these species in the Plan Area. Restoration and subsequent management of this community are expected to benefit covered species habitat and food web processes and result in an increase in ecological function as large stands of new valley foothill riparian community develop within natural landscape and hydrological positions. Figure 5-3 illustrates the expected development of restored riparian habitat functions over time for the riparian-associated covered wildlife species.

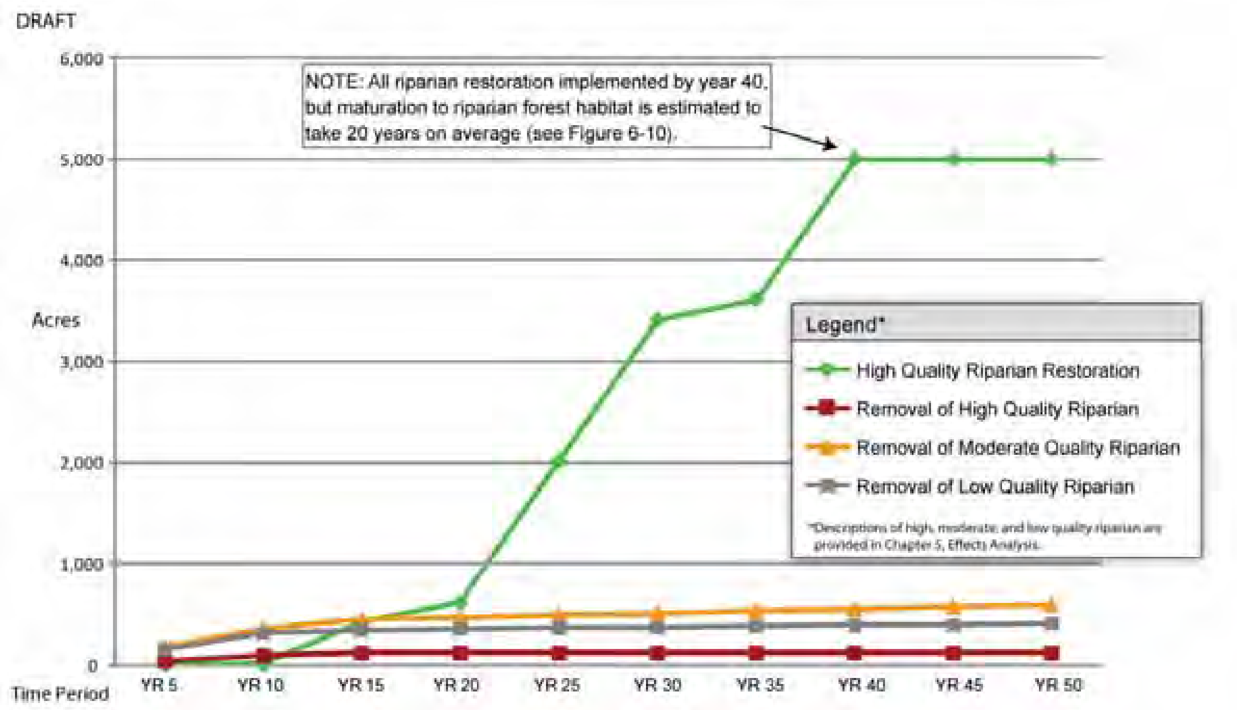

Figure 5-3. Cumulative Riparian Habit Restoration versus Cumulative Permanent Removal

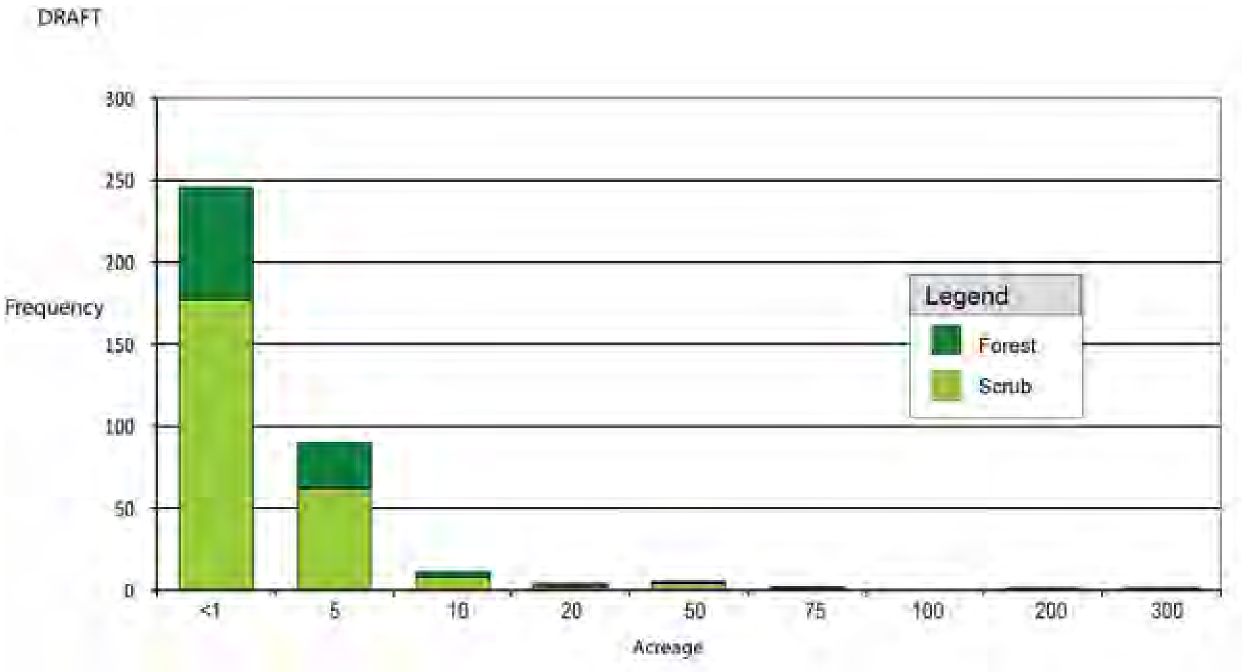

Figure 5-4. Size Distribution of Affected Riparian Forest and Scrub Polygons

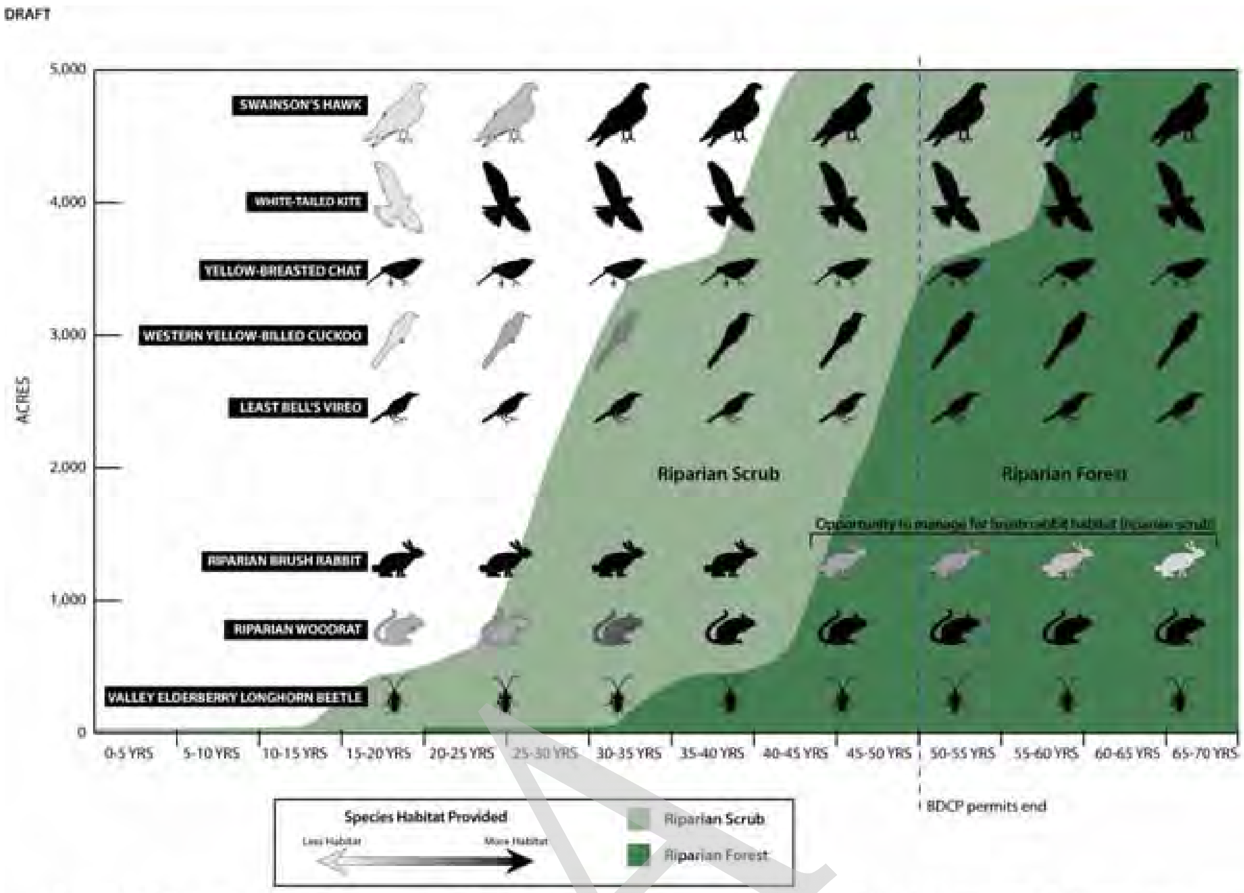

Figure 5-5. Maturation and Succession of Restored Riparian Forest and Scrub and Use by Covered Wildlife Species

5.4.2.6 Grassland Natural Community

The implementation of the BDCP would result in overall benefits for the grassland community through protection and enhancement of existing and restoration of 10,000 acres of grassland habitats. These conservation actions would increase the amount of grassland with protected status in the Plan Area from a current 14,984 acres, or 24 percent, to approximately 23, 955 acres, a 60 percent increase in the extent of protected habitat area (Table 5-2). BDCP actions are expected to permanently, temporarily, and periodically remove 2,831 acres, 437 acres, and 2,111 acres of grassland, respectively (Table 5-1). Sufficient grassland habitat, however, will be protected, enhanced, and restored at each of the evaluation points to address any temporal loss of habitat functions and to contribute to the conservation of grassland-associated covered and other native species.

The 1,854 acres of grassland removed as a result of tidal and associated riparian habitat restoration are subsided, historically supporting tidal habitats rather than grassland (Table 5-1). Furthermore, most of the grassland to be removed consists of naturalized communities of exotic species on lands that were drained for agriculture and on levees; these communities typically support low ecological functions for covered species and other native species. With restoration of 2,000 acres of grassland, there would be a net loss of 823 acres of grassland from the Plan Area (Table 5-1). In contrast to most of the removed grasslands, the grasslands to be protected, enhanced, and restored would be in landscape positions at which grasslands occurred historically. Existing unprotected grassland would be protected in large patch sizes connected to existing large areas of grassland that would serve as gene dispersal and migration corridors as well as transitional habitat areas to maximize the ecological functions of the grasslands for covered and other native wildlife and plant species. The overall habitat quality of protected, enhanced, and restored grassland is expected to be greater than the grasslands adversely affected by the BDCP.

5.4.2.7 Alkali Seasonal Wetland Complex

The implementation of the BDCP would result in overall benefits for the alkali seasonal wetland complex community through protection and enhancement of 400 acres of existing alkali seasonal wetland complex. Priority for protection under the BDCP is given to alkali seasonal wetlands that support occurrences of covered plant species, thus contributing to their conservation (e.g., heartscale, brittlescale, and Carquinez goldenbush). These conservation actions would increase the extent of protected alkali seasonal wetland complex in the Plan Area to 87 percent, representing a 12 percent increase in the extent protected. BDCP actions could permanently remove up to 136 acres and increase the extent of alkali seasonal wetland complex periodically inundated in the Yolo Bypass by 825 acres (Table 5-1). Sufficient alkali seasonal wetland complex, however, will be protected and enhanced at each of the evaluation points to address any temporal loss of habitat functions and to contribute to the conservation of alkali seasonal wetland complex -associated covered and other native species.

Existing unprotected alkali seasonal wetland complex would be protected in conjunction with protected and restored grassland and vernal pool complex to establish large mosaics of these interdependent communities that are connected to existing large areas of grassland. These large patches of protected communities would serve as gene dispersal and migration corridors as well as transitional habitat areas to maximize the ecological functions of protected the alkali seasonal wetland complex for covered and other native species. Consequently, the overall habitat quality of the protected and enhanced alkali seasonal wetland complex is expected to be greater than the affected alkali seasonal wetland complex.

5.4.2.8 Vernal Pool Complex

The implementation of the BDCP would result in overall benefits for the grassland community through protection and enhancement of existing and restoration of 500 acres of vernal pool complex. Priority for protection under the BDCP is given to vernal pool complex that support occurrences of covered plant species, thus contributing to their conservation (e.g., San Joaquin spearscale, dwarf downingia, and delta button celery). These conservation actions would increase the extent of protected vernal pool complex to 69 percent, representing an 11 percent increase in the extent of protected vernal pool complex in the Plan Area (Table 5-2). BDCP actions could permanently remove up to 88 acres of vernal pool complex as a result of restoring tidal habitats (Table 5-1). Sufficient vernal pool complex, however, will be protected and enhanced at each of the evaluation points to address any temporal loss of habitat functions and to contribute to the conservation of vernal pool complex-associated covered and other native species.

Existing unprotected vernal pool complex would be protected and restored in conjunction with protected and restored grassland and the alkali seasonal wetland complex to establish large mosaics of these interdependent communities that are connected to existing large areas of grassland. These large patches of protected communities would serve as gene dispersal and migration corridors as well as transitional habitat areas to maximize the ecological functions of protected and restored vernal pool complex for covered and other native species. Consequently, the overall habitat quality of the protected, enhanced, and restored vernal pool complex is expected to be greater than the affected vernal pool complex.

5.4.2.9 Other Natural Seasonal Wetlands

Implementation of BDCP actions would permanently remove 1 acre of other natural seasonal wetlands, representing less than 1 percent of the existing extent of this community in the Plan Area, and would increase inundation frequency of 2 acres on restored floodplains (see Table 5-1). Protection, enhancement, and management of other natural seasonal wetlands that are present on agricultural lands acquired in fee-title would prevent removal or degradation of other natural seasonal wetlands that function as habitat for covered species resulting from future changes in land use. Enhancement and management of protected wetlands would increase their function as habitat for associated covered plant and other native species.

5.4.2.10 Nontidal Freshwater Perennial Emergent Wetland

Implementation of the BDCP would result in an overall benefit for the nontidal freshwater permanent emergent wetland community through restoration of 400 acres of high functioning nontidal freshwater marsh, of which the nontidal freshwater permanent emergent wetland community will be a component. If at least 200 acres comprises nontidal freshwater permanent emergent wetland, there would be a net increase of 108 acres (approximately 10 percent) of nontidal freshwater permanent emergent wetland in the Plan Area (Table 5-1) and a 37 percent increase in the amount of protected nontidal freshwater permanent emergent wetland in the Plan Area (Table 5-2). The 400 acres of nontidal freshwater marsh will be restored in the near-term implementation period, thus minimizing any temporal loss of habitat functions associated with implementation of BDCP actions on the community. Restored nontidal freshwater marsh would be designed primarily to benefit giant garter snake and other wetland species in Conservation Zones 2 and 4. Restored nontidal freshwater marsh is expected to support higher habitat functions for associated covered and other native species because restoration would occur in relatively large patches compared with the small, isolated patches that currently exist in the Plan Area.

Restoration of 400 acres of nontidal marsh is expected to increase the extent of high value emergent marsh habitat for giant garter snake, western pond turtle, and other native wildlife species (e.g., wintering and resident waterfowl). In addition to restoration and enhancement of habitats that support native wildlife species associated with the nontidal freshwater permanent emergent wetland community, existing emergent marsh habitats present on BDCP-protected lands would be managed to maintain and, where appropriate, increase their habitat functions in support of covered and other native wildlife species (e.g., modifying agricultural conveyance maintenance practices to minimize effects on associated wildlife).

5.4.2.11 Nontidal Perennial Aquatic Natural Community

Implementation of the BDCP would result in an overall benefit for the nontidal perennial aquatic natural community through restoration of 400 acres of high functioning nontidal freshwater marsh, of which the nontidal perennial aquatic natural community will be a component. If at least 200 acres of the restored marsh is comprised of nontidal perennial aquatic habitat, there would be a loss of 45 acres (0.9 percent) of nontidal perennial aquatic natural community in the Plan Area (Table 5-1) and a 12 percent increase in the amount of protected nontidal perennial aquatic community in the Plan Area (Table 5-2). The majority of removed nontidal perennial aquatic community is associated with agricultural ditches and drains and support limited ecological function. Restored nontidal freshwater marsh would be designed primarily to benefit giant garter snake and other wetland species in Conservation Zones 2 and 4. While non-tidal freshwater marsh would be protected on BDCP lands, directed restoration and management of 400 acres would occur primarily to benefit giant garter snake and other wetland species in Conservation Zones 2 and 4. Restored nontidal freshwater marsh is expected to support higher habitat functions for associated covered and other native species because restoration would occur in relatively large patches compared with the small, isolated patches that currently exist in the Plan Area. Restoration of 400 acres of nontidal marsh is expected to increase the extent of high value open water habitat for giant garter snake, western pond turtle, and other native wildlife species (e.g., wintering and resident waterfowl). In addition to restoration and enhancement of habitats that support native wildlife species associated with the nontidal perennial aquatic community, existing open water habitats present on BDCP-protected lands would be managed to maintain and, where appropriate, increase their habitat functions in support of covered and other native wildlife species (e.g., modifying agricultural conveyance maintenance practices to minimize effects on associated wildlife).

5.4.2.12 Inland Dune Scrub Natural Community

Implementation of the BDCP would result in overall beneficial effects on the inland dune scrub community. No BDCP actions would affect inland dune scrub natural community. The BDCP would result in an overall benefit to the ecological function of the inland dune scrub community in the Plan Area though financially supporting the USFWS' existing restoration, long-term management, and enhancement of the community.

5.4.2.13 Managed Wetlands

The implementation of BDCP actions are expected to remove 12,196 acres of managed wetlands, primarily from Suisun Marsh as a result of restoration of tidal habitats (see Appendix N.3, *RMA Description of Hypothetical Restoration Design and Effects).* The habitat functions provided by these managed wetlands for associated covered wildlife species are also supported by natural communities (e.g., tidal and grassland habitats) and agricultural habitats that will be protected, enhanced, and restored under the BDCP. Based on the assessment of effects on these covered wildlife species (see Section 5.5.3, *Covered Wildlife and Plant Species*), protection, enhancement, and restoration of these replacement habitats are expected to result overall benefits for covered wildlife species that use managed wetlands. Managed wetlands are typically managed to provide habitat for wintering waterfowl and migrant shorebirds. As described for covered wildlife species, protection, enhancement, and restoration of natural communities and agricultural habitats also provide waterfowl and shorebird habitats. Based on an evaluation of the effects of BDCP actions on the waterfowl and shorebird habitat functions provided by affected managed wetlands and other natural communities, implementation of BDCP habitat conservation measures are expected to replace or provide greater habitat functions for these species than the affected waterfowl and shorebird habitats (see Appendix N.6, *Waterfowl and Shorebirds Effects Analysis*). Consequently, although BDCP actions will result in a reduction in the extent of managed wetlands within the Plan Area, the habitat functions for covered and other native wildlife species that use managed wetlands are expected to be maintained or increased beyond current conditions.

5.4.2.14 Agricultural Land

Implementation of the BDCP would result in an overall benefit to the ecological function of agricultural lands as habitat for associated covered species through protection and enhancement of 16,620 to 32,640 acres of high value cover types and associated habitats (e.g., adjacent riparian or other woodlands, roadside tree rows, hedge rows, wetlands, etc.) that occur within the agricultural matrix. While there will be an approximate 8 percent net reduction in the extent of agricultural lands in the Plan Area resulting primarily from the restoration of tidal communities, the BDCP would increase the amount of agricultural land under protected status from 11 percent to between 15 and 18 percent (Table 5-2). A sufficient extent agricultural land providing habitat values for covered and other wildlife species, however, will be protected and enhanced at each of the evaluation points to address any temporal loss of habitat functions and to contribute to the conservation of agricultural land-associated covered and other native species.

Agricultural land protection could occur in all Conservation Zones; however, conservation efforts would be directed geographically in order to meet the objectives for individual covered species, including greater sandhill crane, Swainson's hawk, and giant garter snake. BDCP-managed agricultural lands are expected to support higher habitat functions for associated covered species by farming crop types that provide high habitat values for covered and other native wildlife species and, where possible, enhancing patches of native habitat within the agricultural landscape. Because the value of agricultural lands is highly variable and fluid, protected acres were calculated based on an analysis of habitat/cover type value and a conversion to habitat units. Of the 503,799 acres of agricultural land within the Plan Area, approximately 155,000 acres (31 percent) is considered moderate to high value for covered species. Thus, the management of BDCP-protected lands as high value agricultural habitat can successfully offset the overall reduction in the extent of agricultural lands across the landscape and meet the habitat objectives for each agricultural-associated covered species. In addition, the restoration of tidal and nontidal marshes, riparian forests and scrub, and grasslands with the agricultural matrix would enhance the overall ecological value of the adjacent agricultural lands.

5.4.3 Covered Wildlife and Plant Species

The following summarizes the overall effects of implementing the BDCP actions on each of the covered wildlife and plant species. The extent of each covered wildlife and plant species' habitat that would be permanently and temporarily removed and periodically affected by BDCP at the late long-term evaluation point are presented in Table 5-3. The table also indicates the total extent of each species' habitat types that will be present in the Plan Area following full implementation of the BDCP. The extent of habitat benefits provided through implementation of conservation measures to protect and enhance existing habitats and restore new habitat areas for each of the covered wildlife and plant species following full BDCP implementation are presented in Table 5-4.

The complete effects analysis will present the permanent, temporary, and periodic effects on each species for each of the evaluation periods for the entire Plan Area and each of the 11 Plan Area Conservation Zones (Figure 3-1) and will describe the combined effects of implementing all BDCP actions for each of the covered wildlife and plant species at the near-term, early long-term, and late long-term evaluation periods. The mechanisms associated with each of the BDCP actions that can result in a permanent or temporary direct or indirect effect or periodic effect on each of covered wildlife and plant species will also be described and evaluated in the full effects analysis.

5.4.3.1 San Joaquin Kit Fox

Implementation of all BDCP actions will result in an overall benefit to San Joaquin kit fox within the Plan Area and adjacent areas though a directed process of protecting the highest functioning grassland supporting kit fox breeding habitat both intrinsically and in association with other habitat types and habitat corridors and managing protected grasslands to maximize their ecological functions. The BDCP will protect and enhance 1,000 acres kit fox grassland breeding and foraging habitat in Conservation Zone 8 and protect and increase connectivity of its limited Plan Area habitats with extensive kit fox habitat areas outside of the Plan Area. Protected habitat will be managed to enhance rodent prey availability for the kit fox. Following implementation, 31 percent of kit fox breeding habitat within the Plan Area will be protected, increasing the total area of protected breeding habitat by 144 percent (Table 5-4). In addition, any portion of the 2,000 acres of BDCP restored grassland that is located in Conservation Zone 8 would also be expected to benefit the kit fox.

All protection of kit fox habitat would be provided in and all adverse effects on San Joaquin kit fox habitat would be incurred in the near-term evaluation period. Permanent adverse effects on San Joaquin kit fox from implementing BDCP actions include the loss of 163 acres of grassland breeding and 663 acres of adjacent agricultural movement habitat (Table 5-3). Temporary adverse effects include the temporary removal of 161 acres of grassland and 481 acres of adjacent agricultural land, which are expected to be restored following the completion of water conveyance construction (Table 5-3). In contrast to the removed grassland habitats, the grasslands to be protected and enhanced occur in areas of historical natural grassland vegetation.

5.4.3.1.1 Population-Level Effects on San Joaquin Kit Fox

BDCP actions are not expected to have an adverse or beneficial population-level effect on San Joaquin kit fox in the near-term, early long-term, or late long-term evaluation points because species abundance within the Plan Area is considered to be low based on recent data and modeled habitat and because removed habitat is typically low value. There are very few recent records of San Joaquin kit fox from anywhere within its northern range of Alameda and Contra Costa counties. Modeled kit fox habitat to be removed by BDCP actions is low value, highly disturbed, and fragmented from intact grasslands to the west, and occurs on the extreme edge of the species range. Effects associated with implementation of BDCP actions therefore are not expected to adversely affect the regional San Joaquin kit fox population.

5.4.3.2 Riparian Woodrat

Implementation of all BDCP actions will result in an overall potential benefit to riparian woodrat within the Plan Area through protection and restoration of its habitat. The BDCP will restore 5,000 acres of riparian habitat, approximately 4,000 of which will be in Conservation Zone 7. A substantial portion of this is expected to provide high value riparian habitat for the riparian woodrat without implementing site-specific enhancement actions. However, because the extent of high value habitat cannot be quantified, BDCP will also directly restore 300 acres to meet the ecological and habitat requirements of the riparian woodrat in Conservation Zone 7 or 8. Restoration of 300 acres of riparian habitat will increase the extent of available habitat for the riparian woodrat in the Plan Area by 18 percent and increase the number of protected areas by 306 percent (Table 5-3 and 5-4). The actual increase in available and protected acres is expected to be substantially higher due to the overall extent of riparian restoration.

The species is not known to occur in the Plan Area and thus is not expected to be affected by BDCP actions unless the species were to establish in the Plan Area over the term of the BDCP. BDCP actions that affect riparian woodrat modeled habitat consist only of floodplain restoration and protection and management of natural communities. BDCP actions are projected to permanently remove 25 acres, temporarily remove 14 acres, and periodically inundate 98 acres of modeled woodrat habitat, respectively. The majority of these acres would not be affected until the late-long term and would be addressed by ongoing riparian habitat restoration.

5.4.3.2.1 Population-Level Effects on Riparian Woodrat

BDCP actions will not have an adverse population-level effect on riparian woodrat because it is not currently present in the Plan Area and will not be affected by BDCP actions unless the riparian woodrat were to establish in the Plan Area before full BDCP implementation. Implementation of actions to restore 5,000 acres of riparian habitat, 300 of which will be restored specifically to meet the habitat requirements of the riparian woodrat is expected to provide a population-level benefit by providing habitat to accommodate the expansion of existing populations near the Plan Area, increase its distribution and abundance, and reduce the risk for its extinction.

5.4.3.3 Salt Marsh Harvest Mouse

Implementation of all BDCP actions will result in an overall benefit to salt marsh harvest mouse within the Plan Area through restoration and enhancement of its habitat. Based on the RMA hypothetical tidal habitat restorations (see Appendix N3, *RMA Description of Hypothetical Restoration Design and Effects*), 3,600 to 4,800 acres of tidal brackish wetlands supporting salt marsh harvest mouse habitat will be restored in Suisun Marsh (Conservation Zone 11; Table 5-3). BDCP actions are expected to adversely affect salt marsh harvest mouse habitat through the permanent removal of 2,487 acres of modeled wetland habitat and 674 acres of modeled upland habitat (Table 5-3). However, this effect will be gradual and phased over time as restoration is occurring. Tidal wetlands will be restored in large patches supporting a natural gradient extending from subtidal to upland zones which is expected to increase the extent of high value tidal marsh that supported the salt marsh harvest mouse's historical tidal habitat and help achieve the draft Tidal Marsh Ecosystems Recovery Plan (USFWS 2010) salt marsh harvest mouse objectives. The enhancement and restoration of 350-700 acres of upland habitat adjacent to restored marshes are expected to provide high functioning flood refuge habitat for the mouse. Based on the hypothetical tidal marsh restorations, (see Appendix N3, *RMA Description of Hypothetical Restoration Design and Effects*), after full implementation of the BDCP there will be a 10 to 21 percent increase in the extent of salt marsh harvest mouse habitat in the Plan Area. The extent of existing protected salt marsh harvest mouse tidal wetland habitat is expected to increase to 13 to 25 percent (Table 5-4).

5.4.3.3.1 Population-Level Effects on Salt Marsh Harvest Mouse

Salt marsh harvest mouse are restricted to natural saline and brackish wetlands along the northern borders of San Pablo and Suisun Bays and BDCP conservation measures are expected to have a beneficial effect on the overall population of salt marsh harvest mouse by increasing the extent of tidal brackish wetlands that support high function salt marsh harvest mouse habitat. Restoration and subsequent management of this habitat is expected to provide the basis for increasing the abundance of salt marsh harvest mouse such that the Suisun Marsh portion of its population is maintained and increased.

5.4.3.4 Riparian Brush Rabbit

Implementation of all BDCP actions will result in an overall potential benefit to riparian brush rabbit within the Plan Area through protection and restoration of its habitat. The BDCP will restore 5,000 acres of riparian habitat, approximately 4,000 of which will be in Conservation Zone 7. A substantial portion of this is expected to provide high value riparian habitat for the riparian brush rabbit without implementing site-specific enhancement actions. However, because the extent of high value habitat cannot be quantified, BDCP will also directly restore 300 acres to meet the ecological and habitat requirements of the riparian brush rabbit in Conservation Zone 7. Restoration of 300 acres of riparian habitat will increase the extent of available habitat for the riparian brush rabbit in the Plan Area by 8 percent and increase the number of protected acres by 215 percent (Table 5-4). The actual increase in available and protected acres is expected to be substantially higher due to the overall extent of riparian restoration.

BDCP actions that affect riparian brush rabbit modeled habitat consist of water conveyance construction, floodplain restoration, and protection and management of natural communities. None of the affected habitat areas are currently known to be occupied by riparian brush rabbit. BDCP actions are projected to permanently remove 62 acres, temporarily remove 19 acres, and periodically inundate 264 acres of modeled brush rabbit habitat, respectively (Table 5-4). The majority of these acres would not be affected until the late-long term and would be offset by ongoing riparian restoration.

5.4.3.4.1 Population-Level Effects on Riparian Brush Rabbit

BDCP actions will not have an adverse population level effect on riparian brush rabbit because affected areas are not currently occupied by brush rabbit populations. BDCP actions may benefit the riparian brush rabbit by providing potential habitat for future population expansion in the early long-term and late long-term implementation periods. Restoration of 5,000 acres of riparian habitat, 300 acres of which will be restored specifically to meet the habitat requirements of the riparian brush rabbit habitat is expected to provide a population-level benefit by providing habitat to accommodate the expansion of existing populations in the Plan Area, increase its distribution and abundance, and reduce the risk for its extinction.

5.4.3.5 Townsend's Big-eared Bat

Implementation of BDCP actions will result in an overall benefit to Townsend's big-eared bat within the Plan Area through protection and restoration of its foraging and roosting habitats. BDCP actions will restore 5,000 acres of riparian roosting and primary foraging habitat, 2,600 acres of grassland, vernal pool complex, and nontidal marsh foraging habitat, up to 65,000 acres of tidal wetland foraging habitat, and protect 8,000 acres of grassland and up to 32,640 acres of agricultural foraging habitat. Restoration actions will increase the extent of primary foraging and roosting habitat for the Townsend's big-eared bat by 69 percent and increase the overall number of protected acres of foraging and roosting habitat by 258 percent (Table 5-4). Restored foraging habitats replace primarily agricultural lands. Restored habitats are expected to be of higher function because the production of flying insect prey species is expected to be higher in restored wetlands and uplands on which application of pesticides will be reduced relative to affected agricultural habitats.

All BDCP actions will affect Townsend's big-eared bat modeled habitat; however, BDCP actions are expected to increase the habitat value of the majority of affected acres. BDCP actions are expected to permanently convert 860 acres of primary foraging habitat, nearly all of it due to tidal habitat restoration, to other types of foraging habitat. They are also expected to remove 268 acres of roosting and primary foraging habitat and convert 60,051 acres of secondary foraging habitat (primarily agricultural land) in the Plan Area to other foraging habitat types (Table 5-3). The majority of affected acres will convert agricultural land to natural communities with higher potential foraging and roosting value, such as riparian, tidal and non-tidal wetlands, and periodically inundated lands. Temporary effects on the Townsend's big-eared bat are comparatively small, affecting only 76 acres of primary foraging habitat, 86 acres of roosting and primary foraging habitat, and 4,592 acres of secondary foraging habitat (Table 5-3). BDCP actions are expected to periodically convert 291 acres of modeled primary foraging habitat, 301 acres of modeled roosting/primary foraging habitat, and 30,619 acres of modeled secondary foraging habitat to seasonally inundated foraging habitat. Similar to permanent habitat impacts, most temporary and periodic impacts convert existing habitat to higher value habitat and enhance the foraging and roosting functions of BDCP lands for Townsend's big-eared bat.

5.4.3.5.1 Population-Level Effects on Townsend's Big-Eared Bat

BDCP actions will not have an adverse population-level effect on Townsend's big-eared bat because the species is not known to roost and is otherwise uncommon in the Plan Area and because most BDCP actions will enhance habitat function and value for this species. While there will be a temporal loss of primary riparian roosting and foraging habitat (Section 5.4.2.5, *Valley/Foothill Riparian*), the availability of this habitat in the Plan Area likely exceeds the current habitat need based on the lack of documented occurrences of this species in the Plan Area and surrounding lands. The protection, restoration, and enhancement of 5,000 acres of Townsend's big-eared bat roosting and primary foraging habitat by the late-long term period along with the conversion of agricultural lands to higher value foraging habitat is expected to sustain any Townsend's big-eared bat population, were it to establish in the Plan Area.

5.4.3.6 Suisun Shrew

Implementation of all BDCP actions will result in an overall benefit to Suisun shrew within the Plan Area resulting from a net increase in the extent and contiguity of high value historical Suisun shrew tidal habitat. Based on the RMA hypothetical tidal habitat restorations (see Appendix N.3, *RMA Description of Hypothetical Restoration Design and Effects*), 3,600 to 4,800 acres of tidal brackish wetlands supporting Suisun shrew habitat will be restored in Suisun Marsh (Conservation Zone 11; Table 5-3). BDCP actions are expected to adversely affect Suisun shrew habitat through the permanent removal of 6,237 acres of modeled habitat, consisting primarily of managed wetlands (Table 5-3); however, this effect will be gradual and phased over time as restoration is occurring. Tidal wetlands will be restored in large patches supporting a natural gradient extending from subtidal to upland zones which is expected to increase the extent of high value tidal marsh that supported the Suisun shrew's historical tidal habitat and help achieve the draft Tidal Marsh Ecosystems Recovery Plan (USFWS 2010) Suisun shrew objectives. Based on the hypothetical tidal marsh restorations, (see Appendix N.3, *RMA Description of Hypothetical Restoration Design and Effects*), after full implementation of the BDCP there will be a 5 to 9 percent reduction in the extent of Suisun shrew habitat in the Plan Area (Table 5-3), comprised primarily of low value Suisun shrew managed wetland habitat. Because restored tidal wetland habitats are expected to support higher functions as habitat for the Suisun shrew than the affected nontidal wetlands, the overall outcome for Suisun shrew will be beneficial, providing conditions favorable for increasing the distribution and abundance of Suisun shrew within the Plan Area.

5.4.3.6.1 Population-Level Effects on Suisun Shrew

Since Suisun shrew are restricted to natural tidal wetlands along the northern borders of San Pablo and Suisun Bays and BDCP conservation measures are expected to have a beneficial effect on the overall population of Suisun shrew by increasing the extent of tidal brackish emergent wetlands that support high function Suisun shrew habitat. Restoration and subsequent management of this habitat are expected to provide the basis for increasing the abundance of Suisun shrew such that the Suisun Marsh portion of its population is maintained and increased.

5.4.3.7 Tricolored Blackbird

Implementation of all BDCP actions will result in an overall benefit to tricolored blackbird within the Plan Area through restoration and protection of its foraging and nesting habitats. Habitat restoration actions will result in restoration/creation of 17,900 to 26,800 acres of tricolored blackbird nesting habitat (based on the RMA hypothetical tidal habitat restorations presented in Appendix N3, *RMA Description of Hypothetical Restoration Design and Effects*), and after full implementation of the BDCP, 8,700 acres of non-agriculture foraging habitat and 16,620 to 32,640 acres of agriculture foraging habitat will be protected and enhanced for tricolored blackbird and other covered species. As a result of BDCP restoration actions, the total amount of tricolored blackbird nesting habitat within the Plan Area will increase 57 to 94 percent from current conditions (Table 5-4). While the extent of modeled foraging habitat will be reduced by 6 percent (non-agricultural) and 9 percent (agricultural), tricolored blackbirds may also use the restored tidal and nontidal wetland habitats for foraging, a function that was not included in the model formulation (Table 5-3). As a result, implementation of all BDCP actions is expected to result in an overall beneficial effect on tricolored blackbird as BDCP implementation will increase the extent of protected nesting and agricultural and non-agricultural foraging habitats in the Plan Area that will no longer be subject to loss that could result from future changes in land use by 101 to 163 percent, 12 percent, and 43 to 91 percent, respectively, from current conditions (Table 5-4). In addition, restoration of large and contiguous protected patches of nesting habitat is expected to increase the likelihood for increasing the number and distribution of nesting colonies and the abundance of tricolored blackbirds in the Plan Area.

Implementation of BDCP actions is expected to result in the permanent removal of approximately 4,104 acres of modeled nesting habitat, 5,878 acres of non-agriculture foraging habitat, and 24,781 acres of agriculture foraging habitat (Table 5-3). Approximately 35 acres of nesting habitat, 471 acres of non-agriculture foraging habitat, and 1,959 acres of agriculture foraging habitat will be temporarily removed. An additional 303 acres of nesting habitat, 5,414 acres of non-agriculture foraging habitat, and 6,599 acres of agriculture foraging habitat will be periodically affected by BDCP actions.

5.4.3.7.1 Population-Level Effects on Tricolored Blackbird

BDCP actions will not have an adverse population level effect on the tricolored blackbird because protection, restoration, and enhancement of a large extent of tricolored blackbird habitat within the Plan Area is expected to increase the stability of tricolored blackbird populations within and adjacent to the Plan Area and provide for the potential future growth of the local and regional populations.

5.4.3.8 Suisun Song Sparrow

Implementation of all BDCP actions will result in an overall benefit to Suisun song sparrow within the Plan Area through restoration of its habitat. Based on the RMA hypothetical tidal habitat restorations (see Appendix N.3, *RMA Description of Hypothetical Restoration Design* *and Effects*), 3,600 to 4,800 acres of tidal brackish wetlands supporting Suisun song sparrow habitat will be restored in Suisun Marsh (Conservation Zone 11; Table 5-2). BDCP actions are expected to adversely affect Suisun song sparrow through the permanent removal of 5,272 acres of modeled habitat, consisting primarily of managed wetlands (see Table 5-3). However, this effect will be gradual and phased over time as restoration is occurring. Tidal wetlands will be restored in large patches supporting a natural gradient extending from subtidal to upland zones which is expected to increase the extent of high value tidal marsh that supported the sparrow's historical tidal habitat and help achieve the draft Tidal Marsh Ecosystems Recovery Plan (USFWS 2010) Suisun song sparrow objectives.

Based on the hypothetical tidal marsh restorations, (see Appendix N3, *RMA Description of Hypothetical Restoration Design and Effects*), after full implementation of the BDCP there will be a 2-6 percent reduction in the extent of Suisun song sparrow habitat in the Plan Area (Table 5-3), comprised primarily of low value Suisun song sparrow managed wetland habitat. Because tidal habitat restoration in Conservation Zone 11 will affect primarily managed wetland habitats, many of which are protected through conservation easements, the extent of existing protected Suisun song sparrow habitat is expected to decrease by up to 6 percent (Table 5-4). Because restored tidal wetland habitats are expected to support higher functions as habitat for the Suisun song sparrow than the affected nontidal wetlands, the overall outcome for Suisun song sparrow will be beneficial, providing conditions favorable for increasing the distribution and abundance of Suisun song sparrow within the Plan Area.

5.4.3.8.1 Population-Level Effects on Suisun Song Sparrow

BDCP actions will not have an adverse population-level effect on Suisun song sparrow in the near-term, early long-term, or late-long term evaluation points because affected habitat in Suisun Marsh will be sequenced with habitat restoration activities to minimize adverse effects on habitat that could affect that population. Because the entire population of Suisun song sparrow is found within the Plan Area, BDCP tidal habitat restoration actions are expected to be beneficial for the entire Suisun song sparrow population by replacing marginal managed wetland habitat with high quality tidal habitat, and thus creating the potential for extending the species abundance and distribution.

5.4.3.9 Yellow-breasted Chat

Implementation of all BDCP actions is expected to result in an overall benefit to yellow-breasted chat within the Plan Area through restoration of 5,000 acres of its riparian habitat of which at least 2,000 acres is expected to support vireo habitat. BDCP actions are expected to result in the permanent and temporary removal of up to 1,049 acres and 129 acres of modeled yellow-breasted chat habitat, respectively (Table 5-3), primarily due to tidal marsh restoration actions, although the affected habitat is not known to be occupied. Restoration of 5,000 acres of riparian habitat is expected to increase the extent of yellow-breasted chat habitat in the Plan Area by 4,087 acres, or 28 percent, and the extent of chat habitat under protected status within the Plan Area is expected to increase by about 85 percent (Tables 5-3 and 5-4). Most of this restored valley/foothill riparian will be in large patches associated with restored floodplain and tidal habitats. The restoration of such a large area of riparian forest and scrub increases the potential for increasing the abundance and distribution of nesting yellow-breasted chat in the Plan Area and is expected to improve the function of the Plan Area as a migration corridor. As described in Section 5.4.2.5, *Valley/Foothill Riparian*, there is a temporal loss of riparian habitat in the near-term evaluation period because most of the affected riparian vegetation is removed in the near-term implementation period, while large quantities of riparian habitat will not be restored until the early and late long-term implementation periods (Figures 5-3 and 5-5). Effects on yellow-breasted chat of this temporal loss of riparian vegetation is expected to be minimal because much of the riparian habitat in the Plan Area is not known to be currently occupied by the species and most of the affected community is comprised of small patches of riparian scrub and herbaceous vegetation that are fragmented and distributed across the agricultural landscape of the Plan Area (Figure 5-4) and thus are likely to provide no or low value habitat for the chat.

In summary, the yellow-breasted chat is not an established breeder within the Plan Area and seems to use the area as an infrequent migrant. Consequently, BDCP actions are unlikely to adversely affect the species. The overall effect of implementing BDCP actions on yellow-breasted chat is expected to be beneficial as a result of increasing the extent of riparian forest and scrub that supports high-functioning yellow-breasted chat habitat. Restoration and subsequent management of this habitat will provide the basis for increasing the abundance of yellow-breasted chat such that its population is maintained and increased.

5.4.3.9.1 Population-Level Effects on Yellow-breasted Chat

Because yellow-breasted chat is not known to be established in the Plan Area, BDCP actions are not expected to have any adverse population-level effect on yellow-breasted chat populations. BDCP riparian habitat restoration actions are expected to be beneficial for yellow-breasted chat by creating the potential for extending the species occupied range and providing habitat that, if yellow-breasted chat becomes established as a breeding species, could provide a source population for establishment of other historically occupied Central Valley habitats.

5.4.3.10 Least Bell's Vireo

Implementation of all BDCP actions is expected to result in an overall benefit to yellow-breasted chat within the Plan Area through restoration of 5,000 acres of riparian vegetation of which at least 2,000 acres is expected to support vireo habitat. Implementation of BDCP actions is expected to result in the permanent and temporary removal of up to 1,049 acres and 129 acres, respectively of modeled least Bell's vireo habitat (Table 5-3), primarily due to tidal marsh restoration actions. Although least Bell's vireo were observed in the Plan Area in spring 2010, it is not known to currently occupy habitat within the Plan Area, therefore effects are evaluated based on the potential removal or restoration of modeled habitat and some potential for future occupation. Restoration of at least 2,000 acres of riparian forest and scrub that is expected to support least Bell's vireo habitat will increase the extent of potential least Bell's vireo habitat in the Plan Area by approximately 1,092 acres, or 7 percent, and the extent of vireo habitat under protected status within the Plan Area is expected to increase to more than 25 percent (Tables 5-3 and 5-4). Most of this restored valley/foothill riparian will be in large patches associated with restored floodplain and tidal habitats. The restoration of such a large area of riparian forest and scrub increases the potential for restoring formally occupied habitat by establishing the least Bell's vireo as a breeding species within the Plan Area. As described in Section 5.4.2.5, *Valley/Foothill Riparian*, there is a temporal loss of riparian habitat in the near-term evaluation period because most of the affected riparian vegetation is removed in the near-term implementation period, while large quantities of riparian habitat will not be restored until the early and late long-term implementation periods (Figures 5-3 and 5-5). This temporal loss is expected to have no or minimal effects on least Bell's vireo because it is not currently known to occupy the Plan Area.

In summary, the least Bell's vireo is not an established breeder within the Plan Area, and BDCP actions are unlikely to adversely affect the species. The overall effect of implementing BDCP actions on least Bell's vireo is expected to be beneficial as a result of increasing the extent of riparian forest and scrub that supports higher-functioning least Bell's vireo habitat. Restoration and subsequent management of this habitat will to provide the basis for increasing the range of least Bell's vireo by establishing it as a breeding species in the Plan Area.

5.4.3.10.1 Population-Level Effects on Least Bell's Vireo

Because least Bell's vireo is not known to be established in the Plan Area, BDCP actions are not expected to have an adverse population-level effect on least Bell's vireo populations. Overall, BDCP riparian habitat restoration actions are expected to be beneficial for least Bell's vireo by creating the potential for extending the species occupied range northward. By restoring at least 2,000 acres of riparian forest and scrub habitat, BDCP will provide habitat that, if least Bell's vireo becomes established as a breeding species, could support a source population for establishment of other historically occupied Central Valley habitats.

5.4.3.11 Western Burrowing Owl

Implementation of BDCP actions are expected to result in an overall benefit to the burrowing owl in the Plan Area through restoration, protection, and management of its habitat. The BDCP will restore 2,000 acres and protect 8,000 acres of high value grassland habitat within Conservation Zones 1, 8, and 11; and of the 12,000 to 28,000 acres of non-rice agricultural lands that will be protected, 3,000 acres will target moderate and high value (pastureland and grassland) burrowing owl habitats, for a total of 13,000 acres of high and moderate value burrowing owl habitat restored and/or protected in the Plan Area. Through these actions, protection of high and moderate value habitats for burrowing owl will increase by 31 percent and at least 18 percent, representing a total of 45 percent and 40 percent of protected modeled high and moderate value habitat in the Plan Area, respectively (Table 5-4).

BDCP actions are expected to adversely affect burrowing owl through the permanent removal or conversion of 3,569 acres of modeled high value habitat and 4,260 acres of moderate-value habitat. The largest extent of habitat conversion, 21,631 acres, is low value (agricultural land) habitat (Table 5-3). An additional 410 acres of high value habitat and 46 acres of moderate value habitat will be removed temporarily and 2,923 acres of high value habitat and 1,651 acres of moderate value habitat will be periodically affected. Similarly, the largest extent of temporary and periodic habitat effects is low value habitat, 1,970 and 10,265 acres, respectively (Table 5-3). While the extent of modeled high value and moderate value burrowing owl habitat will be reduced in the Plan Area by 2 percent and 8 percent, respectively, BDCP restoration, protection, and enhancement actions, particularly the increase in protection of high and moderate value habitat in the Plan Area is expected to provide for the protection and future expansion of the burrowing owl population (Table 5-3).

5.4.3.11.1 Population-Level Effects on Burrowing owl

BDCP actions will not have an adverse population-level effect on burrowing owl in the Plan Area. The Plan Area represents only a small fraction of the known distribution of burrowing owls in California. The protection, restoration, and enhancement of 13,900 acres of burrowing owl high and moderate-value habitat associated with BDCP action is expected to at least sustain burrowing owl numbers within and adjacent to the Plan Area and increase the permanent protection of high quality habitat for the species.

5.4.3.12 Western Yellow-Billed Cuckoo

Implementation of all BDCP actions is expected to result in an overall benefit to western yellow-billed cuckoo within the Plan Area through restoration of restoration of 5,000 acres of riparian vegetation of which at least 1,000 acres is expected to support cuckoo habitat. BDCP actions are expected to result in the permanent and temporary removal of up to 574 acres and 228 acres of modeled yellow-billed cuckoo breeding and migratory habitat, respectively (Table 5-3), primarily due to tidal marsh restoration actions. The western yellow-billed cuckoo is not known to currently occupy habitat within the Plan Area, therefore effects are evaluated based on the potential removal or restoration of modeled habitat and some potential for future occupation. Restoration of at least 1,000 acres of riparian forest is expected to increase the extent of western yellow-billed cuckoo breeding habitat in the Plan Area by at least 426 acres. A large proportion of the remaining 4,000 acres of the 5,000 acres of riparian forest and scrub to be restored under the BDCP is expected to develop as breeding or migratory western yellow-billed cuckoo.

Most of this restored valley/foothill riparian will be in large patches, as opposed to the primarily smaller isolated patches of affected habitat, associated with restored floodplain and tidal habitats. The restoration of such a large area of riparian forest and scrub increases the potential for restoring formally occupied habitat by establishing western yellow-billed cuckoo as a breeding species within the Plan Area. As described in Section 5.5.2.5, *Valley/Foothill Riparian*, there is a temporal loss of riparian habitat in the near-term evaluation period because most of the affected riparian vegetation is removed in the near-term implementation period, while large quantities of riparian habitat will not be restored until the early and late long-term implementation periods

(Figures 5-3 and 5-5). This temporal loss is expected to have no or minimal effects on western yellow-billed cuckoo because it is not currently known to occupy the Plan Area.

In summary, the yellow-billed cuckoo is not an established breeding species within the Plan Area and seems to use the area as an infrequent migrant. BDCP actions are unlikely to adversely affect the species. The overall effect of implementing BDCP actions on western yellow-billed cuckoo will be beneficial as a result of increasing the extent of riparian forest that supports high-functioning western yellow-billed cuckoo habitat. Restoration and subsequent management of this habitat are expected to provide the basis for increasing the range of western yellow-billed cuckoo by increasing the potential for establishing it as a breeding species in the Plan Area.

5.4.3.12.1 Population-Level Effects on Yellow-billed Cuckoo

Because western yellow-billed cuckoo is not known to be established in the Plan Area, BDCP actions are not expected to have any adverse population-level effect on western yellow-billed cuckoo. BDCP riparian habitat restoration actions are expected to be beneficial for western yellow-billed cuckoo by creating the potential for extending the species occupied range and providing habitat that, if western yellow-billed cuckoo becomes established as a breeding species, could provide a source population for establishment of other historically occupied Central Valley habitats.

5.4.3.13 California Least Tern

Implementation of the BDCP will result in overall beneficial effects on California least tern through restoration of an estimated 10,000 to 20,000 acres of its tidal aquatic foraging habitat, increasing its foraging habitat area by 11 to 23 percent. Implementation of BDCP actions will avoid direct disturbance of California least tern nesting colonies and, compared to the extent of restored habitat, will remove a relatively small about of its tidal aquatic foraging habitat (Table 5-3). Restoration of more than of tidal perennial aquatic will result in enhanced habitat function for California least tern by its proximity to restored and existing aquatic and upland habitats in a natural elevation gradient. The overall outcome for California least tern is beneficial due to restoration of foraging habitat.

5.4.3.13.1 Population-Level Effects on California Least Tern

BDCP actions are not expected to have any adverse effect on California least tern in the Plan Area and, therefore, are not expected to have an adverse population-level effect on California least tern. Only a small fraction of the total California least tern population uses the Plan Area and the Plan Area is not identified as a priority area for conservation action in recovery documents associated with the California least tern. Although BDCP actions are expected to increase the extent of shallow subtidal aquatic California least tern foraging habitat and, potentially increase aquatic food production, the response of the tern to these habitat improvements may be minimal because they do not address major known stressors on the species.

5.4.3.14 Greater Sandhill Crane

Implementation of all BDCP actions will result in an overall benefit to greater sandhill crane within the Plan Area through protection and management of high value foraging habitat and restoration of two roost sites Habitat restoration actions will result in restoration/creation of 320 acres of greater sandhill crane roosting habitat, and habitat protection actions will protect at least 4,800 acres of high value greater sandhill crane agricultural foraging habitat in Conservation Zones 4, 5, or 6. In addition, the restoration of 7,100 acres of tidal freshwater wetlands in Conservation Zones 4 and 7 will provide additional roosting and foraging habitat for cranes. BDCP conservation measures will increase the extent of protected agricultural foraging habitats in the primary use area by at least 4 percent from current conditions (Table 5-4), and protected lands will no longer be subject to loss that could result from future changes in land use. In addition, creation and maintenance of two crane roost sites will help improve the distribution of cranes in the primary use area and ensure the long-term availability of this required and limited habitat, without which cranes could not inhabit the Plan Area.

BDCP actions will permanently remove 6,739 acres of modeled greater sandhill crane foraging habitat and temporarily remove 1,318 acres of modeled crane foraging habitat in the Plan Area (Table 5-3) calculated to total 3,971 habitat units. While there will be a net reduction in the extent of modeled winter foraging habitat in the Plan Area of approximately 4 percent (Table 5-3), management of protected agricultural foraging habitat will focus on providing high value crane foraging habitat and will be maintained such that a minimum of 3,971 habitat units are available on conservation lands each year.

5.4.3.14.1 Population-Level Effects on Greater Sandhill Crane

BDCP actions will not have an adverse population-level effect on greater sandhill crane. Protection, restoration, and enhancement of 5,120 acres of greater sandhill crane foraging and roosting habitat is expected to increase the stability of traditional greater sandhill crane wintering use within and adjacent to the Plan Area and provide for the potential future growth of the local wintering population.

5.4.3.15 California Black Rail

Implementation of all BDCP actions will result in an overall benefit to California black rail within the Plan Area through restoration of its tidal habitats. Based on the RMA hypothetical tidal habitat restorations (see Appendix N.3, *RMA Description of Hypothetical Restoration Design and Effects*), 17,500 to 26,400 acres of tidal brackish and freshwater wetlands supporting California black rail habitat will be restored (Table 5-2). BDCP actions are expected to adversely affect California black rail habitat through the permanent and temporary removal of 5,949 acres and 4 acres of modeled habitat, respectively, consisting primarily of managed wetlands (Table 5-3). Tidal wetlands will be restored in large patches supporting a natural gradient extending from subtidal to upland zones which is expected to increase the extent of high value tidal marsh that supported the rail's historical tidal habitat and help achieve the draft Tidal Marsh Ecosystems Recovery Plan (USFWS 2010) California black rail objectives.

Based on the hypothetical tidal marsh restorations, (see Appendix N.3, *RMA Description of Hypothetical Restoration Design and Effects*), after full implementation of the BDCP there will be a 34 to 61 percent increase in the extent of California black rail habitat in the Plan Area (Table 5-3). The extent of existing protected California black rail tidal wetland habitat is expected to increase to 50 to 86 percent (Table 5-4).

5.4.3.15.1 Population-Level Effects on California Black Rail

BDCP actions are not expected to have an adverse population-level effect on California black rail in the near-term, early long-term, or late-long term because affected habitat in the Delta support very low densities of rail and removal of higher value habitats Suisun Marsh will be sequenced with habitat restoration activities to minimize adverse effects on habitat that could affect that population. Since a significant portion of the entire California black rail population resides in Suisun Marsh, BDCP tidal habitat restoration actions are expected to be beneficial for California black rail by creating the potential for extending the species distribution and abundance in the Delta and its abundance in Suisun Marsh.

5.4.3.16 California Clapper Rail

Implementation of all BDCP actions will result in an overall benefit to California clapper rail within the Plan Area through restoration of its brackish tidal habitats. Based on the RMA hypothetical tidal habitat restorations (see Appendix N.3, *RMA Description of Hypothetical Restoration Design and Effects*), 3,600 to 4,800 acres of tidal brackish wetlands supporting California clapper rail will be restored in Suisun Marsh (Conservation Zone 11; Table 5-3). BDCP actions are expected to adversely affect California clapper rail habitat through the permanent removal of 327 acres of its modeled habitat in Suisun Marsh as a result of tidal habitat restoration actions (Table 5-3). However, this effect will be gradual and phased over time as restoration is occurring. Tidal wetlands will be restored in large patches supporting a natural gradient extending from subtidal to upland zones which is expected to increase the extent of high value tidal marsh that supported the rail's historical tidal habitat and help achieve the draft Tidal Marsh Ecosystems Recovery Plan (USFWS 2010) California clapper rail objectives. Based on the hypothetical tidal marsh restorations, (see Appendix N.3, *RMA Description of Hypothetical Restoration Design and Effects*), after full implementation of the BDCP there will be a 42 to 57 percent increase in the extent of salt marsh harvest mouse habitat in the Plan Area. The extent of existing protected salt marsh harvest mouse tidal wetland habitat is expected to increase to 67 to 89 percent (Table 5-4).

5.4.3.16.1 Population-Level Effects on California Clapper Rail

BDCP actions are not expected to have an adverse population-level effect on California clapper rail in the near-term, early long-term, or late-long term evaluation points because affected habitat in Suisun Marsh will be sequenced with habitat restoration activities to minimize adverse effects on habitat that could affect that population. Because the entire California clapper rail population is restricted to the San Francisco Estuary, BDCP tidal habitat restoration actions are expected to be beneficial for California clapper rail by creating the potential for extending its abundance and distribution in Suisun Marsh, which comprises a sizeable portion of its range and overall population.

5.4.3.17 Swainson's Hawk

Implementation of BDCP actions will result in an overall benefit to Swainson's hawk within the Plan Area through restoration of its nesting and protection and management of its foraging habitats. BDCP protection and enhancement of 20,020 to 36,040 acres of Swainson's hawk foraging habitat to provide a minimum of 17,758 habitat units will increase the extent and quality of Swainson's hawk foraging habitat under protected status within the Plan Area (Table 5-4). Restoration of at least 4,000 acres of riparian habitat is expected to increase the extent of Swainson's hawk nesting habitat in the Plan Area by 3,294 acres (32 percent) and the extent of nesting habitat under protected status within the Plan Area is expected to be increased by 108 percent (Tables 5-3 and 5-4).

BDCP actions are expected to adversely affect Swainson's hawk through the temporary and permanent removal of 40,678 acres (17,758 habitat units) of modeled Swainson's hawk foraging and 844 acres of nesting habitat (Table 5-2). Following full BDCP implementation, the extent of Swainson's hawk nesting habitat acres will increase by 32 percent and the extent of foraging habitat acres will decrease by approximately 9 percent (Table 5-3). However, the overall effect of implementing BDCP actions on Swainson's hawk is expected to be beneficial as a result of protecting a large proportion of its foraging habitat in the Plan Area from loss or degradation that could be associated with future changes in land use, providing consistently high value Swainson's hawk foraging habitat on BDCP lands, restoration of 4,000 acres of nesting habitat that is expected to provide future nesting habitat within the Plan Area, and through enhancement of protected habitats to increase their functions as Swainson's hawk foraging and nesting habitat over the term of the BDCP.

5.4.3.17.1 Population-Level Effects on Swainson's Hawk

BDCP actions will not have an adverse population-level effect on Swainson's hawk. Through the protection, restoration, and enhancement of 24,020 to 40,040 acres of Swainson's hawk foraging and nesting habitat, BDCP is expected to sustain the current range and abundance of Swainson's hawk within the Plan Area and provide for potential increases in Swainson's hawk abundance and distribution within and adjacent to the Plan Area.

5.4.3.18 White-tailed Kite

Implementation of BDCP actions will result in an overall benefit to the white-tailed kite within the Plan Area through restoration of its nesting and protection and management of its foraging habitat. BDCP protection and enhancement of 24,620 to 46,040 acres of white-tailed kite foraging habitat to provide a minimum of 21,693 habitat units will increase the extent and quality of white-tailed kite foraging habitat under protected status within the Plan Area by 12-33 percent (Table 5-4). Restoration of at least 4,000 acres of riparian habitat is expected to increase the extent of white-tailed kite nesting habitat in the Plan Area by 3,132 acres, or 23 percent, and the extent of nesting habitat under protected status within the Plan Area is expected to be increased by 76 percent (Tables 5-3 and 5-4).

BDCP actions are expected to adversely affect white-tailed kite through the temporary and permanent removal of 47,563 acres (21,693 habitat units) of modeled white-tailed kite foraging habitat and 1,013 acres of nesting habitat (Table 5-3). Following full BDCP implementation, the extent of white-tailed kite nesting habitat will increase by 23 percent and the extent of foraging habitat acres will decrease by approximately 9 percent (Table 5-3). However, the overall effect of implementing BDCP actions on white-tailed kite is expected to be beneficial as a result of protecting a large proportion of its foraging habitat in the Plan Area from loss or degradation that could be associated with future changes in land use, providing consistently high value white-tailed kite foraging habitat on BDCP lands, restoration of 4,000 acres of nesting habitat that is expected to provide future nesting habitat within the Plan Area, and through enhancement of protected habitats to increase their functions as white-tailed kite foraging and nesting habitat over the term of the BDCP.

5.4.3.18.1 Population-Level Effects on White-tailed Kite

BDCP actions will not have an adverse population-level effect on white-tailed kite. Through the protection, restoration, and enhancement of 26,020 to 44,040 acres of white-tailed kite foraging and nesting habitat, BDCP is expected to sustain the current range and abundance of white-tailed kites within the Plan Area and provide for potential increases in white-tailed kite abundance and distribution within and adjacent to the Plan Area.

5.4.3.19 Giant Garter Snake

Implementation of all BDCP actions will result in an overall benefit to giant garter snake within the Plan Area through implementation of giant garter snake habitat protection, restoration, and enhancement actions. Following full implementation of the BDCP, at least 6,900 acres of aquatic habitat and 7,100 acres of upland habitat will be protected and enhanced for giant garter snake. An additional 13,690 to 22,040 of potential aquatic breeding habitat will be restored through restoration of tidal and nontidal freshwater habitats. There will be a 66 to 108 percent increase in the extent of giant garter snake aquatic breeding, foraging, and movement habitat in the Plan Area (Table 5-3). The extent of existing protected giant garter snake aquatic habitat present in the Plan Area is expected to increase by 354 to 500 percent and the extent of protected giant garter snake upland habitat by 13 percent (Table 5-4).

BDCP actions are expected to adversely affect giant garter snake through permanent removal of 565 acres of modeled aquatic and 13,713 acres of modeled associated upland habitat; temporary removal of 52 acres of aquatic habitat and 941 acres of upland habitat resulting mainly from water conveyance construction; and periodic inundation of 4,932 acres of aquatic and 5,534 acres of upland habitat resulting primarily from periodic seasonal inundation of the Yolo Bypass (Table 5-3). The overall result of BDCP implementation for giant garter snake will be beneficial through expansion and enhancement of habitats associated with core habitat areas within existing populations areas, providing protected habitat corridors to facilitate movement, and by providing conditions that are favorable, relative to the existing condition of primarily cultivated lands, for maintaining, expanding, and increasing the distribution and abundance of giant garter snake within the Plan Area.

5.4.3.19.1 Population-Level Effects on Giant Garter Snake

BDCP actions will not have an adverse population-level effect on giant garter snake because most affected habitat in the Delta are not believed to be occupied by or support very low densities of giant garter snake. Protection and restoration of giant garter snake habitat may have beneficial population-level effects on giant garter snake by maintaining and improving habitats occupied by the two known subpopulations in the Plan Area and by creating the potential for extending the species distribution and abundance within the Plan Area.

5.4.3.20 Western Pond Turtle

Implementation of all BDCP actions will result in an overall benefit to western pond turtle within the Plan Area through implementation of western pond turtle habitat protection, restoration, and enhancement actions. Full implementation of BDCP habitat actions will restore 27,900 to 46,800 acres of pond turtle aquatic habitat and 5,000 acres of upland nesting and overwintering habitat, and will protect and enhance 4,000 acres of dispersal habitat and at least 5,230 acres of upland nesting and overwintering habitat. The extent of existing protected pond turtle aquatic habitat present in the Plan Area is expected to increase by 76 to 138 percent (Table 5-4) and the extent of protected upland nesting and overwintering habitat by more than 42 percent (Table 5-4).

BDCP actions are expected to permanently and temporarily remove or affect 6,013 acres (8 percent), nearly all of it due to tidal habitat restoration in Suisun Marsh (Conservation Zone 11; Table 5-2), and 84 acres of aquatic habitat, respectively. Tidal habitat restoration is expected to change existing water quality conditions at Suisun Marsh rather than lead to direct loss of aquatic habitat. Changes in salinity and restoration of tidal flow where currently habitat consists of calm waters of managed freshwater ponds and wetlands could have an adverse effect on the western pond turtle.

BDCP actions are also expected to permanently and temporarily remove 51,630 acres and 4,680 acres of dispersal and upland nesting and overwintering habitat in the Plan Area (Table 5-3). Fremont Weir operations and inundation of restored floodplains are expected to periodically affect western pond turtle 20,912 acres of dispersal habitat and 4,163 acres of upland nesting and overwintering habitat (Table 5-3).

Overall, BDCP implementation will increase the extent and distribution of high value aquatic and upland nesting and overwintering habitat for western pond turtle in the Plan Area. While the extent of dispersal habitat is expected to be reduced by approximately 9 percent, this habitat is abundant in the Plan Area (comprised primarily of agricultural lands), not believe to be a factor limiting the turtle, and will be replaced with higher value habitats for western pond turtle.

5.4.3.20.1 Population-Level Effects on Western Pond Turtle

BDCP actions are not expected to have an adverse or beneficial population-level effect on western pond turtle, although enhancement and restoration of its habitats in the Delta are expected to increase its abundance within the Plan Area. A projected rise in salinity and current velocities in Suisun Marsh could adversely affect the western pond turtle population at that location. The restoration of large amounts of subtidal aquatic habitat in other parts of the Plan Area has the potential to increase western pond turtle population numbers. On the terrestrial side, the protection, restoration, and enhancement of upland nesting and overwintering habitat is expected to be beneficial to the species..

5.4.3.21 California Red-legged Frog

Implementation of all BDCP actions will result in an overall benefit to California red-legged frog within the Plan Area through protection and management of at least 1,000 acres its grassland and intermittent stream breeding habitats. The BDCP will protect and enhance these habitats in Conservation Zone 8 and protect and increase connectivity of its limited Plan Area habitats with more extensive California red-legged frog habitat areas outside of the Plan Area. Following implementation, 32 percent of California red-legged frog upland habitat and 6 percent of its breeding within the Plan Area will be protected, increasing the total area of protected breeding habitat and upland habitat by 81 percent and 144 percent, respectively (Table 5-4). In addition, any portion of the 2,000 acres of BDCP restored grassland that is located in Conservation Zone 8 would also be expected to benefit the California red-legged frog.

All protection of frog habitat would be provided in and all adverse effects on California red-legged frog habitat would be incurred in the near-term evaluation period. BDCP actions are expected to adversely affect California red-legged frog through permanent removal of 168 acres of California red-legged frog modeled grassland cover and dispersal and 663 acres of modeled agricultural dispersal habitat. An additional 161 acres of modeled grassland cover and 481 acres of modeled agricultural dispersal habitat will be temporarily removed and restored to their previous habitat condition following the completion of construction activities (Table 5-3).

In contrast to the removed grasslands, the grasslands to be protected, enhanced, and restored occur in areas of historical natural grassland vegetation, much of which is within the range of the California red-legged frog.

5.4.3.21.1 Population-Level Effects on California Red-legged Frog

BDCP actions are not expected to have an adverse or beneficial population-level effect on California red-legged frog because there are few occurrences within the Plan Area and only one site with potential to be affected by proposed project activities. In addition, the relatively small about of modeled grassland habitat that would be removed by the proposed project is on the extreme edge of the species range and based on past and current surveys results is unlikely to be occupied. Although 1,000 acres of high value California red-legged frog habitat will be protected and enhanced under BDCP that is located to maintain connectivity with occupied habitat areas adjacent to the Plan Area, because the Plan Area is located at the margin of the species range, BDCP implementation is not expected to have a measurable beneficial population-level effect on California red-legged frog.

5.4.3.21.2 Effects on Critical Habitat

Designated critical habitat for the California red-legged frog overlaps with the Plan Area along the western edge of Conservation Zone 11. Critical Habitat Unit Sol-1 extends along the west side of Interstate 680 (I-680). Approximately 2,460 acres of Sol-1 occurs within the Plan Area boundary. This area is not expected to be affected by any BDCP actions. All tidal restoration within the Suisun Marsh will occur east of I-680 where the land is currently primarily marshland and managed wetlands. The landscape west of I-680 is primarily higher elevation upland grasslands that will not be directly or indirectly affected through changes in hydrology as a result of restoration activities. Therefore, BDCP actions will not affect critical habitat for the California red-legged frog in Conservation Zone 11.

A small amount of designated critical habitat for the California red-legged frog is also present along the western edge of Conservation Zone 8. Critical Habitat Unit CCS-2 extends along the eastern edge of the grassland foothills of Eastern Contra County, approximately 862 acres of which occur within the Plan Area. This area is not expected to be adversely affected by any BDCP actions. All water conveyance construction activities will occur west of the critical habitat boundary with the exception of the proposed 230kV transmission line that extends down the California Aqueduct canal southwest of CCF, but still outside of the critical habitat boundary. Conservation actions to protect and enhance grassland habitat for covered species, including California red-legged frog, in Conservation Zone 8 could include acquisition and enhancement of designated critical habitat for the California red-legged frog, California tiger salamander, and San Joaquin kit fox. Any habitat enhancement actions for these species in designated critical habitat are expected to enhance and not diminish the value of any affected designated critical habitat for conservation of California red-legged frog.

5.4.3.22 Western Spadefoot Toad

Implementation of all BDCP actions will result in an overall benefit on western spadefoot toad within the Plan Area through protection, enhancement, and restoration of its habitat. BDCP conservation measures will restore 200 acres high value vernal pool complex supporting high value western spadefoot toad breeding habitat and protect and enhance 300 acres of existing breeding and 8,400 acres of upland habitat. These protected habitat areas will be located such that they will maintain and enhance connectivity with more extensive patches of suitable habitat adjacent to the Plan Area. BDCP actions are expected to permanently remove of 48 acres of its modeled breeding habitat and permanently and temporarily remove 464 acres and 169 acres of its modeled upland habitat, respectively (Table 5-3). The extent of western spadefoot toad habitat restored and protected at the near-term and early long-term evaluation points exceeds the extent that will be removed by BDCP actions at those evaluation points. Following full implementation of the BDCP, there will be an increase in 158 acres of western spadefoot toad breeding habitat, representing a 2 percent increase in the Plan Area (Table 5-3), and an increase in the extent of existing protected breeding and upland habitat of 12 percent and 173 percent, respectively (Table 5-4).

5.4.3.22.1 Population-Level Effects on Western Spadefoot Toad

There are no records of western spadefoot toad within the Plan Area. Because of the small amount of modeled habitat affected and the overall increase in breeding and protected upland habitats, BDCP actions will not have an adverse effect on western spadefoot toad populations and may have a beneficial effect by providing additional opportunities for colonization and protecting habitat corridors between protected aquatic habitats.

5.4.3.23 California Tiger Salamander

Implementation of all BDCP actions will result in an overall benefit on California tiger salamander within the Plan Area through protection, enhancement, and restoration of its habitat. BDCP conservation measures will restore 200 acres high value vernal pool complex supporting high value California tiger salamander breeding habitat and protect and enhance 300 acres of existing breeding and 8,400 acres of upland habitat. These protected habitat areas will be located such that they will maintain and enhance connectivity with more extensive patches of suitable habitat adjacent to the Plan Area. BDCP actions are expected to permanently remove42 acres of its modeled breeding habitat and permanently and temporarily remove 464 acres and 169 acres of its modeled upland habitat, respectively (Table 5-3). The extent of California tiger salamander habitat restored and protected at the near-term and early long-term evaluation points exceeds the extent that will be removed by BDCP actions at those evaluation points. Following full implementation of the BDCP, there will be an increase in 158 acres of California tiger salamander breeding habitat, representing a 2 percent increase in the Plan Area (Table 5-3), and an increase in the extent of existing protected breeding and upland habitat of 12 percent and 173 percent, respectively (Table 5-4).

5.4.3.23.1 Population-Level Effects on California Tiger Salamander

BDCP actions are not expected to have an adverse or beneficial population-level effect on California tiger salamander because, while several important California tiger salamander populations occur in the vicinity of the Plan Area, only a few records from Conservation Zone 8 confirm their presence within the Plan Area. In addition, habitat restoration actions will remove 42 acres, or less than 1 percent, of its vernal pool complex breeding habitat, which is most limiting for the species. Although 8,900 acres of high value California tiger salamander breeding and upland habitat will be protected, enhanced, and restored under BDCP that is located to maintain connectivity with potentially occupied habitat areas adjacent to the Plan Area, because the Plan Area is located at the margin of the species range, BDCP implementation is not expected to have a measurable beneficial population-level effect on California tiger salamander.

5.4.3.23.2 Effects on Critical Habitat

Designated critical habitat for California tiger salamander is present in the Plan Area along the western edge of Conservation Zone 1. Critical Habitat Unit 2 extends along the west side of State Route 113 (SR 113) from the short east-west portion of SR-113 south of Hay Road on the north to Creed Road on the south. Approximately 1,781 acres of Unit 2 occur within the Plan Area. While this area occurs within the Cache Slough Complex, it is not expected to be affected by BDCP tidal habitat restoration actions. As modeled in the hypothetical tidal habitat restorations (see Appendix E21), tidal habitat will be restored approximately 2 miles east of SR-113 with some restoration occurring along the Barker and Lindsey Slough channels west to approximately SR-113, and a small amount (0.4 acre) occurring along the Lindsey Slough Channel west of SR-113 into Unit 2. While the actual restoration area my vary from the hypothetical restoration area, because of the existing hydrological transition to a vernal pool grassland west of SR-113, there is little potential for tidal marsh restoration occurring in this area with the possible exception of the Lindsey and Barker Slough channels. Further, because the intent is to protect and enhance vernal pool grassland in the area west of SR-113, conversion of this area to tidal habitats is expected to be avoided. Conservation actions to protect and enhance grassland and vernal pool complex habitat for covered species, including California tiger salamander, in Conservation Zone 1 could include acquisition and enhancement of designated critical habitat for the California tiger salamander, covered vernal pool shrimp species, and vernal pool plant species. Any habitat enhancement actions for these species in designated critical habitat are expected to enhance and not diminish the value of any affected designated critical habitat for conservation of California tiger salamander.

5.4.3.24 Lange's Metalmark Butterfly

Implementation of the BDCP will result in overall beneficial effects on Lange's metalmark butterfly. BDCP actions will have no adverse effect Lange's metalmark butterfly or its habitat and will result in an overall benefit to the ecological function of its habitat at the Antioch Dunes NWR and at other suitable locations, if present, in the Plan Area where Lange's metalmark habitat may be protected and enhanced or restored. Habitat enhancement and butterfly propagation programs are expected to maintain and potentially increase the abundance of Lange's metalmark butterfly.

5.4.3.24.1 Population-Level Effects on Lange's Metalmark Butterfly

BDCP support of USFWS restoration and enhancement actions at the Antioch Dunes NWR will have beneficial population-level effects on Lange's metalmark butterfly. BDCP support will help restore inland dune scrub habitat and augment existing populations of Lange's metalmark butterfly through a program of captive breeding and release into areas of inland dune scrub plant habitat. Lange's metalmark butterfly is a subspecies of a widely distributed species and is likely endemic to the Plan Area. Thus, beneficial effects of BDCP actions could affect the range-wide status of Lange's metalmark butterfly.

5.4.3.25 Valley Elderberry Longhorn Beetle

Implementation of all BDCP actions is expected to result in an overall benefit to valley elderberry longhorn beetle within the Plan Area through restoration 5,000 acres of its riparian habitat supporting its elderberry host plant. Restoration of riparian habitats would increase the distribution and extent of elderberry shrubs and the beetle's potential distribution and abundance in the Plan Area. BDCP actions are expected to adversely affect valley elderberry longhorn beetle through permanent removal of 1,722 acres and temporary removal of 352 acres of its modeled habitat (Table 5-3), primarily due to tidal habitat restoration, although the affected habitat is not known to be occupied. Periodic effects (through inundation) of an additional 1,286 acres of habitat are associated with floodplain restoration and enhancement actions (Table 5-3), which are expected to have no or minimal adverse effects on the beetle. Full implementation of the BDCP will result in an increase of 3,898 acres, or 23 percent, in the extent of riparian habitat in the Plan Area, much of which will support the host plant for valley elderberry longhorn beetle; and a 42 percent increase in the extent of existing protected habitat in the Plan Area (Table 5-4).

As described in Section 5.4.2.5, *Valley/Foothill Riparian*, there is a temporal loss of riparian habitat in the near-term evaluation period because most of the affected riparian vegetation is removed in the near-term implementation period, while large quantities of riparian habitat will not be restored until the early and late long-term implementation periods (Figures 5-3 and 5-5). Effects on valley elderberry longhorn beetle of this temporal loss of riparian vegetation is expected to be minimal because much of the riparian habitat in the Plan Area is not known to be currently occupied by the species and most of the affected community is comprised of small patches of riparian scrub and herbaceous vegetation that are fragmented and distributed across the agricultural landscape of the Plan Area (Figure 5-4) and thus are likely to provide no or low value habitat for the beetle.

5.4.3.25.1 Population-Level Effects on Valley Elderberry Longhorn Beetle

BDCP actions will not have an adverse population-level effect on valley elderberry longhorn beetle because BDCP actions will affect less that 5 percent of its modeled habitat, much of which is likely not occupied, and BDCP restoration actions will increase its habitat by 23 percent commensurate or in advance of when habitat will be affected. Increasing the distribution of its habitat and its extent by 23 percent is expected to provide the basis for increasing the abundance and distribution of valley elderberry longhorn beetle in the Plan Area. Depending on where riparian habitats are restored, increasing the extent of riparian habitat is also expected to increase connectivity of its habitat with habitat areas adjacent to the Plan Area, which will help maintain or improve the regional status of the species' population.

5.4.3.26 Vernal Pool Shrimp Species (Vernal Pool Tadpole Shrimp, Conservancy Fairy Shrimp, Longhorn Fairy Shrimp, Vernal Pool Fairy Shrimp, Mid Valley Fairy Shrimp, and California Linderiella)

Implementation of all BDCP actions will result in an overall benefit to the vernal pool shrimp species through the restoration of 200 acres of vernal pool complex and the protection and enhancement of 300 acres of existing vernal pool complex. The restored and protected habitat areas will be located such that they will maintain and enhance connectivity with more extensive patches of vernal pool complex and grassland habitat areas adjacent to the Plan Area. The restoration and protection of vernal pool shrimp habitat is expected to provide conditions favorable for maintaining and increasing the distribution and abundance of the vernal pool shrimp species and their habitats. The implementation of BDCP actions to restore tidal habitat will result in the permanent loss of 42 acres of vernal pool complex (see in Conservation Zones 1 and 11(see Table 5-4). Additionally, 5 acres of the degraded vernal pool complex vegetation type will be lost but that vegetation type is ephemeral habitat that is primarily a byproduct of agricultural land management actions and therefore is not considered to be the removal of vernal pool shrimp species habitat. The extent of vernal pool shrimp species habitat restored and protected at the near-term and early long-term evaluation points exceeds the extent that will be removed by BDCP actions at those evaluation points.

With the full implementation of the BDCP, in the Plan Area there will be an increase in 158 acres of vernal pool shrimp species habitat through restoration, representing a 2 percent increase, and the extent of protected existing habitat will increase by 300 acres or 11 percent (Table 5-4).

5.4.3.26.1 Population-Level Effects on Vernal Pool Shrimp Species

BDCP actions will not have either an adverse or a beneficial population-level effect on vernal pool shrimp species. Although habitat restoration will increase the extent of their vernal pool complex habitat by 2 percent within the Plan Area and will enhance 300 acres of existing habitat, the Plan Area is located at the margin of the distribution of vernal pool shrimp species habitat within the Central Valley and thus, beneficial and adverse effects of BDCP actions are unlikely to affect the status of vernal pool shrimp species populations beyond the Plan Area.

5.4.3.26.2 Effects on Critical Habitat

Designated critical habitat for vernal pool tadpole shrimp, Conservancy fairy shrimp, and vernal pool fairy shrimp is located in the Plan Area along the northern margin of Suisun Marsh in

Conservation Zone 11. The Critical Habitat includes vernal pool tadpole shrimp Unit 11D, Conservancy fairy shrimp Unit 3, and vernal pool fairy shrimp Unit 16A.

Critical Habitat\PCEs for all three species are:

1) Topographic features characterized by mounds and swales, and depressions within a matrix of surrounding uplands that result in complexes of continuously, or intermittently, flowing surface water in the swales connecting the pools described in PCE (2), providing for dispersal and promoting hydroperiods of adequate length in the pools.

2) Depressional features including isolated vernal pools with underlying restrictive soil layers that become inundated during winter rains and that continuously hold water for a minimum time period (41 days for vernal pool tadpole shrimp, 19 days for Conservancy fairy shrimp, 18 days for vernal pool fairy shrimp) in all but the driest years; thereby providing adequate water for incubation, maturation, and reproduction. As these features are inundated on a seasonal basis, they do not promote the development of obligate wetland vegetation habitats typical of permanently flooded emergent wetlands.

3) Sources of food, expected to be detritus occurring in the pools, contributed by overland flow from the pools' watershed, or the results of biological processes within the pools themselves, such as single-celled bacteria, algae, and dead organic matter, to provide for feeding.

4) Structure within the pools described in PCE (2), consisting of organic and inorganic materials, such as living and dead plants from plant species adapted to seasonally inundated environments, rocks, and other inorganic debris that may be washed, blown, or otherwise transported into the pools, that provide shelter.

The only BDCP action that could affect these Critical Habitat Units is restoration of tidal habitat by restoring tidal action to areas that historically were tidal and the resulting reduced tidal prism resulting from those restoration actions (see Appendix E21). PCE 1 does not exist within those areas of designated critical habitat that could be affected because no vernal pool features are present below the historic tide level; PCE 2 does not exist within those areas of designated critical habitat that could be affected because the tidal area is inundated twice a day by tides and not seasonally during winter rains; PCE 3 does not exist within those areas of designated critical habitat that could be affected because these are tidal areas and not vernal pools; and PCE 4 does not exist within those areas of designated critical habitat that could be affected because these areas are tidal areas and not vernal pools. Consequently, tidal habitat restoration actions will have no effect on any of the four PCEs and thus will not diminish the value of any affected designated critical habitat for conservation of vernal pool tadpole shrimp, Conservancy fairy shrimp, and vernal pool fairy shrimp.

5.4.3.27 Vernal Pool Plant Species (Alkali Milk-Vetch, San Joaquin Spearscale, Boggs Lake Hedge-Hyssop, Heckard's Peppergrass, Dwarf Downingia, and Legenere)

Implementation of all BDCP actions will result in an overall benefit to the vernal pool plant species through the restoration of 200 acres vernal pool complex and the protection and enhancement of 300 acres of existing vernal pool complex. The restored and protected habitat areas will be located such that they will maintain and enhance connectivity with more extensive patches of vernal pool complex and grassland habitat areas adjacent to the Plan Area. The restoration and protection of the vernal pool plant species and their habitat is expected to provide conditions favorable for maintaining and increasing the distribution and abundance of vernal pool plant species and their habitats within the Plan Area. The implementation of BDCP actions to restore tidal habitat will result in the permanent loss of 88 acres of vernal pool complex (Conservation Zones 1 and 11 (see Table 5-3). Additionally, 5 acres of affected degraded vernal pool complex vegetation type will be lost but that vegetation type is ephemeral habitat that is primarily a byproduct of agricultural land management actions and therefore is not considered to be the removal of vernal pool plant species habitat. The extent of vernal pool plant species habitat restored and protected at the near-term and early long-term evaluation points exceeds the extent that will be removed by BDCP actions at those evaluation points.

With the full implementation of the BDCP, in the Plan Area there will be an increase of 112 acres of vernal pool plant species habitat through restoration, representing a 2 percent increase, and the extent of protected existing habitat will increase by 300 acres or 11 percent (Table 5-4).

5.4.3.27.1 Population-Level Effects on Vernal Pool Plant Species

BDCP actions will not have either an adverse or a beneficial population-level effect on vernal pool plant species. Although habitat restoration will increase the extent of their vernal pool complex habitat by 2 percent within the Plan Area and will enhance 300 acres of existing habitat, the Plan Area is located at the margin of the distribution of their vernal pool habitats within the Central Valley and thus, the beneficial and adverse effects of BDCP actions are unlikely to affect the status of vernal pool plant species populations beyond the Plan Area.

5.4.3.28 Heartscale and Brittlescale

Implementation of all BDCP actions will result in an overall benefit to heartscale and brittlescale through the protection and enhancement of 150 acres of existing habitat and the protection of at least 3 occurrences of each species. The protected habitat areas will be located such that they will maintain and enhance connectivity with more extensive patches of habitat areas adjacent to the Plan Area. The protection of heartscale and brittlescale, three additional occurrences, and their habitat is expected to provide conditions favorable for maintaining and increasing the distribution and abundance of heartscale and brittlescale and their habitat within the Plan Area. The implementation of BDCP actions to restore tidal habitat will result in the permanent loss of

10 acres of heartscale and brittlescale habitat (Conservation Zones 1, 8, and/or 11) (Table 5-3). The extent of heartscale and brittlescale habitat restored and protected at the near-term and early long-term evaluation points exceeds the extent that will be removed by BDCP actions at those evaluation points.

With the full implementation of the BDCP, there will be a 115 percent increase in the extent of existing protected habitat and 3 additional occurrences of each species will be protected (Table 5-4).

5.4.3.28.1 Population-Level Effects on Heartscale and Brittlescale

BDCP actions will not have an adverse or beneficial population-level effect on either heartscale or brittlescale. Although BDCP actions will protect and enhance 150 acres of heartscale or brittlescale habitat and protect 3 occurrences of each species, the Plan Area is located at the margin of the species distribution within the Central Valley and thus the effects of BDCP actions are unlikely to affect the range-wide status of heartscale and brittlescale populations beyond the Plan Area.

5.4.3.29 Slough Thistle

Implementation of all BDCP actions will result in an overall benefit to slough thistle through the restoration of at least 1,000 acres of seasonally inundated floodplain habitat. The restoration of seasonally inundated floodplain habitat is expected to provide conditions favorable for maintaining and increasing the distribution and abundance of slough thistle within the Plan Area. The implementation of BDCP actions to restore tidal habitat will result in the permanent loss of 5 acres of slough thistle modeled habitat, the temporary removal of 6 acres of habitat, the periodic inundation of 6 acres of habitat, and the indirect disturbance of 25 acres of habitat (Table 5-3). The extent of slough thistle habitat restored and protected at the near-term and early long-term evaluation points exceeds the extent that will be removed by BDCP actions at those evaluation points.

With the full implementation of the BDCP, in the Plan Area there will be an increase in the extent of seasonally inundated flood plain habitat that will support patches of slough thistle habitat within the Plan Area of at least 1,000 acres and there will be an increase in the extent of existing protected habitat of over 532 percent (Table 5-4).

5.4.3.29.1 Population-Level Effects on Slough Thistle

BDCP actions will not have either an adverse or a beneficial population-level effect on slough thistle. Although BDCP actions will restore 1,000 acres of slough thistle habitat that will create the potential for increase the abundance and distribution of the species in the Plan Area, the Plan Area is located much further north than slough thistle's population center which exists in the areas of former lake beds in the southern San Joaquin Valley.

5.4.3.30 Suisun Thistle and Soft Bird's-beak

Implementation of all BDCP actions will result in an overall benefit to slough thistle through the restoration of between 3,600 and 4,800 acres of tidal brackish marsh habitat (based on the RMA hypothetical tidal habitat restorations described in Appendix N.3, *RMA Description of Hypothetical Restoration Design and Effects*) which will contain areas of suitable habitat for these species and the protection of at least 3 occurrences of each species. The restoration of tidal brackish marsh habitat is expected to provide conditions favorable for maintaining and increasing the distribution and abundance of Suisun thistle and soft bird's-beak within the Plan Area. The implementation of BDCP actions to restore tidal habitat will result in the permanent loss of 636 acres of Suisun thistle and soft bird's-beak habitat (Table 5-3). The extent of Suisun thistle and soft bird's-beak habitat restored at the near-term and early long-term evaluation points exceeds the extent that will be removed by BDCP actions at those evaluation points.

With the full implementation of the BDCP, in the Plan Area the extent of protected tidal brackish marsh that could support areas of Suisun thistle and soft bird's-beak habitat within the Plan Area will be increased between 347 and 485 percent and 3 additional occurrences of each species will be protected (Table 5-4).

5.4.3.30.1 Population-Level Effects on Suisun Thistle and Soft Bird's-beak

BDCP actions will have beneficial population-level effects on Suisun thistle and soft bird's-beak. BDCP actions will restore between 3,600 and 4,800 acres of tidal brackish wetland habitat and protect 3 occurrences of each species. Suisun thistle is endemic to the Plan Area and Suisun Marsh represents a large portion of soft bird's-beak overall population. Thus, beneficial effects of BDCP actions could affect the range-wide status of Suisun thistle and soft bird's-beak populations.

5.4.3.30.2 Effects on Critical Habitat

Designated critical habitat for the Suisun thistle and soft bird's-beak is located in the Plan Area exclusively in tidal areas of Suisun Marsh. Suisun thistle Unit 1 and soft bird's-beak Unit 2 are located at Hill Slough Marsh, Suisun thistle Unit 2 is located at Petonia Slough Marsh, Suisun thistle Unit 3 and soft bird's-beak Unit 4 are located at Rush Ranch/Grizzly Island Wildlife Area.

Critical Habitat PCEs for *Cirsium hydrophilum* var. *hydrophilum* are:

1) Persistent emergent, intertidal, estuarine wetland at or above the mean high-water line (as extended directly across any intersecting channels);

2) Open channels that periodically contain moving water with ocean-derived salts in excess of 0.5 percent; and

3) Gaps in surrounding vegetation to allow for seed germination and growth.

Critical Habitat PCEs for *Cordylanthus mollis* ssp. *mollis* are:

1) Persistent emergent, intertidal, estuarine wetland at or above the mean high-water line (as extended directly across any intersecting channels);
2) Rarity or absence of plants that naturally die in late spring (winter annuals); and
3) Partially open spring canopy cover (approximately 790 nanomoles per square meter per second [$nMol/m^2/s$]) at ground level, with many small openings to facilitate seedling germination.

As modeled in the hypothetical tidal habitat restorations (see Appendix N.3, *RMA Description of Hypothetical Restoration Design and Effects*), tidal habitat restoration actions under full implementation of the BDCP will alter the tidal prism and will result in the compression of the tidal range by approximately 1 foot biased towards a lower elevation of mean lower low water. The result will be the loss of an undeterminable amount of designated critical habitat due to a lowered mean high-water line (PCE1 for both species).

The potential for effects on designated critical habitat will be minimized through design of tidal habitat restoration projects and temporal and spatial staging of when and where restoration projects are implemented. Implementation of the tidal habitat restoration projects are expected to restore patches of Suisun thistle and soft bird's-beak habitat and to contribute to the achieving the objectives of the Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California (USFWS 2010). Consequently, any adverse effects of habitat restoration on designated critical habitat are not expected to appreciably diminish the value of critical habitat for species conservation.

5.4.3.31 Delta Button Celery

Implementation of all BDCP actions will result in an overall benefit to Delta button celery through the protection of at least 100 acres of alkali habitat and the restoration of at least 1,000 acres of seasonally inundated floodplain habitat that will support areas of Delta button celery habitat. The restoration and protection of Delta button celery habitat is expected to provide conditions favorable for maintaining and increasing the distribution and abundance of Delta button celery and its habitat within the Plan Area. The implementation of BDCP actions to restore tidal habitat will result in the permanent loss of 25 acres of Delta button celery habitat, the temporary removal of 8 acres of habitat, the periodic inundation of 18 acres of habitat (Table 5-3). The extent of Delta button celery habitat restored and protected at the near-term and early long-term evaluation points exceeds the extent that will be removed by BDCP actions at those evaluation points.

With the full implementation of the BDCP, there will be a 407 percent increase in the extent of existing protected habitat (Table 5-4).

5.4.3.31.1 Population-Level Effects on Delta Button Celery

BDCP actions will not have either an adverse or a beneficial population-level effect on Delta button celery. Although BDCP actions will protect at least 100 acres of existing habitat and restore at least 1,000 acres of Delta button celery habitat that will create the potential for increasing the abundance and distribution of the species in the Plan Area, the Plan Area is located at the northern edge of its range and thus will be unlikely to have a population-level effect on the species' abundance and distribution.

5.4.3.32 Inland Dune Scrub Plant Species (Contra Costa Wallflower, Antioch Dunes Primrose)

Implementation of the BDCP will result in overall beneficial effects on Contra Costa wallflower and Antioch Dunes primrose. BDCP actions will have no adverse effect on Contra Costa wallflower and Antioch Dunes primrose or their habitat. BDCP support for USFWS habitat enhancement and propagation programs are expected to maintain and potentially increase the abundance of Contra Costa wallflower and Antioch Dunes primrose.

5.4.3.32.1 Population-Level Effects on Inland Dune Scrub Plant Species

BDCP support of USFWS restoration and enhancement actions at the Antioch Dunes NWR will have beneficial population-level effects on Contra Costa wallflower and Antioch Dunes primrose. BDCP support will help restore inland dune scrub habitat and augment existing populations throughout-planting of nursery grown stock into areas of inland dune scrub plant habitat. Both Contra Costa wallflower and Antioch Dunes evening primrose are subspecies that are endemic to the Plan Area. Thus, beneficial effects of BDCP actions could affect the range-wide status of Contra Costa wallflower and Antioch Dunes evening primrose.

5.4.3.32.2 Effects on Critical Habitat

Designated critical habitat for Contra Costa wallflower and Antioch Dunes primrose is located in the Plan Area on the Antioch Dunes NWR refuge and slightly into the San Joaquin River. It is designated as "an area of land, water, and airspace (exclusive of those existing man-made structures or settlements which are not necessary to the survival or recovery of the species) in Contra Costa County." Inland dune scrub actions supported by the BDCP will be implemented by the USFWS and will have no adverse effect on the designated critical habitat. Any habitat enhancement actions for these species in designated critical habitat are expected to enhance and not diminish the value of any affected designated critical habitat for conservation of Contra Costa wallflower and Antioch Dunes primrose. Proposed changes in water operations will periodically alter the salinity or temperature of the water but will not affect the sediment supply to the due so will have no adverse effect on the designated critical habitat.

5.4.3.33 Carquinez Goldenbush

Implementation of all BDCP actions will result in an overall benefit to Carquinez goldenbush through the protection and enhancement of 300 acres of existing habitat and the protection of at least 3 occurrences. The protected habitat areas will be located such that they will maintain and enhance connectivity with more extensive patches of habitat areas adjacent to the Plan Area. The protection of Carquinez goldenbush, its occurrences, and its habitat is expected to provide conditions favorable for maintaining and increasing the distribution and abundance of Carquinez goldenbush and its habitats within the Plan Area. The implementation of BDCP actions to restore tidal habitat will result in the permanent loss of 42 acres of Carquinez goldenbush habitat and temporarily disturb 17 acres of Carquinez goldenbush habitat (Table 5-3). The extent of Carquinez goldenbush habitat restored and protected at the near-term and early long-term evaluation points exceeds the extent that will be removed by BDCP actions at those evaluation points.

With the full implementation of the BDCP, there will be a 76 percent increase in the extent of existing protected habitat and 3 additional occurrences of Carquinez goldenbush will be protected (Table 5-4).

5.4.3.33.1 Population-Level Effects on Carquinez Goldenbush

BDCP actions will have a beneficial population-level effect on Carquinez goldenbush. The species' range is limited to Solano County, a large portion of which is located in the Plan Area. Implementation of the BDCP will increase the extent of protected and managed Carquinez goldenbush habitat from 38 percent to 70 percent within the Plan Area and protect all remaining known occurrences in the Plan Area.

5.4.3.34 Delta Tule Pea and Suisun Marsh Aster

Implementation of all BDCP actions will result in an overall benefit to Delta tule pea and Suisun Marsh aster through the restoration of between 16,970 to 26,470 acres of tidal marsh habitat (based on the RMA hypothetical tidal habitat restorations described in Appendix N.3, *RMA Description of Hypothetical Restoration Design and Effects*) which will contain areas of suitable habitat for these species. The restoration of Delta tule pea and Suisun Marsh aster habitat is expected to provide conditions favorable for maintaining and increasing the distribution and abundance of Delta tule pea and Suisun Marsh aster and their habitat within the Plan Area. The implementation of BDCP actions to restore tidal habitat will result in the permanent loss of 1,137 acres, the temporary disturbance of 1 acre, and the periodic inundation of 10 acres of Delta tule pea and Suisun Marsh aster habitat (Table 5-3). The extent of Delta tule pea and Suisun Marsh aster habitat restored and protected at the near-term and early long-term evaluation points exceeds the extent that will be removed by BDCP actions at those evaluation points.

With the full implementation of the BDCP, there will be an increase in the extent of tidal habitat with areas of Delta tule pea and Suisun Marsh aster habitat within the Plan Area by 16,970 to

26,470 acres and there will be an increase in the extent of existing protected tidal habitat with areas of Delta tule pea and Suisun Marsh aster habitat of between 430 and 687 percent (Table 5-4).

5.4.3.34.1 Population-Level Effects on Delta Tule Pea and Suisun Marsh Aster

BDCP actions will have beneficial population-level effects on Delta tule pea and Suisun Marsh aster. BDCP actions will restore 16,970 to 26,470 acres of tidal wetland habitat. Delta tule pea and Suisun Marsh aster are nearly endemic to the Plan Area. Thus, beneficial effects of BDCP actions could beneficially affect the range-wide status of Delta tule pea and Suisun Marsh aster.

5.4.3.35 Delta Mudwort and Mason's Lilaeopsis

Implementation of all BDCP actions will result in an overall benefit to Delta mudwort and Mason's lilaeopsis through the restoration of between 16,980 to 26,560 acres of tidal marsh habitat (based on the RMA hypothetical tidal habitat restorations described in Appendix N3, *RMA Description of Hypothetical Restoration Design and Effects*) which will contain areas of suitable habitat for these species. The restoration of Delta mudwort and Mason's lilaeopsis habitat is expected to provide conditions favorable for maintaining and increasing the distribution and abundance of Delta mudwort and Mason's lilaeopsis and their habitat within the Plan Area. The implementation of BDCP actions to restore tidal habitat will result in the permanent loss of 146 acres, the temporary disturbance of 9 acres, and the periodic inundation of 205 acres of Delta mudwort and Mason's lilaeopsis habitat (Table 5-3). The extent of Delta mudwort and Mason's lilaeopsis habitat restored and protected at the near-term and early long-term evaluation points exceeds the extent that will be removed by BDCP actions at those evaluation points.

With the full implementation of the BDCP, there will be an increase in the extent of tidal habitat with areas of Delta mudwort and Mason's lilaeopsis habitat within the Plan Area by 16,980 to 26,560 acres and there will be an increase in the extent of existing protected tidal habitat with areas of Delta mudwort and Mason's lilaeopsis habitat of between 984 and 1,542 percent (Table 5-4).

5.4.3.35.1 Population-Level Effects on Delta Mudwort and Mason's Lilaeopsis

BDCP actions will have beneficial population-level effects on Delta mudwort and Mason's lilaeopsis. BDCP actions will restore 16,980 to 26,560 acres of tidal wetland habitat that will contain areas of delta mudwort and Mason's lilaeopsis habitat. Delta mudwort and Mason's lilaeopsis are nearly endemic to the Plan Area. Thus, beneficial effects of BDCP actions could affect the range-wide status of Delta mudwort and Mason's lilaeopsis.

5.4.3.36 Side-flowering Skullcap

Implementation of all BDCP actions will result in an overall benefit to side-flowering skullcap through the restoration of 5,000 acres of valley/foothill riparian community and between 13,900 and 21,600 acres of tidal freshwater emergent wetland community (based on the RMA hypothetical tidal habitat restorations described in Appendix N.3, *RMA Description of Hypothetical Restoration Design and Effects*). The restoration of the two communities is expected to provide conditions favorable for maintaining and increasing the distribution and abundance of side-flowering skullcap and its habitat within the Plan Area. The implementation of BDCP actions to restore tidal habitat will result in the permanent loss of 37 acres, temporarily disturb 3 acres, and periodically inundate 41 acres of side-flowering skullcap habitat (Table 5-3). The extent of side-flowering skullcap habitat restored and protected at the near-term and early long-term evaluation points exceeds the extent that will be removed by BDCP actions at those evaluation points.

Because of its unique habitat, decaying stumps and pilings, with the full implementation of the BDCP there will be an indeterminable increase in the extent of existing protected habitat of side-flowering skullcap.

5.4.3.36.1 Population-Level Effects on Side-flowering Skullcap

BDCP actions will have beneficial population-level effects on side-flowering skullcap. BDCP actions will restore 5,000 acres of valley/foothill riparian community and between 13,900 and 21,600 acres of tidal freshwater emergent wetland community containing patches of side-flowering skullcap habitat. Within California, side-flowering skullcap is endemic to the Plan Area while it is widely distributed across the United States and Canada. Thus, beneficial effects of BDCP actions will not affect the range-wide status of side-flowering skullcap.

5.4.3.37 Caper-fruited Tropidocarpum

Implementation of all BDCP actions will result in an overall benefit for caper-fruited tropidocarpum within the Plan Area by protecting and enhancing at least 100 acres of its modeled habitat to provide conditions favorable for reestablishing caper-fruited tropidocarpum in the Plan Area. Any occurrences that establish on protected BDCP lands will be managed to maintain and increase the extent of occupied habitat and the abundance of caper-fruited tropidocarpum plants. Adverse effects on caper-fruited tropidocarpum from implementing BDCP includes the temporary removal of 34 acres caper-fruited tropidocarpum habitat through deposits of spoils generated during conveyance construction activities (Table 5-3). Full implementation of BDCP will result in protection of 9 percent of caper-fruited tropidocarpum within the Plan Area, and increase of 476 percent in the extent of protected habitat (Table 5-4).

5.4.3.37.1 Population-Level Effects on Caper-fruited Tropidocarpum

BDCP actions are expected to have no adverse population-level effect on caper-fruited tropidocarpum and could have a beneficial population-level effect if one or more occurrences of this species, which is believed to be extirpated from the Plan Area, become established. BDCP direct effects on caper-fruited tropidocarpum are limited to 34 acres of modeled caper-fruited tropidocarpum habitat which will be temporarily removed through deposits of spoils generated during conveyance construction activities. This will result in no or very little effect on the species' total distribution.

Table 5-1. Summary of Impacts on the Extent of Natural Communities with Full BDCP Implementation (i.e., conditions at the late long-term evaluation point)

Natural Community	**A**	**B**	***Temporarily Removed (acres)*** [2]	***Periodically Removed (acres)*** [3]	**C**	**D=(A-B)+C**	**[(D-A)/A]-1*100**
	Existing Extent (acres)	***Permanently Removed (acres)*** [1]			***Restored (acres)***	***Future Extent with Full BDCP Implementation (acres)***	***Percent Change in Extent***
Tidal perennial aquatic [4]	86,240	46	69	39	25,000-32,000[5]	111,194 – 118,194	29-37
Tidal mudflat[6]	Not available	Not available	Not available	Not available	Not available	Not available	Not available
Tidal brackish emergent wetland [7]	8,351	515	0	0	3,600-4,800 [5]	11,436 – 12,636	37-51
Tidal freshwater emergent wetland [7]	8,947	41	4	231	13,200 – 21,600 [5]	21,106-30,506	136-241
Valley foothill riparian	17,338	1,114	165	589	5,000	21,223	22
Grassland	62,880	2,831	437	2,111	2,000	62,049	-1
Alkali seasonal wetland complex	3,722	136	0	825	0	3,586	-4
Vernal pool complex	6,959	88	0	0	200	7,071	2
Other natural seasonal wetland	264	1	0	2	0	263	0
Non-tidal permanent freshwater emergent wetland [9]	1,134	92	0	8	200	1,242	10
Non-tidal perennial aquatic [9]	5,341	245	37	329	200	5,295	-1
Managed wetlands	64,844	12,196	48	2,477	0	52,648	-19
Inland Dune Scrub	19	0	0	0	0	19	0
Agricultural lands [10]							
Alfalfa	82,282	10,398	541	2,277	0	71,884	-13
Irrigated Pasture	49,694	3,692	44	1,409	0	46,002	-7
Vine yard	28,901	1,844	470	336	0	27,058	-6
Orchar d	18,019	498	321	85	0	17,520	-3
Rice	12,637	0	0	4,585	0	12,637	0
Other Cultivated Crops	229,828	18,900	2,152	9,532	0	210,928	-8
Subtotal: Cropland only	*421,361*	*35,333*	*3,527*	*18,223*	0	386,028	-8
Other A gricultural lands	82,418	6,283	500	2,619	0	76,135	-8
Subtotal: All agricultural land	*503,779*	*41,615*	*4,027*	*20,842*	*0*	462,163	-8

[1]Permanent impacts represent those associated with construction of forebays, Intake facilities, permanent access roads, shaft locations, muck areas, levee setback footprints, riparian restoration areas, nontidal marsh restoration and conservation hatcheries facilities.
[2]Features in this category include the following conveyance features: Barge Unloading Facility, Control Structure Work Area, Intake Road Work Area, Intake Work Area, Pipeline, Pipeline Work Area, Road Work, Borrow and Spoils sites, Area, Safe Haven Work Area, Temporary Access Road Work Area, Tunnel Work Area.
[3]Periodic impacts represent those associated with the periodic flooding of the Yolo Bypass and floodplain setbacks along the San Joaquin River.
[4]Tidal Perennial Aquatic impacts related to the intake right of ways have been removed as it is assumed that these would not pose an impact to this natural community. Tidal restoration impacts were assessed based on areas expected to become desiccated based on RMA modeling results.
[5]As modeled in the hypothetical tidal habitat restorations, see Appendix Z [RMA tech #4 & SAIC memo]).
[6]Tidal mudflat features were not mapped within the BDCP vegetation layer, however will be evaluated in linear miles of tidal marsh/shallow subtidal aquatic interface.
[7]Impacts assessed for tidal marsh restoration reflect those incurred to tidal brackish emergent wetland habitat components expected to be desiccated based on RMA modeling results.
[8]Actual sum of 400 acres may be distributed differently between non-tidal perennial aquatic and non-tidal permanent freshwater emergent wetland communities.
[9]Does not include removal of agricultural lands to restore 2,000 acres of grassland and 200 acres of vernal pools. These effects will be included in the next version of this table.

Table 5-2. Summary of Conservation Provided for Natural Communities with Full BDCP Implementation (i.e., conditions at the late long-term evaluation point)

Natural Community	*Existing Extent (acres)*		*Permanently Removed (acres)*[1]		[E=A-C] *Extent Remaining*	[F=B-D] *Remaining Existing Protected Habitat*	[G] *Protected Under BDCP (acres)*	[H] *Restored Under BDCP (acres)*	[I=G+H] Total Conserved Under BDCP (acres)	Total Protected with Full BDCP Implementation		[L=(J-B)/B] *Percent Change in Extent of Protected from Extent of Existing Protected*
	[A] Total	[B] Extent Protected	[C] Total	[D] Permanently Removed Protected						[J=F+I]	[K=J/(E+H)]*100 Percent Protected	
Tidal perennial aquatic [2]	86,240	18,080	46	30	86,194	18,050	0 [1]	25,000-32,000 [2]	25,000-32,000 [1,2]	43,050-50,050 [1,2]	38.7 to 42.3	138-177
Tidal mudflat[3]	Not available	Not available	Not available	Not available	Not available	Not available	0 [1]	Not available[4]	Not available[4]	Not available[4]	Not available[4]	Not available[4]
Tidal brackish emergent wetland [4]	8,351	5,102	515	485	7,836	4,616	0 [1]	3,600-4,800 [2]	3,600-4,800 [1,2]	8,216-9,416 [1,2]	71.8 to 74.5	61-85
Tidal freshwater emergent wetland [4]	8,947	4,990	41	17	8,905	4,973	0 [1]	13,200-21,600 [2]	13,200-21,600 [1,2]	18,173-26,573 [1,2]	82.2 to 87.1	264-433
Valley foothill riparian	17,338	5,338	1,114	730	16,223	4,608	0 [1]	5,000	5,000 [1]	9,608 [1]	45.30	80
Grassland	62,880	14,984	2,831	1,010	60,049	13,974	8,000[1]	2,000	10,000 [1]	23,974 [1]	38.60	60
Alkali seasonal wetland complex	3,722	2,769	136	57	3,586	2,712	400	0	400	3,112	86.80	12
Vernal pool complex	6,959	4,379	88	30	6,871	4,349	300	200	500	4,849	68.60	11
Other natural seasonal wetland	264	205	1	0	263	205	0 [1]	0	0 [1]	205 [1]	78	0
Non-tidal permanent freshwater emergent wetland [5]	1,134	408	92	48	1,042	360	0 [1]	200	200 [1]	560 [1]	45.1	37.3
Non-tidal perennial aquatic [5]	5,341	1,239	245	51	5,095	1,188	0 [1]	200	200 [1]	1,388 [1]	26.20	12.0
Managed wetlands	64,844	52,676	12,196	10,649	52,648	42,027	0 [6]	0 [6]	0 [6]	42,027[6]	79.8 [6]	-20.20
Inland Dune Scrub	19	17	0	0	19	17	0	0	0	17	90	0
Agricultural lands [6]												
Alfalfa	82,282	3,665	10,398	374	71,884	3,291	Not available[6]	0	Not available[6]	Not available[6]	Not available[6]	Not available[6]
Irrigated Pasture	49,694	12,748	3,692	1,240	46,002	11,508	Not available[5]	0	Not available[6]	Not available[6]	Not available[6]	Not available[6]
Vineyard	28,901	2,476	1,844	210	27,058	2,266	0	0	0	2,266	8.4	-8
Orchard	18,019	343	498	66	17,520	277	0	0	0	278	1.6	-19
Rice	12,637	2,202	0	0	12,637	2,202	4,600	0	4,600	6,802	53.8	209
Other Cultivated Crops	229,828	24,736	18,900	2,924	210,928	21,812	Not available[5]	0	Not available[6]	Not available[6]	Not available[6]	Not available[6]
Subtotal: Cropland only	*421,361*	46,171	*35,333*	4,814	386,028	41,357	16,620-32,640	0	16,620-32,640	57,976-73,996	15 to 19.2	26-60
Other Agricultural lands	82,418	10,997	6,283	1,746	76,135	9,251	0	0	0	9,252	12.2	-16
Subtotal: All agricultural land	*503,779*	57,168	*41,615*	6,560	462,163	50,608	*16,620-32,640*	*0*	*16,620-32,640*	*67,228-83,248*	*14.6 to 18.0*	18-46
Total	**769,818**	167,338	**58,922**	19,668	710,896	147,671	**25,320-41,340**[7]	**50,113-65,692**	**75,433-107,032**	**223,104-254,703**	**29.3 to 32.8**	**33-52**

[1]Includes both non-tidal freshwater permanent emergent wetland and non-tidal perennial aquatic and does not include patches of these communities that are present on BDCP lands acquired for other purposes and that would be incidentally protected under BDCP

[2]Based on RMA modeling of hypothetical tidal habitat restoration footprints.

[3]The extent of existing tidal mudflat cannot be delineated based on available information.

[4]The extent of total tidal mudflat that will develop as a component of 65,000 acres of tidal habitat restoration could not be reasonably predicted with the models developed. BDCP biological objectives, however, require establishment of at least 20 linear miles of tidal mudflat substrate.

[5]Actual sum of 400 acres may be distributed differently between non-tidal perennial aquatic and non-tidal permanent freshwater emergent wetland communities

[6]The mix of alfalfa, irrigated pasture, and other cultivated crops annually maintained under the BDCP will vary among years over the term of the BDCP depending on market drivers on growers with conservation easements.

[7]Does not include acquisition of any additional lands associated with restoration of 65,000 acres of tidal habitat that may be required to provide transitional upland and sea level rise accommodation space.

Table 5-3. Summary of Impacts on the Extent of Covered Wildlife and Plant Species Habitats with Full BDCP Implementation (i.e., conditions at the late long-term evaluation point)

Covered Species	A *Existing Extent (acres)*	B *Permanently Removed (acres)* [1]	*Temporarily Removed (acres)*[2]	*Periodically Removed (acres)*	C *Restored (acres)*	D=(A-B)+C *Future Extent with Full BDCP Implementation (acres)*	[(D-A)/A]*100 *Percent Change in Extent*
Mammals							
San Joaquin kit fox							
Breeding, Foraging, and Dispersal Habitat	5,217	163	161	0	0	5,054	-3.1
Foraging and Dispersal Habitat	20,573	663	481	0	0	19,911	-3.2
Total	25,791	826	642	0	0	24,965	-3.2
Riparian woodrat							
Habitat	1,539	25	14	98	300	1,814	17.9
Salt marsh harvest mouse							
Wetland habitat	11,124	2,487	0	0	3,600-4,800 [3]	12,237 - 13,437	10.0 to 20.8
Upland habitat	2,815	674	0	0	350-700	2,491 - 2,841	-11.5 to 1.0
Total	13,940	3,161	0	0	3,950-5,500 [3]	14,729 -16,279	5.7 to 16.8
Riparian brush rabbit							
Habitat	2,894	62	19	264	300	3,132	8.2
Townsend's big-eared bat							
Primary foraging habitat	10,880	860	76	291	0	10,020	-7.9
Roosting and primary foraging habitat	6,892	268	86	301	5,000	11,624	68.7
Secondary foraging habitat	753,408	60,051	4,592	30,619	0	693,357	-8.0
Total	771,180	61,179	4,754	31,211	5,000	715,001	-7.3
Suisun shrew							
Habitat	28,742	6,237	0	0	3,600-4,800 [3]	26,105 - 27,305	-9.2 to -5.0
Birds							
Tricolored blackbird							
Nesting habitat	24,036	4,104	35	303	17,900-26,800	37,832 - 46,732	57.4 to 94.4
Foraging habitat: non agriculture	99,587	5,878	471	5,414	0	93,709	-5.9
Foraging habitat: agriculture	275,937	24,781	1,959	6,599	0	251,156	-9.0
Total	399,560	34,763	2,465	12,316	17,900-26,800	382,697 - 391,597	-4.2 to -2.0
Suisun song sparrow							
Habitat	26,958	5,272	0	0	3,600-4,800 [3]	25,286 -26,486	-6.2 to -1.8

Table 5-4. Summary of Impacts on the Extent of Covered Wildlife and Plant Species Habitats with Full BDCP Implementation (i.e., conditions at the late long-term evaluation point) (continued)

	A	B			C	D=(A-B)+C	[(D-A)/A]*100
Covered Species	*Existing Extent (acres)*	*Permanently Removed (acres)* [1]	*Temporarily Removed (acres)*[2]	*Periodically Removed (acres)*	*Restored (acres)*	*Future Extent with Full BDCP Implementation (acres)*	*Percent Change in Extent*
Yellow-breasted chat							
Primary Nesting and Migratory Habitat	7,384	351	22	203	≥2,000	7,233	-2.0
Secondary Nesting and Migratory Habitat	5,530	468	12	94	≤3,000	5,362	-3.0
Suisun Marsh/Upper Yolo Bypass Nest and Migratory Habitat	1,256	230	95	145	0	1,026	-18.3
Total	14,171	1,049	129	442	5,000	18,122	27.9
Least Bell's Vireo							
Habitat	14,137	1,049	129	442	≥2,000	15,088	6.7
Western burrowing owl							
High-value habitat	78,447	3,569	410	2,923	2,000	76,878	-2.0
Moderate-value habitat	52,800	4,260	46	1,651	0	48,540	-8.1
Low-value habitat	243,129	21,631	1,971	10,265	0	221,498	-8.9
Total	374,377	29,460	2,427	14,839	0	344,917	-7.9
Western Yellow-billed Cuckoo							
Breeding Habitat	6,825	574	112	223	≥1,000	7,251	6.2
Migratory Habitat	4,890	228	12	198	0	4,662	-4.7
Total	11,715	802	124	421	>1,000	11,913	1.7
California Least Tern [2]							
Habitat	86,242	46	64	39	25,000 – 32,000 [3]	96,196 - 106,196	11.5 to 23.1
Greater sandhill crane							
Roosting/Foraging Habitat	11,829	0	16	0	320	12,149	2.7
Foraging Habitat	184,257	6,739	1,318	0	0	177,518	-3.7
Total	196,086	6,739	1,334	0	320	189,667	-3.3
California black rail							
Habitat	33,563	5,949	4	247	17,500-26,400 [8]	45,114 - 54,014	34.4 to 60.9
California clapper rail							
Habitat	7,895	327	0	0	3,600-4,800 [3]	11,168 - 12,368	41.5 to 56.7
Swainson's hawk							
Foraging habitat	436,417	37,552	3,081	17,355	0	398,865	-8.6
Nesting habitat	10,149	706	138	440	4,000	13,443	32.5
Total	446,566	38,258	3,219	17,795	4,000	412,308	-7.7

Table 5-5. Summary of Impacts on the Extent of Covered Wildlife and Plant Species Habitats with Full BDCP Implementation (i.e., conditions at the late long-term evaluation point) (continued)

Covered Species	A *Existing Extent (acres)*	B *Permanently Removed (acres)* [1]	*Temporarily Removed (acres)*[2]	*Periodically Removed (acres)*	C *Restored (acres)*	D=(A-B)+C *Future Extent with Full BDCP Implementation (acres)*	[(D-A)/A]*100 *Percent Change in Extent*
White-tailed kite							
Breeding habitat	13,714	868	145	515	4,000	16,846	22.8
Foraging habitat	478,251	44,417	3,101	20,436	0	433,834	-9.3
Total	491,965	45,285	3,246	20,951	4,000	450,680	-8.4
Reptiles							
Giant Garter Snake							
Aquatic Breeding, Foraging and Movement	19,824	565	52	4,932	13,690-22,040	32,949 - 41,299	66.2 to 108.3
Upland Aestivation and Movement	190,805	13,713	941	5,534	0	177,092	-7.2
Total	210,629	14,278	993	10,465	13,690-22,040	210,041 - 218,391	
Aquatic Breeding, Foraging and Movement (miles)	6,000	342	25	66	0	5,658	-5.7
Western pond turtle							
Aquatic habitat [4]	78,511	6,013	84	4,046	27,900-46,800	100,398-131,324	27.9 to 67.3
Dispersal habitat	579,334	47,471	4,159	20,912	0	531,863	-8.2
Upland nesting and overwintering	54,880	4,317	363	4,163	5,000	55,563	1.2
Total	712,725	57,801	4,606	29,122	32,900-51,800	687,824-718,750	-3.5 to 0.8
Amphibians							
California red-legged frog							
Aquatic habitat	117	1	0	0	0	117	-0.8
Upland cover and dispersal habitat	4,984	168	161	0	0	4,816	-3.4
Dispersal habitat	19,572	663	481	0	0	18,909	-3.4
Total	24,673	832	643	0	0	23,841	-3.4
Western spadefoot toad							
Aquatic Breeding Habitat	6,790	48	0	0	200	6,942	2.2
Terrestrial Cover and Aestivation Habitat	14,353	464	169	0	500	14,389	0.3
Total	21,143	512	169	0	700	21,331	0.9

Table 5-6. Summary of Impacts on the Extent of Covered Wildlife and Plant Species Habitats with Full BDCP Implementation (i.e., conditions at the late long-term evaluation point) (continued)

	A	**B**			**C**	**D=(A-B)+C**	**[(D-A)/A]*100**
Covered Species	***Existing Extent (acres)***	***Permanently Removed (acres) [1]***	***Temporarily Removed (acres)[2]***	***Periodically Removed (acres)***	***Restored (acres)***	***Future Extent with Full BDCP Implementation (acres)***	***Percent Change in Extent***
California tiger salamander							
Aquatic breeding habitat	6,772	42	0	0	200	6,930	2.3
Terrestrial Cover and Aestivation Habitat	14,353	464	169	0	500	14,389	0.3
Total	21,125	506	169	0	700	21,319	0.9
Invertebrates							
Valley elderberry longhorn beetle							
Riparian vegetation	17,130	1,102	150	564	5,000	21,028	22.8
Non-riparian channels and grasslands	16,022	620	202	722	0	15,402	-3.9
Total	33,152	1,722	352	1,286	5,000	36,430	9.9
Lange's metalmark butterfly							
Habitat	1,108	0	0	0	0	1,108	0.0
Vernal pool tadpole shrimp							
Vernal Pool Complex	6,821	42	0	0	200	6,979	2.3
Degraded Vernal Pool Complex	2,493	5	0	0	0	2,488	-0.2
Conservancy fairy shrimp							
Vernal Pool Complex	6,821	42	0	0	200	6,979	2.3
Degraded Vernal Pool Complex	2,493	5	0	0	0	2,488	-0.2
Longhorn fairy shrimp							
Vernal Pool Complex	6,821	42	0	0	200	6,979	2.3
Degraded Vernal Pool Complex	2,493	5	0	0	0	2,488	-0.2
Vernal pool fairy shrimp							
Vernal Pool Complex	6,821	42	0	0	200	6,979	2.3
Degraded Vernal Pool Complex	2,493	5	0	0	0	2,488	-0.2
Mid Valley fairy shrimp							
Vernal Pool Complex	6,821	42	0	0	200	6,979	2.3
Degraded Vernal Pool Complex	2,493	5	0	0	0	2,488	-0.2
California linderiella	0						
Vernal Pool Complex	6,821	42	0	0	200	6,979	2.3
Degraded Vernal Pool Complex	2,493	5	0	0	0	2,488	-0.2

Table 5-7. Summary of Impacts on the Extent of Covered Wildlife and Plant Species Habitats with Full BDCP Implementation (i.e., conditions at the late long-term evaluation point) (continued)

Covered Species	A *Existing Extent (acres)*	B *Permanently Removed (acres)* [1]	*Temporarily Removed (acres)* [2]	*Periodically Removed (acres)*	C *Restored (acres)*	D=(A-B)+C *Future Extent with Full BDCP Implementation (acres)*	[(D-A)/A]*100 *Percent Change in Extent*
Plants							
Alkali milk-vetch							
Vernal pool Complex	6,959	88	0	0	200	7,070	1.6
Degraded Vernal Pool Complex	2,493	5	0	0	0	2,488	-0.2
Heartscale							
Habitat	495	10	0	0	0	485	-2.1
Brittlescale							
Habitat	495	10	0	0	0	485	-2.0
San Joaquin spearscale							
Vernal pool Complex	6,959	88	0	0	200	7,070	1.6
Degraded Vernal Pool Complex	2,493	5	0	0	0	2,488	-0.2
Slough thistle							
Habitat	1,831	5	6	6	≥ 1,000	2,826	54.3
Suisun thistle[4]							
Habitat	1,129	636	0	0	3,600-4,800[3]	4,093 - 5,293	262.5 to 368.8
Soft bird's-beak[4]							
Habitat	1,224	636	0	0	3,600-4,800[3]	4,188 - 5,388	242.2 to 340.2
Dwarf Downingia							
Vernal pool Complex	6,959	88	0	0	200	7,070	1.6
Degraded Vernal Pool Complex	2,493	5	0	0	0	2,488	-0.2
Delta button celery							
Habitat	3,344	25	8	18	≥ 1,000	4,319	129.2
Boggs Lake hedge-hyssop							
Vernal pool Complex	6,959	88	0	0	200	7,070	1.6
Degraded Vernal Pool Complex	2,493	5	0	0	0	2,488	-0.2
Carquinez goldenbush							
Habitat	1,032	42	0	0	0	990	-4.1
Delta tule pea							
Habitat	5,948	1,137	1	10	16,970-26,470[3]	21,781 - 31,281	266.2 to 426.0

Table 5-8. Summary of Impacts on the Extent of Covered Wildlife and Plant Species Habitats with Full BDCP Implementation (i.e., conditions at the late long-term evaluation point) (continued)

Covered Species	A	B			C	D=(A-B)+C	[(D-A)/A]*100
	Existing Extent (acres)	*Permanently Removed (acres)* [1]	*Temporarily Removed (acres)*[2]	*Periodically Removed (acres)*	*Restored (acres)*	*Future Extent with Full BDCP Implementation (acres)*	*Percent Change in Extent*
Legenere							
Vernal pool Complex	6,959	88	0	0	200	7,070	1.6
Degraded Vernal Pool Complex	2,493	5	0	0	0	2,488	-0.2
Heckard's peppergrass							
Vernal pool Complex	6,959	88	0	0	200	7,070	1.6
Degraded Vernal Pool Complex	2,493	5	0	0	0	2,488	-0.2
Mason's lilaeopsis							
Habitat	6,931	146	9	205	16,980-26,560[3]	23,765 - 33,345	242.9 - 381.1
Delta mudwort							
Habitat	6,931	146	9	205	16,980-26,560[3]	23,765 - 33,345	242.9 - 381.1
Suisun Marsh aster							
Habitat	5,948	1,137	1	10	16,970-26,470[3]	21,781 - 31,281	266.2 - 426.0
Side-flowering skullcap							
Habitat	2,495	37	3	41	0	2,458	-1.5
Caper-fruited tropidocarpum							
Habitat	1,345	0	34	0	0	1,345	0.0
Contra Costa wallflower							
Habitat	19	0	0	0	0	19	0.0
Antioch Dunes evening primrose							
Habitat	19	0	0	0	0	19	0.0

[1]Permanent impacts represent those associated with construction of forebays, Intake facilities, permanent access roads, shaft locations, muck areas, levee setback footprints, riparian restoration areas, nontidal marsh restoration and conservation hatcheries facilities

[2]Tidal perennial aquatic impacts related to the intake right of ways have been removed as it is assumed that these would not pose an impact to this natural community. Tidal restoration impacts were assessed based on areas expected to become desiccated based on RMA modeling results.

[3]As modeled in the hypothetical tidal habitat restorations, see Appendix N3 (RMA Description of Hypothetical Restoration Design and Effects).4Impacts assessed for tidal marsh restoration reflect those incurred to habitat that are expected to experience inundation and desiccation.

Table 5-9. Summary of Conservation Provided for Covered Wildlife and Plant Species with Full BDCP Implementation (i.e., conditions at the late long-term evaluation point)

Covered Species	*Existing Extent (acres)*		*Permanently Removed (acres)* [2]		[E = A-C] *Extent Remaining*	[F = B-D] *Remaining Existing Protected Habitat*	[G] *Protected Under BDCP (acres)*	[H] *Restored Under BDCP (acres)*	[I = G+H] *Total Conserved Under BDCP (acres)*	*Total Protected with Full BDCP Implementation*		[L=(J-B)/B] *Percent Change in Extent of Protected from Extent of Existing Protected*
	[A] Total	[B] Extent Protected	[C] Total	[D] Permanently Removed Protected						[J=F+I] Protected	[K=(J/(E+H)] Percent Protected	
Mammals												
San Joaquin kit fox												
Breeding, Foraging, and Dispersal Habitat	5,217	638	163	81	5,054	557	1,000 [8]	0	1,000 [8]	1,557 [8]	30.8	144
Foraging and Dispersal Habitat	20,573	151	663	13	19,911	138	0 [8]	0	0 [8]	138 [8]	1	-9
Total	25,791	789	826	94	24,965	695	1,000	0	1,000	1,695	6.7	115
Riparian woodrat												
Habitat	1,539	97	25	3	1,514	94	0	300	300	394	21.7	306
Salt marsh harvest mouse												
Wetland habitat	11,124	9,600	2,487	2,369	8,637	7,231	0 [8]	3,600-4,800 [9]	3,600-4,800 [9]	10,831-12,031 [8,9]	88.5 - 89.5	13-25
Upland habitat	2,815	2,334	674	618	2,141	1,716	350-700 [8]	350-700	700-1,400 [8]	2,415-3,115 [8]	96.9 - 109.6	4-33
Total	13,940	11,934	3,161	2,987	10,779	8,947	350-700	3,950-5,500 [9]	4,300-6,200 [9]	13,246-15,146 [9]	89.9 - 93	11-27
Riparian brush rabbit												
Habitat	2,894	138	62	3	2,832	135	0 [8]	300	300 [8]	435 [8]	13.9	215
Townsend's big-eared bat												
Primary foraging habitat	10,880	3,641	860	582	10,020	3,059	0 [8]	0	0 [8]	3,059 [8]	30.5	-16
Roosting and primary foraging habitat	6,892	1,876	268	156	6,624	1,720	0 [8]	5,000	5,000 [8]	6,720 [8]	57.8	258
Secondary foraging habitat	753,408	162,668	60,051	20,467	693,357	142,201	0 [8]	0	0 [8]	142,201 [8]	20.5	-13
Total	771,180	168,185	61,179	21,205	710,001	146,980	0	5,000	5,000	151,980	21.2	-10
Suisun shrew												
Habitat	28,742	22,590	6,237	5,672	22,505	16,918	0 [8]	3,600-4,800 [9]	3,600-4,800 [8,9]	20,518-21,718 [8,9]	74.6 -79	-9-(-4)

Table 5-10. Summary of Conservation Provided for Covered Wildlife and Plant Species with Full BDCP Implementation (i.e., conditions at the late long-term evaluation point) (continued)

Covered Species	*Existing Extent (acres)*		*Permanently Removed (acres)* [2]								*Total Protected with Full BDCP Implementation*		
	[A] Total	**[B] Extent Protected**	**[C] Total**	**[D] Permanently Removed Protected**	**[E = A-C]** *Extent Remaining*	**[F = B-D]** *Remaining Existing Protected Habitat*	**[G]** *Protected Under BDCP (acres)*	**[H]** *Restored Under BDCP (acres)*	**[I = G+H]** *Total Conserved Under BDCP (acres)*	**[J=F+I] Protected**	**[K=(J/(E+H)] Percent Protected**	**[L=(J-B)/B]** *Percent Change in Extent of Protected from Extent of Existing Protected*
Birds												
Tricolored blackbird												
Nesting habitat	24,036	14,372	4,104	3,420	19,932	10,952	0 [8]	17,900-26,800	17,370-26,870 [8,9]	28,852-37,752 [8,9]	76.2 - 80.8	101-163
Foraging habitat: non agriculture	99,587	40,818	5,878	3,865	93,709	36,953	8,700 [8]	0	8,700 [8]	45,653 [8,9]	48.7	12
Foraging habitat: agriculture	275,937	33,097	24,781	2,464	251,156	30,633	16,620-32,640 [8]	0	16,620-32,640 [8]	47,253-63,273 [8]	18.8 - 25.2	43-91
Total	399,560	88,287	34,763	9,749	364,797	78,538	25,320-41,340	17,900-26,800	43,220-68,140 [9]	121,757-146,677 [9]	31.8 to 37.5	38-66
Suisun song sparrow												
Habitat	26,958	21,177	5,272	4,798	21,686	16,379	0 [8]	3,600-4,800 [9]	3,600-4,800 [8,9]	19,979-21,179 [8,9]	79.0 - 80.0	-6-0
Yellow-breasted chat												
Primary Nesting and Migratory Habitat	7,384	2,192	351	200	7,033	1,992	0 [8]	_2,000	≥2,000 [8]	_3,993 [8]	44.2	≥82
Secondary Nesting and Migratory Habitat	5,530	1,896	468	335	5,062	1,561	0 [8] >	_3,000	≤3,000 [8] >	_4,561 [8]	56.6	≤141
Suisun Marsh/Upper Yolo Bypass Nest and Migratory Habitat	1,256	933	230	204	1,026	729	0 [8] <	0	0 [8] <	729 [8]	71.0	-22
Total	14,171	5,022	1,049	739	13,122	4,283	0	5,000	5,000	9,282	51.2	85
Least Bell's Vireo												
Habitat	14,137	5,008	1,049	736	13,088	4,272	0 [8]	_2,000	≥2,000 [8]	_6,272 [8]	41.6	≥25
Western burrowing owl												
High-value habitat	78,447	26,261	3,569	1,980	74,878	24,281	8,000 [8]	2,000	10,000 [8] >	34,281 [8]	44.6	31
Moderate-value habitat	52,800	16,214	4,260	1,020	48,540	15,194	>3,900> [8]	0	>3,900 [8]	>19,094 [8]	39.3	>18
Low-value habitat	243,129	27,833	21,631	1,045	221,498	26,788	0 [8,10]	0	0 [8,10]	26,375 [8,10]	11.9	-5
Total	374,377	70,309	29,460	4,045	344,917	66,264	>11,900 [8]	2,000	>13,900 [8]	>78,978 [8]	22.8	>12
Western Yellow-billed Cucko												
Breeding Habitat	6,825	2,763	574	407	6,251	2,356	0 [8]	_1,000	≥1,000 [8]	_3,356 [8]	46.8	≥21
Migratory Habitat	4,890	1,325	228	151	4,662	1,174	0 [8]	0	0 [8]	1,174 [8]	25.2	-11
Total	11,715	4,088	802	558	10,913	3,530	0 >	≥1,000	≥1,000 >	≥4,531	38.0	≥11

Table 5-10. Summary of Conservation Provided for Covered Wildlife and Plant Species with Full BDCP Implementation (i.e., conditions at the late long-term evaluation point) (continued)

Covered Species	*Existing Extent (acres)*		*Permanently Removed (acres)* [2]		**[E = A-C]** *Extent Remaining*	**[F = B-D]** *Remaining Existing Protected Habitat*	**[G]** *Protected Under BDCP (acres)*	**[H]** *Restored Under BDCP (acres)*	**[I = G+H]** *Total Conserved Under BDCP (acres)*	*Total Protected with Full BDCP Implementation*		**[L=(J-B)/B]** *Percent Change in Extent of Protected from Extent of Existing Protected*
	[A] Total	**[B] Extent Protected**	**[C] Total**	**[D] Permanently Removed Protected**						**[J=F+I] Protected**	**[K=(J/(E+H)] Percent Protected**	
California Least Tern [2]												
Habitat	86,242	18,080	46	64	86,196	18,016	0 [8]	>10,000->20,000 [9]	>10,000->20,000 [9]	>28,016->38,016 [8,9]	29.1 - 35.8	>54->110
Greater sandhill crane												
Roosting/Foraging Habitat	11,829	6,743	0	0	11,829	6,743	0	320	320	7,063	58.1	0
Foraging Habitat	184,257	33,259	6,739	3,686	177,518	29,573	>4,800	0	>4,800	>34,373 [8]	19.4	>3
Total	196,086	40,002	6,739	3,686	189,347	36,316	>4,800	320	>5,120	>41,436	21.9	>4
California black rail												
Habitat	33,563	24,593	5,949	5,265	27,614	19,328	0 [8]	17,500-26,400 [9]	17,500-26,400 [8,9]	36,828-45,728 [8,9]	81.6 - 84.7	50-86
California clapper rail												
Habitat	7,895	5,013	327	318	7,568	4,694	0 [8]	3,600-4,800 [9]	3,600-4,800	8,294-9,494 [8,9]	74.3 - 76.8	67-89
Swainson's hawk												
Foraging habitat	436,417	75,743	37,552	6,828	398,865	68,915	20,020-36,040 [8,10]	0	20,020-36,040 [8,10]	88,935-104,955	22.3 - 26.3	17-39
Nesting habitat	10,149	3,258	706	469	9,443	2,789	0 [8]	4,000	4,000 [8]	6,789 [8]	50.5	108
Total	446,566	79,001	38,258	7,297	408,308	71,704	20,020-36,040	4,000	24,020-40,040	95,724-111,744	23.2 - 27.1	21-41
White-tailed kite												
Breeding habitat	13,714	4,518	868	567	12,846	3,951	0 [8]	4,000	4,000 [8]	7,951 [8]	47.2	76
Foraging habitat	478,251	101,068	44,417	12,837	433,834	88,231	24,620-46,040 [8,10]	0	24,620-46,040 [8,10]	112,851-134,271	26.0 - 30.9	12-33
Total	491,965	105,586	45,285	13,404	446,680	92,182	24,620-40,040	4,000	28,620-50,040	120,802-142,222	26.8 - 31.6	14-35
Reptiles												
Giant Garter Snake												
Aquatic Breeding, Foraging and Movement	19,824	5,725	565	321	19,259	5,404	>6,900 [8]	13,690-22,040	>20,590->28,940	>25,994->34,344	78.9 - 83.2	>354->500
Upland Aestivation and Movement	190,805	31,954	13,713	2,941	177,092	29,013	7,100 [8]	0	7,100 [8]	36,113 [8]	20.4	13
Total	210,629	37,679	14,278	3,262	196,351	34,417	>14,000	13,690-22,040	>27,690->36,040 [9]	>62,106->70,456 [9]	29.6 - 32.2	>65->87

Table 5-10. Summary of Conservation Provided for Covered Wildlife and Plant Species with Full BDCP Implementation (i.e., conditions at the late long-term evaluation point) (continued)

Covered Species	*Existing Extent (acres)*		*Permanently Removed (acres)* [2]		[E = A-C] *Extent Remaining*	[F = B-D] *Remaining Existing Protected Habitat*	[G] *Protected Under BDCP (acres)*	[H] *Restored Under BDCP (acres)*	[I = G+H] *Total Conserved Under BDCP (acres)*	*Total Protected with Full BDCP Implementation*		[L=(J-B)/B] *Percent Change in Extent of Protected from Extent of Existing Protected*
	[A] Total	[B] Extent Protected	[C] Total	[D] Permanently Removed Protected						[J=F+I] Protected	[K=(J/(E+H)] Percent Protected	
Aquatic Breeding, Foraging and Movement (miles)	6,000	1,012	342	80	5,658	932	0 [8]	0	0 [8]	932 [8]	16.5	-8
Western pond turtle												
Aquatic habitat [7]	78,511	30,591	6,013	4,636	72,498	25,955	0 [8]	27,900-46,800	27,900-46,800 [8,9]	53,855-72,755 [8,9]	53.6 - 61.0	76-138
Dispersal habitat	579,334	109,348	47,471	14,820	531,863	94,528	4,000 [8]	0	4,000 [8]	98,528 [8]	18.5	-10
Upland nesting and overwintering	54,880	19,738	4,317	2,010	50,563	17,728	≥5,230 [8]	5,000	≥10,230 [8]	_27,958 [8]	50.3	≥42
Total	712,725	159,677	57,801	21,466	654,924	138,211	≥9,230	32,900-51,800	>42,130- > >61,030 [9]	>180,341- >199,241 [9]	26.2 - 30.0	>13->25
Amphibians												
California red-legged frog												
Aquatic habitat	117	4	1	0	117	4	3 [8]	0	3 [8]	7 [8]	6.0	81
Upland cover and dispersal habitat	4,984	640	168	81	4,816	560	1,000 [9]	0	1,000 [9]	1,560 [9]	32.2	144
Dispersal habitat	19,572	151	663	13	18,909	138	0 [8]	0	0 [8]	138 [8]	0.7	-9
Total	24,673	795	832	94	23,841	701	1,003	0	1,003	1,704	7.1	114
Western spadefoot toad												
Aquatic Breeding Habitat	6,790	4,256	48	9	6,742	4,246	300	200	500	4,746	68.4	12
Terrestrial Cover and Aestivation Habitat	14,353	5,071	464	150	13,889	4,921	8,400 [8]	500	8,900 [8]	13,821 [8]	96.1	173
Total	21,143	9,327	512	159	20,631	9,168	8,700	700	9,400	18,567	87.0	99
Aquatic Breeding Habitat (miles)	41	11	0	0	41	11	0	0	0	11	26.8	-2
California tiger salamander												
Aquatic breeding habitat	6,772	4,255	42	9	6,730	4,246	300	200	500	4,746	68.5	12
Terrestrial Cover and Aestivation Habitat	14,353	5,071	464	150	13,889	4,921	8,400 [8]	500	8,900 [8]	13,821 [8]	96.1	173
Total	21,125	9,327	506	159	20,619	9,167	8,700	700	9,400	18,567	87.1	99
Invertebrates												
Valley elderberry longhorn beetle												
Riparian vegetation	17,130	5,310	1,102	727	16,028	4,583	0 [8]	5,000	5,000 [8]	9,583 [8]	45.6	80
Non-riparian channels and grasslands	16,022	4,168	620	276	15,402	3,893	0 [81]	0	0 [8]	3,893 [8]	25.3	-7

Table 5-10. Summary of Conservation Provided for Covered Wildlife and Plant Species with Full BDCP Implementation (i.e., conditions at the late long-term evaluation point) (continued)

Covered Species	*Existing Extent (acres)*		*Permanently Removed (acres)* [2]		[E = A-C] *Extent Remaining*	[F = B-D] *Remaining Existing Protected Habitat*	[G] *Protected Under BDCP (acres)*	[H] *Restored Under BDCP (acres)*	[I = G+H] *Total Conserved Under BDCP (acres)*	*Total Protected with Full BDCP Implementation*		[L=(J-B)/B] *Percent Change in Extent of Protected from Extent of Existing Protected*
	[A] Total	[B] Extent Protected	[C] Total	[D] Permanently Removed Protected						[J=F+I] Protected	[K=(J/(E+H)] Percent Protected	
Total	33,152	9,478	1,722	1,003	31,430	8,476	0	5,000	5,000	13,476	37.0	42
Lange's metalmark butterfly												
Habitat	1,108	67	0	0	1,108	66	0	0	0	67	6.0	0
Vernal pool tadpole shrimp												
Vernal Pool Complex	6,821	4,319	42	9	6,779	4,310	300	200	500	4,810	68.9	11
Degraded Vernal Pool Complex	2,493	683	5	0	2,488	683	0	0	0	683	27.5	0
Conservancy fairy shrimp												
Vernal Pool Complex	6,821	4,319	42	9	6,779	4,310	300	200	500	4,810	68.9	11
Degraded Vernal Pool Complex	2,493	683	5	0	2,488	683	0	0	0	683	27.5	0
Longhorn fairy shrimp												
Vernal Pool Complex	6,821	4,319	42	9	6,779	4,310	300	200	500	4,810	68.9	11
Degraded Vernal Pool Complex	2,493	683	5	0	2,488	683	0	0	0	683	27.5	0
Vernal pool fairy shrimp												
Vernal Pool Complex	6,821	4,319	42	9	6,779	4,310	300	200	500	4,810	68.9	11
Degraded Vernal Pool Complex	2,493	683	5	0	2,488	683	0	0	0	683	27.5	0
Mid Valley fairy shrimp												
Vernal Pool Complex	6,821	4,319	42	9	6,779	4,310	300	200	500	4,810	68.9	11
Degraded Vernal Pool Complex	2,493	683	5	0	2,488	683	0	0	0	683	27.5	0
California linderiella												
Vernal Pool Complex	6,821	4,319	42	9	6,779	4,310	300	200	500	4,810	68.9	11
Degraded Vernal Pool Complex	2,493	683	5	0	2,488	683	0	0	0	683	27.5	0
Plants												
Alkali milk-vetch *var.*												
Vernal pool Complex	6,959	4,380	88	30	6,870	4,350	300	200	500	4,850	68.6	11
Degraded Vernal Pool Complex	2,493	683	5	0	2,488	683	0	0	0	683	27.5	0
Heartscale												
Habitat	495	127	10	4	485	124	150	0	150	274	56.5	115
Brittlescale												

Table 5-10. Summary of Conservation Provided for Covered Wildlife and Plant Species with Full BDCP Implementation (i.e., conditions at the late long-term evaluation point) (continued)

Covered Species	*Existing Extent (acres)*		*Permanently Removed (acres)* [2]		[E = A-C] *Extent Remaining*	[F = B-D] *Remaining Existing Protected Habitat*	[G] *Protected Under BDCP (acres)*	[H] *Restored Under BDCP (acres)*	[I = G+H] *Total Conserved Under BDCP (acres)*	*Total Protected with Full BDCP Implementation*		[L=(J-B)/B] *Percent Change in Extent of Protected from Extent of Existing Protected*
	[A] Total	[B] Extent Protected	[C] Total	[D] Permanently Removed Protected						[J=F+I] Protected	[K=(J/(E+H)] Percent Protected	
Habitat	495	127	10	4	485	124	150	0	150	274	56.5	115
San Joaquin spearscale												
Vernal pool Complex	6,959	4,380	88	30	6,870	4,350	300	200	500	4,850	68.6	11
Degraded Vernal Pool Complex	2,493	683	5	0	2,488	683	0	0	0	683	27.5	0
Slough thistle												
Habitat	1,831	188	5	0	1,826	188	0	≥ 1,000	≥ 1,000	≥ 1,188	42.0	≥532
Suisun thistle[7]												
Habitat	1,129	869	636	579	493	290	0[8]	3,600-4,800[9]	3,600-4,800[9]	3,890-5,090	95 - 96.2	347-485
Soft bird's-beak[7]												
Habitat	1,224	869	636	579	588	290	0[8]	3,600-4,800[9]	3,600-4,800[9]	3,890-5,090	92.9 - 94.5	347-485
Dwarf Downingia												
Vernal pool Complex	6,959	4,380	88	30	6,870	4,350	300	200	500	4,850	68.6	11
Degraded Vernal Pool Complex	2,493	683	5	0	2,488	683	0	0	0	683	27.5	0
Delta button celery												
Habitat	3,344	270	25	1	3,319	269	≥ 100	≥ 1,000	≥ 1,100	≥ 1,369	31.6	≥407
Boggs Lake hedge-hyssop												
Vernal pool Complex	6,959	4,380	88	30	6,870	4,350	300	200	500	4,850	68.6	11
Degraded Vernal Pool Complex	2,493	683	5	0	2,488	683	0	0	0	683	27.5	0
Carquinez goldenbush												
Habitat	1,032	391	42	2	990	389	300	0	300	689	69.6	76
Delta tule pea												
Habitat	5,948	3,699	1,137	1,076	4,811	2,623	0	16,970-26,470[9]	16,970-26,470[9]	19,593-29,093	90.0 - 93.0	430-687
Legenere												
Vernal pool Complex	6,959	4,380	88	30	6,870	4,350	300	200	500	4,850	68.6	11
Degraded Vernal Pool Complex	2,493	683	5	0	2,488	683	0	0	0	683	27.5	0

Table 5-10. Summary of Conservation Provided for Covered Wildlife and Plant Species with Full BDCP Implementation (i.e., conditions at the late long-term evaluation point) (continued)

Covered Species	*Existing Extent (acres)*		*Permanently Removed (acres)* [2]		[E = A-C] *Extent Remaining*	[F = B-D] *Remaining Existing Protected Habitat*	[G] *Protected Under BDCP (acres)*	[H] *Restored Under BDCP (acres)*	[I = G+H] *Total Conserved Under BDCP (acres)*	*Total Protected with Full BDCP Implementation*		[L=(J-B)/B] *Percent Change in Extent of Protected from Extent of Existing Protected*
	[A] Total	[B] Extent Protected	[C] Total	[D] Permanently Removed Protected						[J=F+I] Protected	[K=(J/(E+H)] Percent Protected	
Heckard's peppergrass												
Vernal pool Complex	6,959	4,380	88	30	6,870	4,350	300	200	500	4,850	68.6	11
Degraded Vernal Pool Complex	2,493	683	5	0	2,488	683	0	0	0	683	27.5	0
Mason's lilaeopsis	6,931	1,717	146	80	6,785	1,637	0	16,980-26,560[9]	16,980-26,560[9]	18,617-28,197	78.3 - 84.6	984-1,542
Habitat												
Delta mudwort	6,931	1,717	146	80	6,785	1,637	0	16,980-26,560[9]	16,980-26,560[9]	18,617-28,197	78.3 - 84.6	984-1,542
Habitat												
Suisun Marsh aster	5,948	3,699	1,137	1,076	4,811	2,623	0	16,970-26,470[9]	16,970-26,470[9]	19,593-29,093	90.0 - 93.0	430-687
Habitat												
Side-flowering skullcap	2,495	701	37	12	2,458	689	0	0	0	689	28.0	-2
Habitat												
Caper-fruited tropidocarpum	1,345	21	0	0	1,345	21	≥ 100	0	≥ 100	≥ 121	9.0	≥476
Habitat												
Contra Costa wallflower	19	17	0	0	19	17	0		0	17	89.5	0
Habitat												
Antioch Dunes evening primrose	19	17	0	0	19	17	0	0	0	17	89.5	0
Habitat							0					

[1]Permanent impacts represent those associated with construction of forebays, Intake facilities, permanent access roads, shaft locations, muck areas, levee setback footprints, riparian restoration areas, nontidal marsh restoration and conservation hatcheries facilities

[2]Tidal Perennial Aquatic impacts related to the intake right of ways have been removed as it is assumed that these would not pose an impact to this natural community. Tidal restoration impacts were assessed based on areas expected to become desiccated based on RMA modeling results.

[3]Impacts assessed for tidal marsh restoration reflect those incurred to tidal brackish emergent wetland habitat components expected to be desiccated based on RMA modeling results.

[4]Does not include removal of agricultural lands to restore 2,000 acres of grassland and 200 acres of vernal pools. These effects will be included in the next version of this table.

[5]Features in this category include the following conveyance features: Barge Unloading Facility, Control Structure Work Area, Intake Road Work Area, Intake Work Area, Pipeline, Pipeline Work Area, Road Work, Borrow and Spoils sites, Area, Safe Haven Work Area, Temporary Access Road Work Area, Tunnel Work Area

[6]Periodic impacts represent those associated with the periodic flooding of the Yolo Bypass and floodplain setbacks along the San Joaquin River.

[7]Impacts assessed for tidal marsh restoration reflect those incurred to habitat that are expected to experience inundation and desiccation.

[8]Does not include patches of these habitat types that are present on BDCP lands acquired for other purposes and that would be incidentally protected under BDCP.

[9]As modeled in the hypothetical tidal habitat restorations, see Appendix Z [RMA tech #4 & SAIC memo]).

[10]The mix of alfalfa, irrigated pasture, and other cultivated crops annually maintained under the BDCP will vary among years over the term of the BDCP depending on market drivers on growers with conservation easements.

CHAPTER 6. PLAN IMPLEMENTATION

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CHAPTER 6 PLAN IMPLEMENTATION

[***Note to Reviewers****: This is a revised version of BDCP Chapter 6, Implementation Plan. The last draft of Chapter 6 was presented to the Steering Committee at the September 9, 2010 meeting. Revisions have been made throughout the text to address comments received, to clarify concepts, and to bring the document up to date with the progress on various components of the BDCP in 2010. The BDCP Steering Committee members have submitted comments to various drafts of this chapter during development, which may or may not have been incorporated into this November 18, 2010 draft. While the text of this chapter is subject to change and revision as the BDCP planning process progresses, the chapter has been drafted and formatted to appear as it may in a completed draft HCP/NCCP. Although the chapter includes declarative statements (e.g., the Implementation Office will…), it is nonetheless a "working draft" that will undergo further modification based on input from the BDCP Steering Committee, state and federal agencies, and the public*.]

To effectively achieve the overall goals of ecosystem restoration and water supply reliability, the Bay Delta Conservation Plan (BDCP) sets out a Conservation Strategy that will be implemented over the long-term. This chapter identifies the key issues that are related to plan implementation and describes the approaches that will be used to address those issues. The chapter, for instance, establishes a schedule for the implementation of the BDCP conservation measures, which will guide the timing and sequencing of measures to enhance opportunities to advance the biological goals and objectives. It further describes requirements for short-term and long-range planning, annual workplans and budgets, monitoring, compliance reporting, and scientific review to ensure transparency in decision-making and to promote refinements to approaches to BDCPimplementation.

The chapter further describes the regulatory assurances under the federal Endangered Species Act (ESA) and the Natural Community Conservation Planning Act (NCCPA) that are expected to be provided to the Authorized Entities. It also describes the commitment of the Implementation Office and the Authorized Entities to respond to foreseeable changes in circumstances that may adversely affect Covered Species and habitats, and identifies a process by which changes that are not foreseeable can be addressed. The chapter identifies the circumstances under which regulatory authorizations may be suspended or revoked. This chapter, in combination with Chapter 3 *Conservation Strategy*, Chapter 7 *Implementation Structure*, and Chapter 8 *Implementation Costs and Funding Sources*, provides the full description of actions, commitments, and approaches to ensure effective implementation of the BDCP.

6.1 PLAN IMPLEMENTATION SCHEDULE

The implementation of the BDCP conservation measures will be guided by a schedule that has been developed to maximize the effectiveness of the Conservation Strategy (Figure 6-1). The BDCP implementation schedule establishes an approximate timeframe and sequence for the initiation of the actions associated with each of the conservation measures. The cumulative habitat outcomes of implementing BDCP conservation measures under this implementation schedule are depicted in Figure 6-2. Implementation of these actions will begin in Year 0, the year in which regulatory authorizations are issued by the state and federal fish and wildlife agencies pursuant to the BDCP. The implementation schedule will inform the Implementation Office as it establishes priorities and develops annual workplans and budgets. This implementation schedule has served as the basis for estimating funding needs over the term of BDCP implementation (see Chapter 8, *Implementation Costs and Funding Sources*). It has also been used in the effects analysis to assess the anticipated timing of biological impacts and benefits to covered species and natural communities associated with the implementation of the BDCP (see Chapter 5, *Effects Analysis*).

Figure 6-1. BDCP Conservation Measure Implementation Schedule

	Near-Term Period Implementation Year (1-year intervals)										Long-Term Period Implementation Year (5-year intervals)							
Conservation Actions	1	2	3	4	5	6	7	8	9	10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50
CM1: Water Facilities and Operation																		
Water facilities start up and construction[1]																		
Water operations																		
CM2: Yolo Bypass Fisheries Enhancements																		
Fremont Weir Modifications and Operation																		
Fremont Weir passage improvement																		
Lisbon Weir passage improvement																		
Sacramento Weir improvements																		
Lower Putah Creek passage improvements																		
CM3: Natural Communities Protection																		
Protect 87 acres of vernal pool complex terrain[3]																		
Protect 44 acres of vernal pool complex terrain[3]																		
Protect 43 acres of vernal pool complex terrain[3]																		
Protect 93 acres of vernal pool complex terrain[3]																		
Protect 33 acres of vernal pool complex terrain[3]																		
Protect 9 acres of alkali seasonal wetland complex[3]																		
Protect 8 acres of alkali seasonal wetland complex[3]																		
Protect 8 acres of alkali seasonal wetland complex[3]																		
Protect 8 acres of alkali seasonal wetland complex[3]																		
Protect 267 acres of alkali seasonal wetland complex[3]																		
Protect 100 acres of alkali seasonal wetland complex[3]																		
Protect 500 acres of grassland[3]																		
Protect 500 acres of grassland[3]																		
Protect 500 acres of grassland[3]																		
Protect 500 acres of grassland[3]																		
Protect 1,000 acres of grassland[3]																		
Protect 1,000 acres of grassland[3]																		
Protect 1,000 acres of grassland[3]																		
Protect 1,000 acres of grassland[3]																		
Protect 1,000 acres of grassland[3]																		
Protect 1,000 acres of grassland[3]																		
Preserve 1,500 acres of cultivated habitat[4]																		
Preserve 1,700 acres of cultivated habitat[4]																		
Preserve 2,745 acres of cultivated habitat[4]																		
Preserve 1,500 acres of cultivated habitat[4]																		
Preserve 1,000 acres of cultivated habitat[4]																		
Preserve 1,000 acres of cultivated habitat[4]																		
Preserve 4,600 acres of rice land[5]																		
Preserve 1,100 acres of cultivated habitat[4]																		
Preserve 3,490 acres of cultivated habitat[4]																		
Preserve 3,590 acres of cultivated habitat[4]																		
Preserve 2,645acres of cultivated habitat[4]																		
Preserve 2,590 acres of cultivated habitat[4]																		
Preserve 2,590 acres of cultivated habitat[4]																		
Preserve 2,590 acres of cultivated habitat[4]																		

Figure 6-1. BDCP Conservation Measure Implementation Schedule

Conservation Actions	*Near-Term Period Implementation Year (1-year intervals)* 1	2	3	4	5	6	7	8	9	10	*Long-Term Period Implementation Year (5-year intervals)* 11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50
CM4: Tidal Habitat Restoration[2]	**Restore 14,000 acres by Year 10**										**Restore 25,000 acres by Year 15 and 65,000 acres by Year 40**							
Restore 1,000 acres of tidal habitat																		
Restore 2,500 acres of tidal habitat																		
Restore 3,500 acres of tidal habitat																		
Restore 3,500 acres of tidal habitat																		
Restore 3,500 acres of tidal habitat																		
Restore 11,000 acres of tidal habitat																		
Restore 8,000 acres of tidal habitat																		
Restore 8,000 acres of tidal habitat																		
Restore 8,000 acres of tidal habitat																		
Restore 8,000 acres of tidal habitat																		
Restore 8,000 acres of tidal habitat																		
CM5: Seasonally Inundated Floodplain Restoration											**Restore 1,000 acres by Year 15 and 10,000 acres by Year 40**							
Restore 1,000 acres of seasonally inundated floodplain																		
Restore 3,000 acres of seasonally inundated floodplain																		
Restore 3,000 acres of seasonally inundated floodplain																		
Restore 3,000 acres of seasonally inundated floodplain																		
CM6: Channel Margin Habitat Enhancement	**Enhance 5 miles by Year 10**										**Enhance 10 miles by Year 20, 15 miles by Year 25, and 20 miles by Year 30**							
Restore 5 miles of channel margin habitat																		
Restore 5 miles of channel margin habitat																		
Restore 5 miles of channel margin habitat																		
Restore 5 miles of channel margin habitat																		
CM7: Riparian Habitat Restoration											**Restore 400 acres by year 15 and 5,000 acres by Year 40**							
Restore 5 acres of riparian habitat																		
Restore 5 acres of riparian habitat																		
Restore 4 acres of riparian habitat																		
Restore 417 acres of riparian habitat																		
Restore 190 acres of riparian habitat																		
Restore 1,397 acres of riparian habitat																		
Restore 1,397 acres of riparian habitat																		
Restore 199 acres of riparian habitat																		
Restore 1,386 acres of riparian habitat																		
CM8: Grassland Communities Restoration	**Restore 1,000 acres by Year 10**										**Restore 1,250 acres by year 15 and 2,000 acres by Year 30**							
Restore 250 acres of grassland																		
Restore 250 acres of grassland																		
Restore 250 acres of grassland																		
Restore 250 acres of grassland																		
Restore 250 acres of grassland																		
Restore 250 acres of grassland																		
Restore 250 acres of grassland																		
Restore 250 acres of grassland																		
CM9: Vernal Pool Complex Restoration[2]	**Restore 100 acres by year 10**										**Restore 150 acres by year 15 and 200 acres by Year 20**							
Restore 58 acres of vernal pool complex habitat																		
Restore 29 acres of vernal pool complex habitat																		
Restore 29 acres of vernal pool complex habitat																		

Figure 6-1. BDCP Conservation Measure Implementation Schedule

Conservation Actions	*Near-Term Period Implementation Year (1-year intervals)*										*Long-Term Period Implementation Year (5-year intervals)*							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11-15**	**16-20**	**21-25**	**26-30**	**31-35**	**36-40**	**41-45**	**46-50**
Restore 42 acres of vernal pool complex habitat																		
Restore 42 acres of vernal pool complex habitat																		
CM10*: Nontidal Marsh Restoration[6]	**Restore 400 acres by year 10**																	
Restore 100 acres of nontidal marsh																		
Restore 100 acres of nontidal marsh																		
Restore 100 acres of nontidal marsh																		
Restore 100 acres of nontidal marsh																		
Other Species-Level Stressors Conservation Measures																		
CM11: Natural Communities Enhancement and Management																		
CM12: Methylmercury Management[7]																		
CM13: Nonnative Aquatic Vegetation Control[8]																		
CM14: Stockton Deep Water Ship Channel Dissolved Oxygen Levels																		
CM15: Predator Control																		
CM16: Non-Physical Fish Barriers																		
CM17: Hatchery and Genetic Management Plans																		
CM18: Illegal Harvest																		
CM19: Conservation Hatcheries																		

[1]Assumes no ground disturbance in the first year
[2]Implemented in Conservation Zones 1, 2, 4, 5, 7, and 11.
[3]Implemented in Conservation Zones 1, 8, and/or 11.
[4]Acreage implementation encompasses a range based upon quality of habitat.
[5]Implemented in Conservation Zone 2.
[6]Implemented in Conservation Zones 2 and 4.
[7]Phased implementation occurs in conjunction with tidal habitat restoration schedule.
[8]Implementation occurs at tidal habitat restoration sites 3 years following restoration.

Legend

- Near-term operations
- Long-term operations
- Conservation measure becomes functional (for habitat restorations, initial function may be low, with increasing function over time)
- Interagency coordination, feasibility evaluations, site acquisition, planning, environmental compliance, and construction

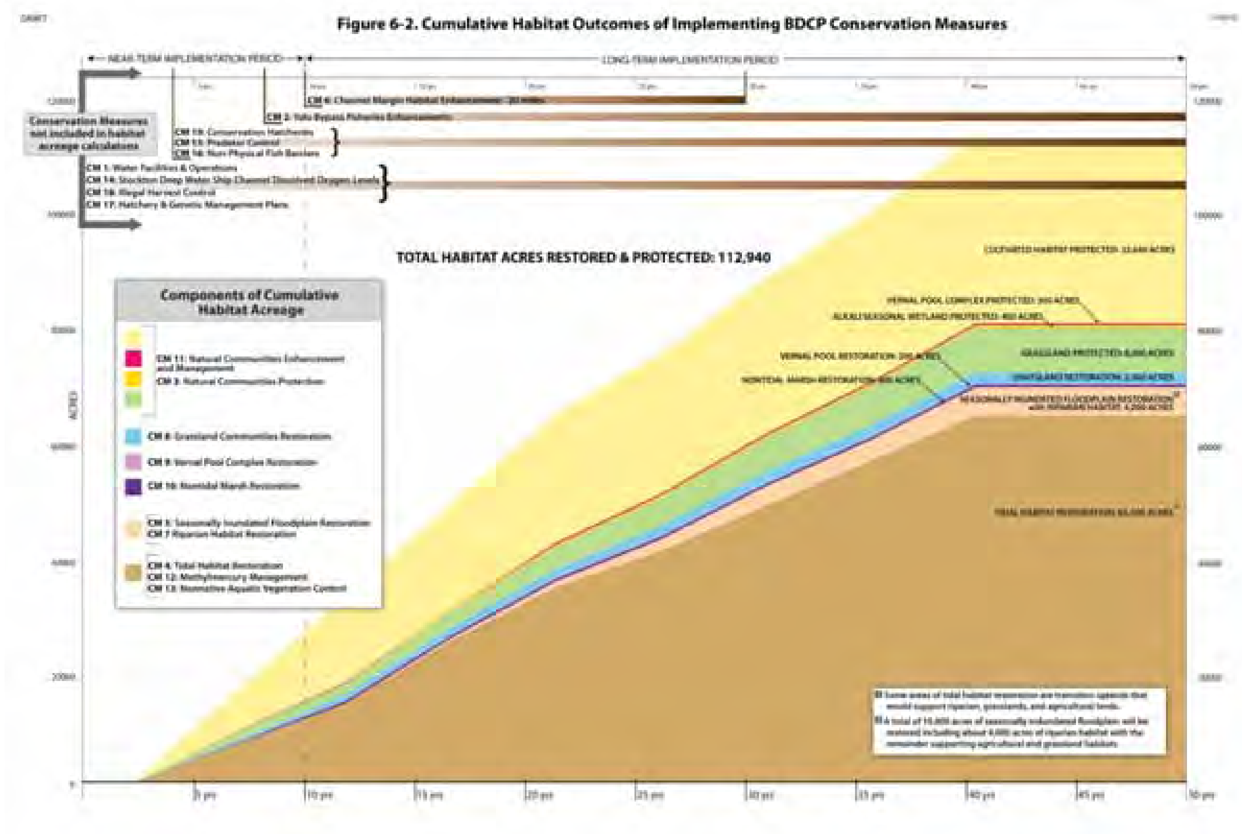

Figure 6-2. Cumulative Habitat Outcomes of Implementing BDCP Conservation Measures

The implementation schedule represents a reasonable estimate of the temporal sequence for implementation of the various interdependent conservation actions over the term of the BDCP based on the best available information. The BDCP is a large and complex plan and, to ensure successful implementation, the Implementation Office will need to retain a degree of flexibility to address new information that is developed over the term of BDCP that may require adjustments in the implementation schedule to better ensure that the biological goals and objectives are achieved. Consequently, the actual timing of implementation of some conservation actions may vary from the implementation schedule described below. Substantial variances in the implementation schedule may need to be addressed through the adaptive management process described in Section 3.7, *Adaptive Management Program*.

The BDCP implementation schedule was informed by information, data, and analysis used to develop the Conservation Strategy, including:

- The near-term, early long-term, and late long-term restoration targets established for tidal, seasonally inundated floodplain, and channel margin habitats (Section 3.4, *Conservation Measures*) and the extent of habitat restoration effects on natural communities and covered species habitats (Chapter 5, *Effects Analysis*);
- Vernal pool complex and grassland restoration targets (Section 3.4, *Conservation Measures*) and the extent of habitat restoration effects on natural communities and covered species habitats (Chapter 5, *Effects Analysis*);
- Vernal pool complex, alkali seasonal wetland complex, grassland, and agricultural habitat protection/preservation targets (Section 3.4, *Conservation Measures*); and
- The pipeline/tunnel construction schedule and the extent of construction effects on natural communities and covered species habitats (Chapter 5, *Effects Analysis*).

The estimated timeframes for implementation of each of the conservation measures were determined based on evaluations of similar type actions that have been completed and on input from individuals experienced with similar types of projects.

6.1.1 Ecosystem-Level Conservation Measures

Ecosystem-level conservation measures include actions that affect large areas of the Delta and large-scale ecosystem processes, including flow, hydrodynamics, water quality, and large areas of terrestrial, floodplain, and aquatic habitat.

6.1.1.1 Conservation Measure CM1: Water Facilities and Operation

6.1.1.1.1 Near-Term Water Operations

The implementation schedule assumes that near-term water operations of the State Water Project (SWP) and Central Valley Project (CVP) will be implemented in year 0 and continue until long-term water operations are implemented (Figure 6-1). Operation of the modified Fremont Weir is assumed to commence in year 7 following completion of construction necessary to install an operable gate on Fremont Weir (Section 6.1.1.2, *Yolo Bypass Fishery Enhancement*). Changes in operation of the Suisun Marsh Salinity Control Gate require changes to existing agreements that are assumed to become effective in early long-term implementation period.

6.1.1.1.2 Construction of North Delta Diversion and Conveyance Facilities

The implementation schedule is based on an assumption that construction of the new north Delta diversion and conveyance facilities and related actions will require up to 10 years to complete (Figure 6-1). Scheduled activities that would be implemented during this period include acquisition of lands, preparation and submittal of regulatory permit applications, preparation and letting of construction-related contracts, and facilities construction. This construction time assumption is based on rough estimates provided by DHCCP engineers.

<u>Long-Term Water Operations</u>

Implementation of the long-term water operations conservation measures is dependent on completion of construction of the north Delta diversion and conveyance facilities, assumed to be 10 years. Long-term operations would then continue over the remaining 50-year term of the BDCP. The schedule is based on the assumption that construction of the north Delta diversion and conveyance facilities will be completed in year 10 and that long-term water operations will commence in year 11 (Figure 6-1).

6.1.1.2 Conservation Measure CM2: Yolo Bypass Fisheries Enhancements

The implementation schedule for the Yolo bypass fisheries enhancements assumes that modifications to the Fremont Weir and any attendant modifications necessary to the configuration of the Yolo Bypass to allow for operation of the weir will be completed in year 6 following BDCP approvals. Implementation activities assumed to occur and to be completed by year 6 include completion of project planning, environmental compliance documentation, permitting, engineering design, acquisition of flood easements and land (if necessary), modification of the Fremont Weir, and construction of Bypass modifications that may be necessary to direct and contain bypass flows resulting from operation of the modified weir. Planning, permitting, and construction of improvements to the Fremont Weir fish passage structures are assumed to be completed by the end of year 4 and the modified passage structures to be operational in year 5.

The implementation schedule assumes that modifications to the Lisbon Weir, lower Putah Creek channel, and any other modifications of the bypass to improve fish passage will be completed by year 6. Initial grading, excavation, and filling that may be required to reduce the potential for fish stranding is also expected to be completed by year 6, although localized actions to further reduce fish stranding are expected to occur in subsequent years under the Adaptive Management Program based on results of fish stranding monitoring. Implementation activities assumed to occur and to be completed by year 6 include completion of any additional regulatory compliance processes, acquisition of land or easements necessary to implement the Bypass modifications, and construction-related activities.

6.1.1.3 Conservation Measure CM3: Natural Communities Protection

The implementation schedule for actions to preserve natural communities assumes that acquisition, protection/preservation, enhancement, and management of existing vernal pool complex, alkali seasonal wetland complex, grassland habitat and agricultural habitats will be implemented approximately concurrent with or in advance of the commensurate adverse effects of BDCP implementation on these natural communities and the covered species habitats they support. The schedule assumes that, except for protection actions implemented in the second year following BDCP authorization, a 2 year period will be necessary to identify and bring under protection (e.g., through conservation easement, fee title acquisition, or other means) existing natural communities. Based on the expected timing of adverse impacts on natural communities and covered species habitat resulting from construction activities early in BDCP implementation, the schedule is based on the assumption that planning for the first increment of protection of existing alkali seasonal wetland complex, grassland, and agricultural habitat will be initiated prior to BDCP authorization.

In addition to the protection of existing natural communities and covered species habitat, natural communities and covered species habitat that will be restored under Conservation Measures CM4-CM10 will be included within the BDCP preserve system. The implementation schedule for habitat restoration actions is described in Section 6.1.2, *Natural Community-Level Conservation Measures*.

The schedule for protection of natural communities and covered species habitat includes time for activities by the Implementation Office to identify specific parcels of land that are available for acquisition that have the physical and biological characteristics that make the lands suitable for achieving habitat protection targets.

Figures 6-3 through 6-6 show the timing of effects of BDCP actions on existing vernal pool complex, alkali seasonal wetland complex, grassland, and agricultural habitats in relation to when these habitat protection/preservation actions are implemented. The implementation schedule assumes that monitoring and management of protected/preserved habitats will occur over the remainder of the term of the BDCP following completion of each restoration increment as described in Conservation Measure CM11: Natural Communities Enhancement and Management.

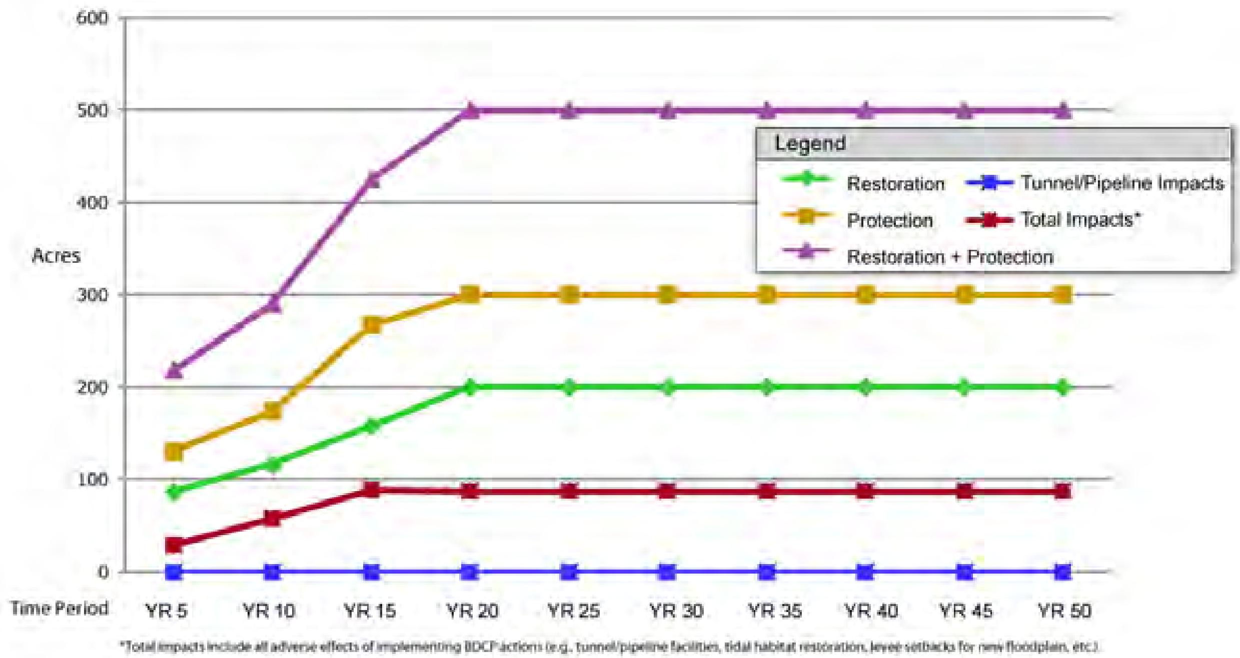

Figure 6-3. Vernal Pool Habitat Restoration and Protection versus Permanent Impacts

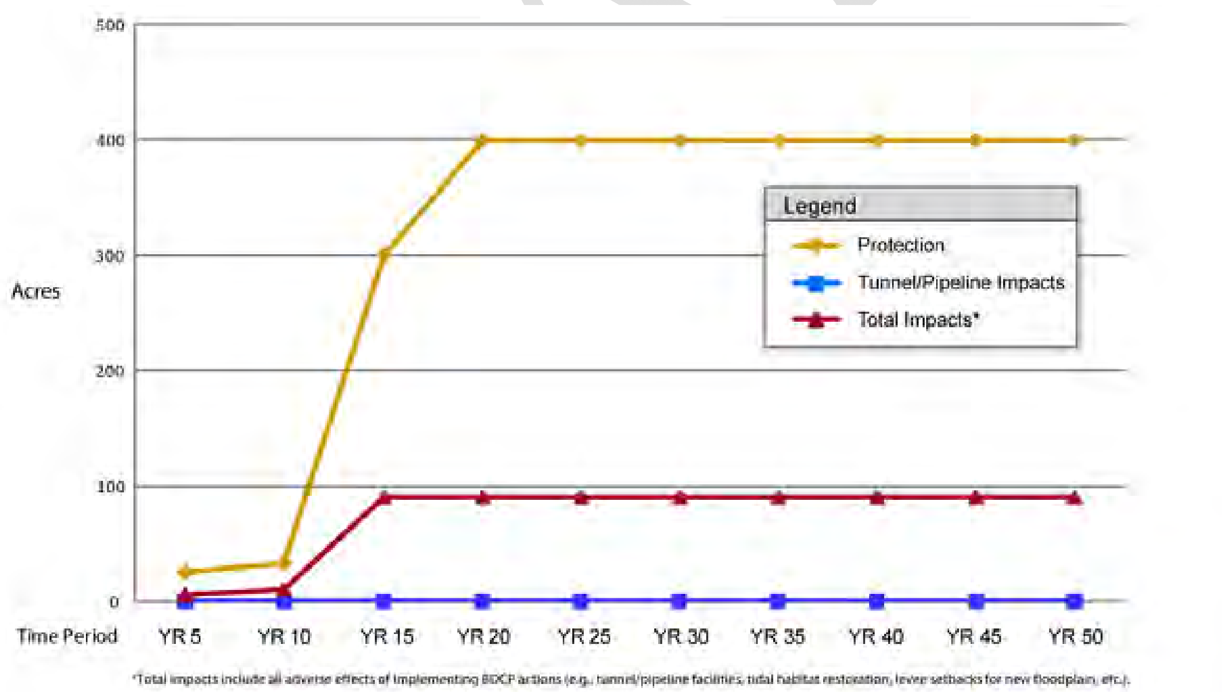

Figure 6-4. Alkali Seasonal Wetland Habitat Protection versus Permanent Impacts

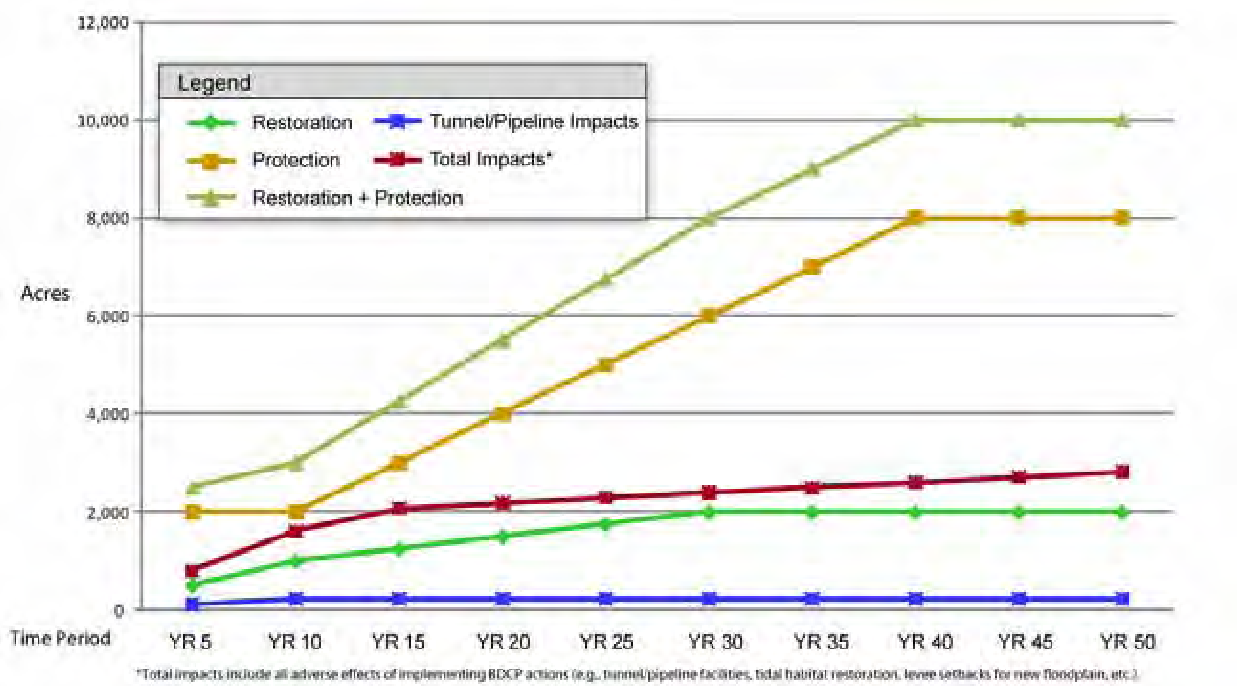

Figure 6-5. Grassland Habitat Restoration and Protection versus Permanent Impacts

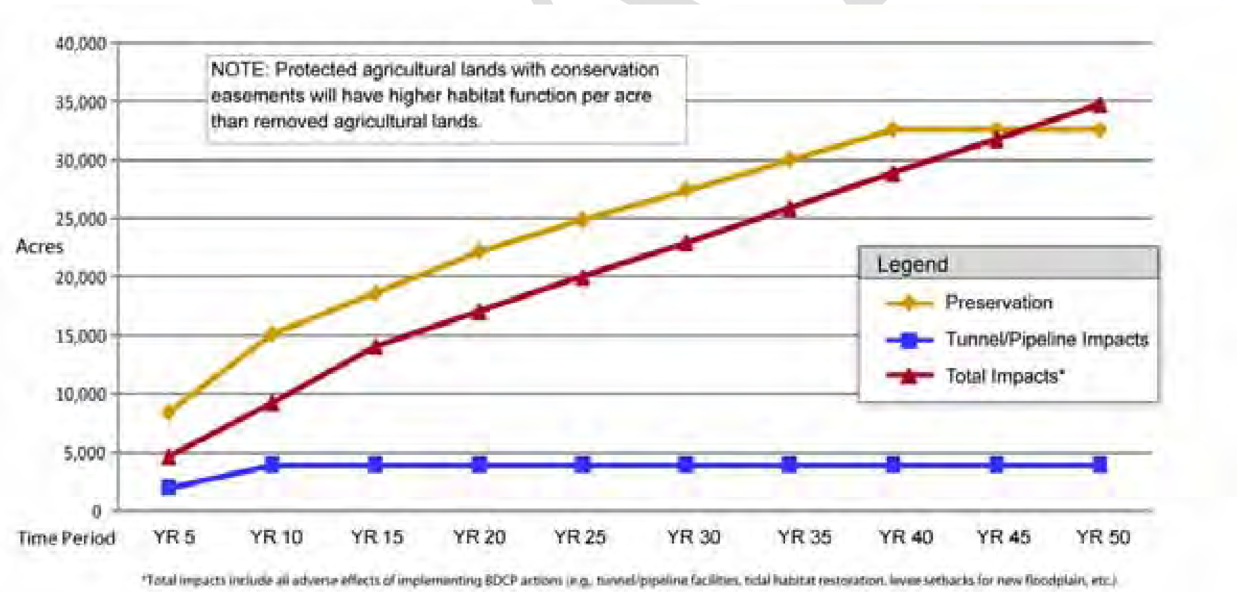

Figure 6-6. Cropland Preservation versus Permanent Impacts

6.1.2 Natural Community-Level Conservation Measures

Natural community conservation measures address actions to restore tidal, riparian, seasonally inundated floodplain, vernal pool complex, and grassland habitat; enhance channel margin habitat; and enhance and manage BDCP preserve lands. The schedule for implementing each habitat restoration action is comprised of the following elements:

- Habitat enhancement and restoration site acquisition;
- Enhancement and restoration planning and design;
- Regulatory compliance; and
- Habitat restoration and enhancement implementation activities.

These elements are generally expected to be implemented concurrently and are aggregated in the implementation schedule (Figure 6-1).

Habitat enhancement and restoration site acquisition. These actions include the identification and acquisition of specific parcels of available land that have the physical and biological characteristics sufficient to advance habitat protection, enhancement, and restoration objectives. Site acquisitions for actions that involve modifications to levees (e.g., setting back levees to restore seasonally inundated floodplain habitat) include obtaining concurrence of the responsible agencies to initiate planning studies.

Enhancement and restoration planning and design. This implementation element includes all activities related to:

- Development of conceptual habitat enhancement and restoration designs, including coordinating development of conceptual restoration designs with stakeholders (e.g., local, state, and federal agencies and potentially affected landowners);
- Development of detailed habitat enhancement and restoration designs and cost estimates;
- Development of bid specifications and drawings; and
- Preparation of habitat enhancement and restoration contracts and contractor selection

Regulatory compliance. This implementation element includes the preparation and submittal of documents and applications associated with compliance with and acquisition of the permits associated with applicable laws and regulations, including:

- Additional project-level review under the California Environmental Quality Act (CEQA), and National Environmental Policy Act (NEPA);
- Sections 401 and 404 of the federal Clean Water Act (CWA), including Nationwide Permit 27, Stream and Wetland Activities;

- California Water Code Sections 1000 et seq. (water rights);
- Water Code Sections 13000 et seq. (water quality);
- Sections 10 (33 USC 403) and 14 (33 USC 408) of the Rivers & Harbors Act of 1899;
- Section 1602 of the California Fish and Game Code (Streambed and Lakebed Alteration Agreements);
- Section 106 of the National Historic Preservation Act; and
- Encroachment permits for work on levees from the Central Valley Flood Protection Board and reclamation districts.

Habitat restoration and enhancement implementation activities. This implementation element includes all activities related to completing habitat restoration actions including:

- Contractor mobilization;
- Site preparation, including grading, excavation, and placement of fill;
- Construction/installation of water management, utility and other operational infrastructure;
- Demolition of or refurbishment of existing infrastructure;
- Construction of dikes, levees, and roads; and
- Planting vegetation.

6.1.2.1 CM4: Tidal Habitat Restoration

The implementation schedule for tidal habitat restoration actions is based on the assumption that site acquisition, planning, and regulatory compliance related activities are initiated prior to BDCP authorization for first 7,000 acres of tidal habitat to be restored in the near-term implementation period. These initial restoration actions could, therefore, be constructed immediately following BDCP authorization. These initial restoration actions are expected to require less time to acquire and permit because they are assumed to be implemented on sites that will be readily available to the Implementation Office (e.g., state and federal owned lands). The schedules for implementation of subsequent tidal habitat restoration actions are based on the assumption that 5 years are required for all the elements of restoration. It is anticipated that most or all of tidal habitat restored during the near-term implementation period will be restored in the Cache Slough Complex, Suisun Marsh, and West Delta areas.

Figure 6-7 shows the timing of adverse effects of construction activities on existing tidal habitats in relation to when tidal habitat restoration actions are implemented. The implementation schedule assumes that monitoring and management of restored tidal habitats will occur over the remainder of the term of the BDCP following completion of each restoration increment as described in Conservation Measure CM11: Natural Communities Enhancement and Management.

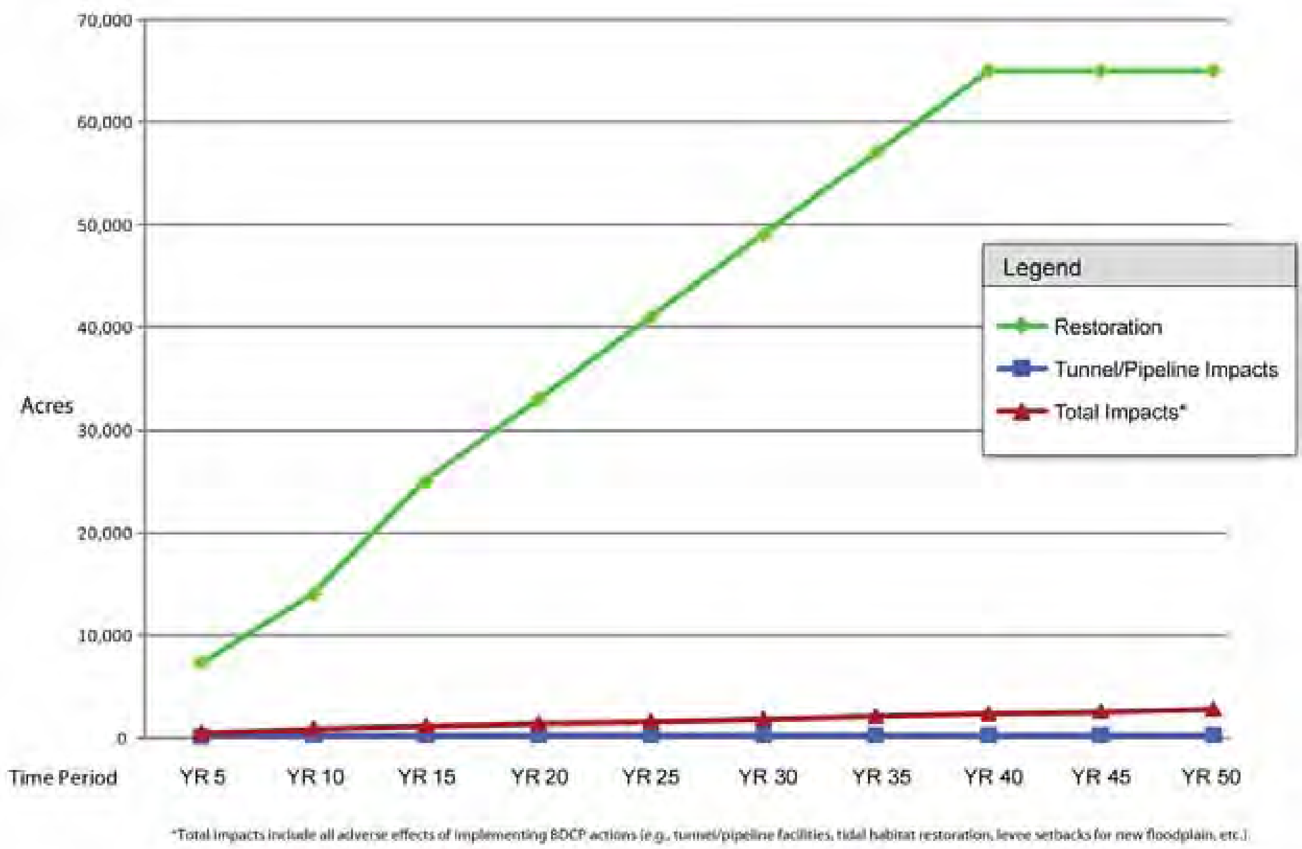

Figure 6-7. Tidal Habitat Restoration versus Permanent Impacts

The tidal habitat restoration conservation measure provides for the restoration of varying amounts of subtidal aquatic, tidal mudflat, and tidal marsh habitat over time, depending on location and restoration design within the Plan Area. Figure 6-8 presents reasonable representations of how restored tidal habitat may develop over time within 1,000 acre conceptual restoration sites at Suisun Marsh, the Cache Slough Complex, and the south Delta. The habitat functions supported for covered species will also change over time as marsh vegetation composition, structure, and density and tidal channels evolve over time.

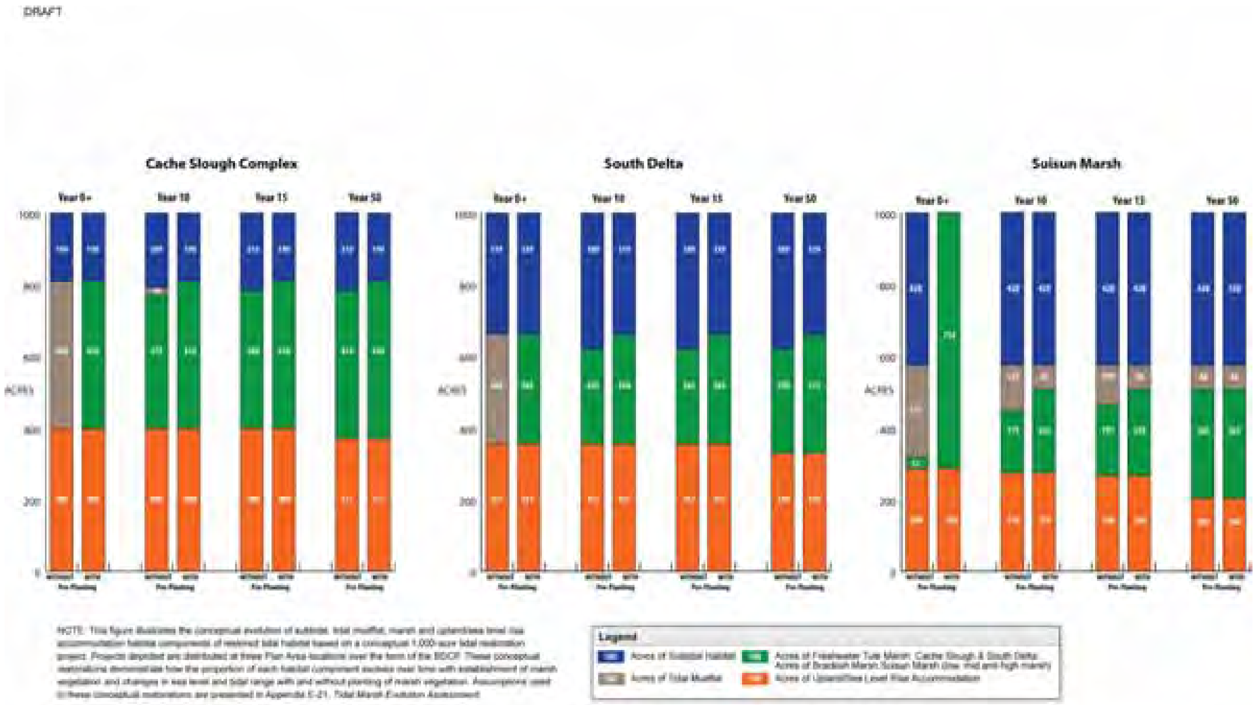

Figure 6-8. Conceptual Evaluation of Restored Tidal Habitat with and without Pre-Planting of Marsh Vegetation at Three BDCP Locations

6.1.2.2 Conservation Measure CM5: Seasonally Inundated Floodplain Restoration

Restoration of seasonally inundated floodplain habitat will require extensive levee setbacks to reconnect historical floodplain with Delta channels. The implementation schedule assumes that at least 1,000 acres of floodplain will be restored by year 15 and that restoration of the remaining 9,000 acres of floodplain restoration will be completed in increments of 3,000 acres by years 25, 30, and 40, respectively. Each floodplain restoration increment will, on average, require five years to identify potential floodplain restoration sites, coordinate planning with the U.S. Army Corps of Engineers (USACE), California Department of Water Resources (DWR) and other flood control agencies and Reclamation Districts, and conduct feasibilities studies prior to implementation. Following approval of floodplain restoration plans, an additional 5 years are assumed to be required to acquire restoration lands, obtain any outstanding regulatory approvals and permits, develop bid specifications and drawings, construct the new levees and floodplain, and breach existing levees.

The implementation schedule assumes that monitoring and management of restored seasonally inundated floodplains will occur over the remainder of the term of the BDCP following completion of each restoration increment as described in CM11: Natural Communities Enhancement and Management.

6.1.2.3 Conservation Measure CM6: Channel Margin Habitat Enhancement

The implementation schedule for enhancing channel margin habitat assumes that channel margin enhancements will be completed in increments of 5 miles of channel (achieved at multiple sites for a total of 5 miles of channel margin length) by years 10, 20, 25, and 30, respectively. Each channel margin habitat enhancement increment will, on average, require 5 years to identify potential channel margin enhancement sites, coordinate planning with USACE, DWR, and other flood control agencies and Reclamation Districts, and conduct feasibilities studies prior to implementation. Following approval of enhancement plans, an additional five years are assumed to be required to obtain any outstanding regulatory approvals and permits and develop bid specifications and drawings and implement channel margin enhancements.

The implementation schedule assumes that monitoring and management of enhanced channel margin habitats will occur over the remainder of the term of the BDCP following completion of each restoration increment as described in Conservation Measure CM11: Natural Communities Enhancement and Management.

6.1.2.4 Conservation Measure CM7: Riparian Habitat Restoration

Restoration of riparian habitat will be a component of tidal habitat restoration, seasonally inundated floodplain restoration, and channel margin habitat enhancement projects; therefore, the schedule for planning, site acquisition, environmental compliance, and implementation of riparian restoration actions is the same as the implementation schedule for those tidal, floodplain, and channel margin habitat restoration actions. The amount of riparian habitat restored varies greatly among the three restoration types. The preponderance of the 5,000 acres of riparian habitat to be restored will be performed in conjunction with seasonally inundated floodplain restoration and tidal habitat restoration in the south Delta in the early long-term and late long-term evaluation periods.

Figure 6-9 shows the timing of adverse effects of construction activities on existing riparian habitats in relation to when riparian restoration actions would be implemented. There is a temporal loss of habitat function as a result of the time lag between when riparian habitats are affected and when riparian habitat is restored and become functional as habitat for associated covered species (Figure 6-9).

The implementation schedule assumes that monitoring and management of restored riparian habitat will occur over the remainder of the term of the BDCP following completion of each restoration increment as described in Conservation Measure CM11: Natural Communities Enhancement and Management. Figure 6-10 illustrates how restored riparian habitats are expected to evolve from riparian scrub to riparian forest and to develop habitat functions that support covered species over time. A description of methods used to identify riparian habitat maturation rates is provided in Appendix N.2, *Riparian Habitat Succession*.

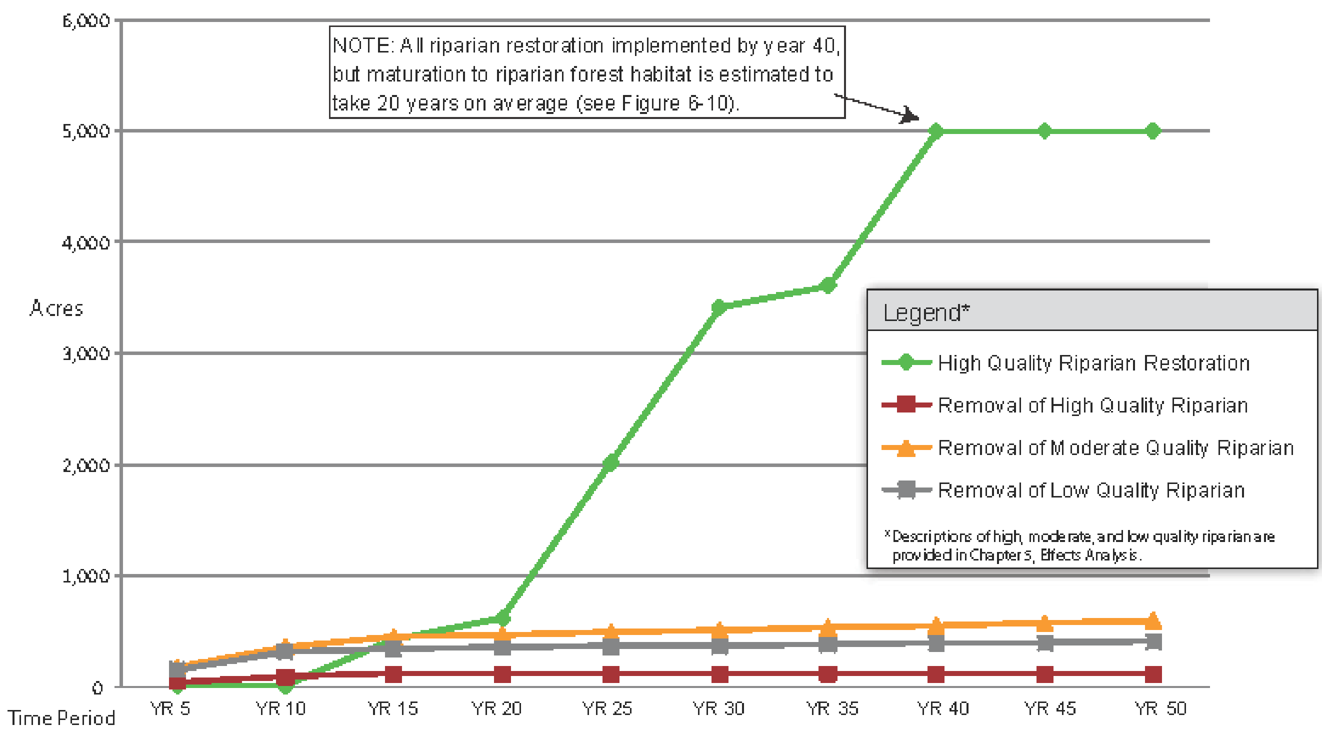

Figure 6-9. Cumulative Riparian Habitat Restoration versus Cumulative Permanent Removal

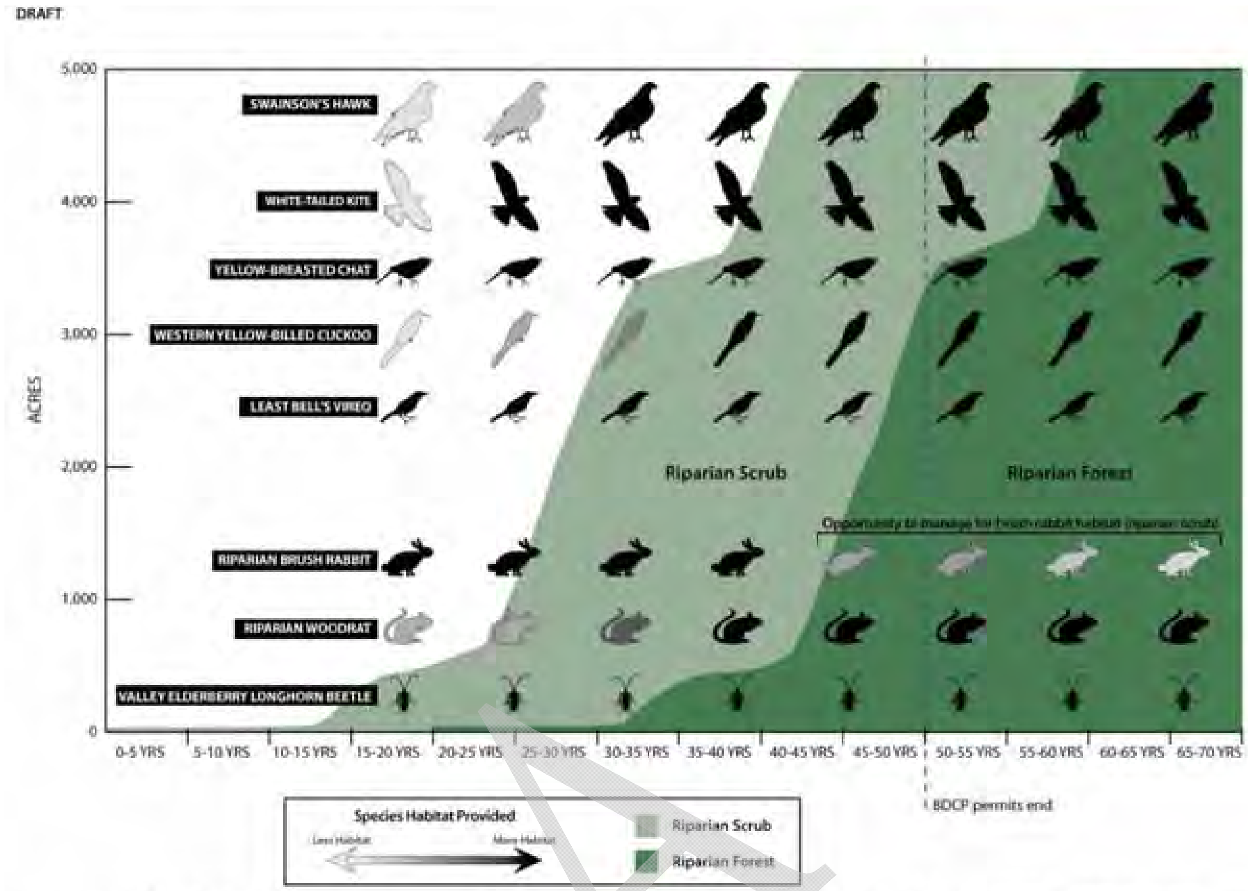

Figure 6-10. Maturation and Succession of Restored Riparian Forest and Scrub and Use by Covered Wildlife Species

6.1.2.5 Conservation Measure CM8: Grassland Communities Restoration

The implementation schedule assumes that all grassland habitat restoration actions will be implemented between years 3 and 30. A total of 1,000 acres of grassland will be restored in the near-term implementation period, 250 acres in the early long-term implementation period, and 750 acres in the late long-term implementation period. The implementation schedule assumes that site acquisition, planning, and regulatory compliance related activities for the first 250 acres of grassland restoration to be completed in year 3 is initiated in the first year following BDCP authorization and requires a total of 2 years to complete those implementation elements. All subsequent restoration increments also require a 2 year period to complete site acquisition, planning, and regulatory compliance prior to implementing restoration actions.

Figure 6-5 shows the timing of adverse effects of BDCP activities on existing grassland habitats in relation to when grassland restoration actions are implemented. The implementation schedule assumes that monitoring and management of restored grassland habitat will occur over the remainder of the term of the BDCP following completion of each restoration increment as described in Conservation Measure CM11: Natural Communities Enhancement and Management.

6.1.2.6 Conservation Measure CM9: Vernal Pool Complex Restoration

The implementation schedule assumes that all vernal pool complex habitat restoration actions will be implemented between years 2 and 15. A total of 116 acres of vernal pool complex will be restored in the near-term implementation period, 42 acres in the early long-term implementation period, and 42 acres in the late long-term implementation period. The implementation schedule assumes that site acquisition, planning, and regulatory compliance related activities for the first 58 acres of vernal pool complex restoration to be completed in year 2 is initiated before BDCP authorization and requires a total of 3 years to complete those implementation elements. All subsequent restoration increments also require a 3 year period to complete site acquisition, planning, and regulatory compliance prior to implementing restoration actions.

Figure 6-3 shows the timing of adverse effects of BDCP activities on existing vernal pool complex habitats in relation to when vernal pool complex restoration actions are implemented. The implementation schedule assumes that monitoring and management of restored vernal pool complex will occur over the remainder of the term of the BDCP following completion of each restoration increment as described in Conservation Measure CM11: Natural Communities Enhancement and Management.

6.1.2.7 Conservation Measure CM10: Nontidal Marsh Restoration

The implementation schedule assumes that all nontidal freshwater marsh restoration actions will be completed by year 9 in the near-term implementation period. The restored nontidal freshwater marsh will be designed specifically to support giant garter snake habitat and would be completed in the near-term implementation period to provide benefits for this endangered species as early as practicable. The implementation schedule assumes that site acquisition, planning, and regulatory compliance related activities for each 100 acres of restoration requires 2 years to complete with the restoration actions being completed in the third year.

The implementation schedule assumes that monitoring and management of restored nontidal freshwater marsh will occur over the remainder of the term of the BDCP following completion of each restoration increment as described in Conservation Measure CM11: Natural Communities Enhancement and Management.

6.1.2.8 Conservation Measure CM11: Natural Communities Enhancement and Management

This conservation measure applies to all BDCP protected and restored habitats and is implemented at the time each parcel of land is acquired for the BDCP conservation lands system. Within two years of acquisition of conservation land parcels, the Implementation Office will conduct surveys to collect the information necessary to assess the ecological condition and function of conserved species habitats and supporting ecosystem processes (note that such surveys would be in addition to due-diligence biological and physical surveys conducted prior to site acquisitions, see Chapter 3, *Conservation Strategy*). Based on results of the assessment, the Implementation Office will develop management plans. These management plans may be prepared for specific parcels or for multiple preserved parcels within a specified geographic area that describe habitat enhancement and management actions necessary to achieve the biological objectives established for the preserve lands addressed by each plan. Subsequent habitat enhancement and management actions will be implemented in accordance with the preserve-specific habitat enhancement and management schedule for each plan.

6.1.2.9 Conservation Measure CM12: Methylmercury Management

This conservation measure provides for specific tidal habitat restoration design elements to reduce the potential for methylation of mercury and/or its bioavailability in tidal habitats. Consequently, this conservation measure is implemented as part of the tidal habitat restoration design schedule indicated in Figure 6-1.

6.1.2.10 Conservation Measure CM13: Nonnative Aquatic Vegetation Control

This conservation measure provides for control of nonnative aquatic vegetation in subtidal habitats restored as a component of BDCP tidal habitat restoration actions. The implementation schedule assumes that nonnative aquatic vegetation control actions will be required at each tidal habitat restoration site 3 years following the restoration. Because current nonnative aquatic vegetation control methods are dependent on the use of herbicides, the implementation schedule assumes 3 years to complete planning and environmental compliance for the first tidal habitat restoration to be completed in year 2. Thereafter, the schedule assumes that planning and environmental compliance processes will be streamlined, requiring no more than 2 years to complete, and run concurrent with planning and compliance elements conducted for each of the subsequent tidal habitat restoration actions.

6.1.3 Species-Level Other Stressors Conservation Measures

6.1.3.1 Conservation Measure CM14: Stockton Deep Water Ship Channel Dissolved Oxygen Levels

The implementation schedule assumes the current Stockton Deep Water Ship Channel dissolved oxygen diffuser demonstration project will be implemented immediately following BDCP authorization (i.e., continued operation). The implementation schedule assumes the dissolved oxygen diffuser technology will need to be modified to provide substantial biological benefits for the covered fish species. The implementation schedule also assumes completion of a demonstration study by at the end of year 1 that will provide guidance on how to modify the diffusers. Additional planning, coordination, environmental compliance, and construction is assumed to require an additional 2 years and, assuming modifications are necessary, the modified dissolved oxygen diffusion facilities becoming operational in Year 4 with operations continuing over the term of the BDCP.

6.1.3.2 Conservation Measure CM15: Predator Control

The implementation schedule assumes that predator control actions to remove artificial structures and abandoned boats from Delta channels will require 2 years of planning and environmental compliance, with actions being implemented in year 3. Authorizations to implement actions to remove nonnative predatory fish from specific locations are assumed to be completed in the first year following BDCP authorization and implemented in year 3. Following the first year of their implementation, predator control actions are assumed to be implemented annually over the term of BDCP.

6.1.3.3 Conservation Measure CM16: Non-Physical Fish Barriers

The existing non-physical fish barrier serving as a pilot project at the Head of Old River is assumed to continue to be operated immediately following BDCP implementation. Planning and compliance activities for placing barriers at the Delta Cross Channel and Georgiana Slough are assumed to be initiated in the year following BDCP approval, requiring 2 years to complete, followed by construction and operation in the third year. The schedule assumes that up to four additional barriers may be constructed at operated if studies indicate substantial benefits for the covered fish species. The implementation schedule assumes 2 years of studies will be conducted following BDCP authorization and, assuming the studies indicate the placement of barriers will be beneficial, that 2 years will be required for planning and compliance and 1 year for construction as described above for the initial barriers.

6.1.3.4 Conservation Measure CM17: Hatchery and Genetic Management Plans

The implementation schedule assumes that preparation of each of the 12 hatchery and genetic management plans is initiated in the year following BDCP authorization and are all completed at the end of the third year of implementation. Because preparation of some plans will have been initiated before BDCP authorization, some of the plans may be completed earlier. The schedule subsequently assumes each plan will be updated every 5 years, requiring 1 year to complete each update. Staff support for implementing and updating plans is assumed to be implemented the year that the initial hatchery and genetic management plans are completed.

6.1.3.5 Conservation Measure CM18: Illegal Harvest

The implementation schedule assumes that planning and coordination with DFG and the existing Delta-Bay Enhanced Enforcement Program (DBEEP) necessary to expand DBEEP staffing will immediately following BDCP authorization such that the conservation measure is implemented by the end of year 2. The funding for enhanced staffing support is assumed to be maintained over the term of the BDCP.

6.1.3.6 Conservation Measure CM19: Conservation Hatcheries

The implementation schedule assumes that site acquisition, planning, and environmental compliance necessary for construction of the new the California Department of Fish and Game (DFG) conservation hatchery facility will require 3 years following BDCP authorization; an additional 2 years would be necessary for construction; and the facility would become operational in year 6. Planning and environmental compliance necessary for the expansion of the UC Davis conservation hatchery are assumed to be initiated before BDCP authorization such that the facility expansion is completed by the end of the second year of BDCP implementation, becoming operational in the year 3 of implementation. Both the USFWS and the University of California at Davis facilities are assumed to be operated over the term of the BDCP once they have become operational.

6.2 Compliance and Progress Reporting

The BDCP Implementation Office will prepare, on a regular basis, planning documents and implementation reports to demonstrate compliance with the BDCP and its associated authorizations and to facilitate interagency coordination, scientific exchange, and public outreach. Under ESA, habitat conservation plans are required to establish monitoring programs to assess the effects of plan implementation on covered species.[1] In addition, the USFWS/ National Marine Fisheries Service (NMFS) Five-Point Policy[2] recommends that such plans provide for annual reporting on matters related to compliance with permit terms and conditions. Similarly, the NCCPA requires that implementation agreements include "provisions for periodic reporting to wildlife agencies and the public for purposes of information and evaluation of plan progress."[3] The Implementation Office will, over the term of the BDCP, submit various reports and plans to the fish and wildlife agencies that serve the following purposes:

- Provide the necessary data and information to demonstrate that the BDCP is being properly implemented;
- Identify the effect of BDCP implementation on covered species and on the effectiveness of the Conservation Strategy at advancing the BDCP biological goals and objectives;
- Document actions taken under the adaptive management program (e.g., process, decisions, changes, results, corrective actions);
- Disclose issues and challenges concerning BDCP implementation, and identify potential modifications or amendments to the BDCP that would increase the likelihood of success;
- Describe schedule and cost related to the implementation of actions over one-year and five-year timeframes.

Throughout the course of BDCP implementation, the Implementation Office will prepare and submit to the fish and wildlife agencies the following documents, as described in this chapter:

- Annual Workplan and Budget;
- Annual Water Operations Strategy;
- Annual Progress Report;
- Annual Water Operations Report;
- Five-Year Comprehensive Review; and
- Five-Year Implementation Plan.

The Implementation Office will work in partnership with DWR, Reclamation, USFWS, NMFS, DFG, the BDCP Stakeholder Committee, the Delta Stewardship Council, and the Delta Science Program in the development of these planning and reporting documents. The totality of these documents will enable the range of interested public and private stakeholders, and the general public, to assess on an ongoing basis the progress and performance of the BDCP toward meeting the biological goals and objectives of the BDCP and make informed recommendations to the Implementation Office regarding matters relating to plan implementation. To accommodate

[1] 50 C.F.R. § 17.22(b)(3) and 50 C.F.R. § 222.307(b)(5)
[2] Five-Point Policy for HCPs, 65 FR 106, June 1, 2000
[3] California Fish & Game Code § 2820(b)(7)

access to this information, these reports will be available to the public and posted on the BDCP website.

6.2.1 Annual Workplan and Budget

On an annual basis[4], the Implementation Office will prepare a workplan and budget for the upcoming implementation year. The workplan will identify planned actions for the implementation of conservation measures and the monitoring, research, and adaptive management programs. The budget will set out the anticipated expenditures and identify the sources of funding for those expenditures. A final Annual Workplan and Budget will be completed no later than one month prior to the beginning of the implementation year. A draft of the Annual Workplan and Budget will be provided to BDCP Implementation Board and the BDCP Stakeholder Committee for review no later than one month prior to the due date for the final plan.

At a minimum, the Annual Workplan and Budget will contain the following information:

- A description of the planned actions (including anticipated adaptive management changes) to implement conservation measures (for water operations conservation measures, see Section 6.2.2 *Annual Water Operations Strategy*) and the entities that will carry out the actions;
- A description of the planned monitoring actions and the entities that will implement those actions;
- A description of the anticipated research studies to be undertaken, and the entities that will conduct the studies;
- A budget reflecting the costs of implementing the planned actions, including a line item for each specific action; and
- A description of the sources of funding to support the budget.

6.2.2 Annual Water Operations Strategy

The Implementation Office will work closely with CVP and SWP operation managers to ensure the proper implementation of operations conservation measures. DWR and Reclamation will retain their authority and obligation to determine overall water project operations consistent with their various permit terms and conditions and other applicable requirements. DWR and Reclamation will conduct Delta operations in close coordination with DFG, USFWS, and NMFS and in accordance with permitted operating criteria, and consistent with the following planning processes.

[4] The Implementation Office will decide how the planning year will be bounded (e.g., calendar year, federal fiscal year, state fiscal year; or water year).

No later than December 15 each year, DWR, Reclamation, DFG, FWS, and NMFS will develop a Water Operations Strategy, including provisions for seasonal variations, that identifies:

- Operations priorities for both fishery and water supply for the coming year;
- Expected operations or "most likely" criteria that will guide operations within the real-time operations ranges established in the water operations conservation measures; and
- Monitoring, data collection, research, and adaptive management experiments associated with that water year's water operations.

The BDCP Science Manager will use prior years' Annual Water Operations Reports to inform development of the Annual Water Operations Strategy. The Science Manager will seek independent science input on an initial draft of the Annual Water Operations Strategy to be submitted for review to an independent science panel in an open, public forum. The independent science panel will review the draft plan and provide a comprehensive written review of the draft plan.

The Annual Water Operations Strategy will include the first of three Seasonal Operations Strategies**.** No later than December 31, March 31, and July 31 of each year, DFG, USFWS, and NMFS will seasonally evaluate then current hydrologic and fishery information and will update the expected operating criteria within the real-time operations range, as necessary. Based on this information, DWR and Reclamation will prepare Seasonal Operations Strategies that update their operating forecasts and expected water supply projections. The Seasonal Operations Strategies documents will be completed no later than January 15, April 15, and August 15.

6.2.3 Annual Progress Report

At the end of each implementation year[5], the Implementation Office will prepare an Annual Progress Report. These reports will provide a summary of the activities carried out during the previous implementation years. The Annual Report, for instance, will include a description and accounting of land acquisitions and habitat restoration activities, and an update on the status of the monitoring and research programs, including a discussion of the synthesis and use of data and information and the identification of important trends. Annual reports will be completed within three months of the close of the reporting year, which will provide sufficient time to compile data and complete analyses.

The annual reports will include the following elements:

1. Documentation of the implementation of habitat conservation measures (i.e., protection/ enhancement/ creation/ restoration) in relationship to the implementation schedule set out in Section 6.1, *Plan Implementation Schedule*, including:

[5] The Implementation Office will decide how the implementation year will be bounded (e.g., calendar year, federal fiscal year, state fiscal year; or water year).

   a) A summary of the completed or in-progress habitat conservation actions, including information related to type, extent, and location of restored, enhanced, and existing protected habitats and natural communities. This summary will identify the habitat lands acquired and the restoration and enhancements actions undertaken over the year, and a description of the covered species that are expected to benefit from each action. The report will document, on an annual and cumulative basis, the habitat conservation actions that have been carried out.

   b) A summary of all land management activities undertaken on BDCP conservation lands, including a description of the management issues facing the Implementation Office at each preserve unit.

   c) Identification of habitat protection, restoration, or enhancement actions that have not been implemented in accordance the implementation schedule (i.e., actions that are either behind or ahead of the implementation schedule) and an explanation for the deviation from the schedule.

2. A summary of the water operations conservation measures implemented during the prior year (a detailed description of water operations will be included in the Annual Water Operations Report [Section 6.2.4]), including:

   a) Documentation of compliance with the water operation criteria in effect during the reporting period.

   b) Documentation and rationale for any deviations from the water operation criteria in effect during the reporting period.

   c) Documentation of “real time” operational decisions.

   d) Documentation of Fremont Weir operations, including:

      i) Periods of operation.

      ii) Flow volume by operation period.

      iii) Documentation and rationale for any deviations from the Fremont Weir operation ranges in effect during the reporting period.

3. A description of the status of natural communities and covered species and their habitats, including:

   a) An assessment of nature and extent of the impacts of covered activities on covered natural communities and covered species. The report will also contain:

      i) The entity that carried out the covered activity.

      ii) The location of habitat permanently or temporarily disturbed.

      iii) A description of the covered activity that disturbed natural communities and covered species habitats.

b) A description of the type, extent, and location of measures implemented to avoid and minimize the potential impacts of Covered Activities on covered species during the reporting period.

c) A summary of the overall level of impacts in the current year and a summation of impacts of all prior years of BDCP Covered Activities on covered natural communities and covered species habitats and a description of how implementation of conservation measures is roughly proportional in time and extent to the impacts on covered species and their habitat.

d) The status of the BDCP conservation lands system assembly with respect to authorized take/habitat loss, and an assessment of the progress toward all acquisition goals, including those related to land-cover types, landscape linkages, covered plant populations, and wetland protection. This assessment will include evaluation of compliance with the reserve design and assembly principles as described in Chapter 3, *Conservation Strategy*.

4. An evaluation of the results of monitoring and research activities, including:

a) A description of the ecosystem/landscape-level, natural-community level and species level monitoring activities (as described in Section 3.6, *Monitoring and Research Program* or in monitoring plans subsequently developed during implementation) undertaken during the reporting period and a summary of monitoring results with appropriate assessment of population trends and status of covered species.

b) A description of all BDCP directed research conducted during the reporting period, a summary of research results to date.

5. A description of adaptive management activities, including:

a) A description of the adaptive management decisions made during the reporting period, including how existing information was used to guide these decisions and the rationale for the action.

b) A description of the use of independent scientists or other experts in the adaptive management decision making processes.

c) A description of adopted and recommended changes to the operating conservation program based on interpretation of monitoring results and research findings.

6. A financial report describing funds provided to the Implementation Office by source; annual and cumulative expenditures by cost category; deviations in expenditures from the annual budget; and other relevant information as appropriate.

7. A description of actions implemented or pending to respond to changed circumstances, including:

a) A description of the changed circumstance and its effects on covered species and natural communities.

b) A description of the actions taken to address the changed circumstance and the effectiveness of those actions, including the outcomes of actions to address changed circumstances from earlier years.

8. A summary of any administrative changes, minor modifications, or major amendments to the Plan proposed or approved during the reporting period.

6.2.4 Annual Water Operations Report

No later than November 15 of each year, DWR and Reclamation, with participation from DFG, USFWS and NMFS, will prepare a Water Operations Report on the prior water year's (October 1 to September 30) operational effects on covered species. The report will include:

- A summary of the prior year's operations, including a comparison of the actual operations with planned operations;
- A discussion of new data collected and information from new scientific research;
- Evaluation of the effectiveness of actions for covered fish species and ecological processes, including the responses to real-time operational changes;
- Description of the extent to which water supply projections in the prior year's Annual and Seasonal Operations Strategies were met, and if not, identification factors affecting the ability to meet projections;
- Consideration of whether any protective actions should be altered in light of new information, an inability to meet fishery protection or water supply reliability targets.

The Science Manager will seek independent science input on the draft of the Water Operations Report.

6.2.5 Five Year Comprehensive Review

The implementation of the BDCP will be subject to a comprehensive review every five years throughout the term of the Plan. As part of this review, the Implementation Office will prepare a report, which will be known as the Five-Year Comprehensive Review, that memorializes the findings of this review.

The objectives of the Five-Year Comprehensive Review are as follows:

- To provide an overview of the status of BDCP implementation, including implementation of conservation measures and the progress made toward meeting biological goals and objectives;
- To assess covered species trends and habitat conditions associated with BDCP implementation relative to overall trends and conditions for covered species and natural

communities based on all relevant information (i.e., not limited to BDCP data and reports);

- To evaluate the relevance of the various monitoring actions and research projects to the implementation of conservation measures; and
- To evaluate changes that have been made in the implementation of the BDCP and set out potential modifications that may be advisable in the future based on new information and lessons learned.

The primary purpose of the Five-Year Comprehensive Review is to provide a periodic, program-level assessment of the progress made under the BDCP toward achieving the biological goals and objectives. As such, the Review will be focused on identifying and evaluating broad ecological trends within the Delta, including covered species abundance, variability, distribution, and population growth rate; ecological processes and stressors such as hydrodynamics, foodwebs, and contaminants; natural community distribution, function, and diversity; habitat restoration extent and functionality; and other relevant measures.

In contrast to the annual reports, the Five-Year Comprehensive Reviews will require significant analysis and synthesis of data collected over time, utilizing data and information compiled from various sources. Five-Year Comprehensive Reviews will include critical evaluations of the assumptions and model outputs upon which the BDCP has been based and of the efficacy of the conservation measures in light of monitoring data and the analysis and synthesis of information through the adaptive management process.

The Five-Year Comprehensive Review will also include an evaluation of the BDCP monitoring program, assessing such issues as the program's capacity to adequately measure the BDCP's progress toward achieving biological goals and objectives. The Review will discuss the lessons that have been learned during the course of implementation and reach conclusions regarding how best to approach monitoring into the future. The Review will also afford an opportunity to evaluate the BDCP biological goals and objectives and assess their continued relevance in light of new information that has become available.

The Five-Year Comprehensive Review will be developed in close coordination with the Interagency Ecological Program (IEP), Delta Science Program, and Independent Science Board. The Implementation Office will work with the IEP Lead Scientist and Science Manager for the Delta Science Program to consolidate data and information from a range of sources. The Review may be scheduled to coincide with the Delta Science Conference to capitalize on the gathering of the community of scientists engaged in Delta issues.

The Implementation Office will post the Five-Year Comprehensive Review on the BDCP website and include a summary of the Review to assist stakeholders and the public in their review of the report.

6.2.6 Five Year Implementation Plan

Based on the Five-Year Comprehensive Review, the Implementation Office will prepare a Five-Year Implementation Plan that covers the upcoming five years. In contrast to the Annual Workplan and Budget, the Five-Year Implementation Plan will focus more broadly on potential future conservation actions and adaptive management changes, other potential modifications to the BDCP, and on the significance of ecological trends. At a minimum, the Five-Year Implementation Plan will contain the following information:

- Description of adaptive management changes to BDCP implementation of conservation measures, monitoring, research, and program administration;
- Modifications, if necessary, to biological goals and objectives;
- Identification of any changes to the BDCP that may require amendments to the permits or other authorizations;
- Summary of the planned actions and schedule to implement conservation measures;
- Description of the long-term and system-wide monitoring actions and anticipated research studies; and
- Summary budget projection reflecting the costs of implementing the planned actions.

In years when Five-Year Plans are prepared, the Annual Workplan and Budget may be included within or prepared separately from the Five-Year Plan.

6.3 Regulatory Assurances and Changed Circumstances and Unforeseen Circumstances

6.3.1 Regulatory Assurances

ESA regulations and provisions of the NCCPA each provide for regulatory and economic assurances to parties covered by approved habitat conservation plans (HCPs) and/or Natural Community Conservation Plans (NCCPs) concerning their financial obligations under a plan. Specifically, these assurances are intended to provide a degree of certainty regarding the overall costs associated with species mitigation and other conservation measures, and add durability and reliability to agreements reached between permittees and the fish and wildlife agencies. That is, if unforeseen circumstances occur that adversely affect species covered by an HCP or NCCP, the fish and wildlife agencies will not require additional land, water, or financial compensation or impose additional restrictions on the use of land, water, or other natural resources.

The assurances provided under the ESA and the NCCPA do not limit or constrain USFWS, NMFS, or DFG, or any other public agency, from taking additional actions to protect or conserve species covered by an NCCP and/or HCP. The state and federal agencies may use the variety of tools at their disposal and take actions to reduce the effects of other stressors to ensure that the needs of species affected by unforeseen events are adequately addressed.

6.3.1.1 Regulatory Assurances under the ESA - The No Surprises Rule

Under the No Surprises Rule,[6] once an incidental take permit has been issued pursuant to an HCP, and its terms and conditions are being fully implemented, the federal government will not require additional conservation or mitigation measures, including land, water (including quantity and timing of delivery), money, or restrictions on the use of those resources.[7] If the status of a species addressed under an HCP unexpectedly declines, the primary obligation for undertaking additional conservation measures rests with the federal government, other government agencies, or other non-federal landowners who have not yet developed HCPs. As explained by the federal fish and wildlife agencies:

> *"Once an HCP permit has been issued and its terms and conditions are being fully complied with, the permittee may remain secure regarding the agreed upon cost of conservation and mitigation. If the status of a species addressed under an HCP unexpectedly worsens because of unforeseen circumstances, the primary obligation for implementing additional conservation measures would be the responsibility of the Federal government, other government agencies, and other non-Federal landowners who have not yet developed an HCP."*[8]

However, the federal fish and wildlife agencies may, in the event of unforeseen circumstances, require additional measures provided they are limited to modifications within conserved habitat areas or to the conservation plan's operating conservation program for the affected species, and that these measures do not involve additional financial commitments or resource restrictions without the consent of the permittee. These assurances are provided to all HCP permittees that properly implement their plans. The No Surprise Rule, however, does not apply to Reclamation, which will use the BDCP as the basis for a biological assessment (BA) to support the issuance of take authorizations from USFWS and NMFS pursuant to Section 7 of the ESA for its actions in the Delta.

The assurances provided by the No Surprises rule, however, are not absolute and are tempered by other regulatory provisions of the ESA. The "Permit Revocation" rule moderates the scope of the No Surprises rule, providing that in instances where a species covered by an HCP is threatened with extinction, assurances may be nullified and USFWS may revoke the HCP permit.[9] The federal fish and wildlife agencies may exercise this authority even if a permittee is

[6] 63 Fed. Reg. 8859 (Feb. 23, 1998).
[7] *Id*. at 8868. The No Surprises rule was promulgated jointly by the Department of the Interior (Service) and the Department of Commerce (National Marine Fisheries Service).
[8] *Id.* at 8867.
[9] 50 C.F.R. § 17.22(b)(8).

in compliance with the terms and conditions of the permit, provided the permitted activity would appreciably reduce the likelihood of the survival and recovery of the species in the wild.[10]

*[**Note to Reviewers:** Additional text will be added regarding the application of the No Surprises rule to the various BDCP authorized entities]*

6.3.1.2 Regulatory Assurances under the NCCPA

Under the NCCPA, DFG provides assurances to permittees commensurate with the long-term conservation assurances and associated implementation measures that will be implemented under the plan.[11] In its determination of the level and term of the assurances to be afforded a permittee, DFG takes into account the conditions specific to the plan, including such factors as: the level and quality of information regarding covered species and natural communities, the sufficiency and use of the best available scientific information in the analysis of impacts on these resources, reliability of mitigation strategies, and appropriateness of monitoring techniques, including the use of centralized information to evaluate the effectiveness of the plan; the adequacy of funding assurances; the range of foreseeable circumstances that are addressed by the plan; and the size and duration of the plan.[12]

The assurances provided to the entities receiving permits under the NCCPA will, at a minimum, ensure that if there are unforeseen circumstances, no additional financial obligations or restrictions on the use of resources will be required of the permittees without their consent. Specifically, the NCCPA directs that, "[i]f there are unforeseen circumstances, additional land, water, or financial compensation or additional restrictions on the use of land, water, or other natural resources shall not be required without the consent of plan participants for a period of time specified in the implementation agreement, unless [DFG] determines that the plan is not being implemented consistent with the substantive terms of the implementation agreement."[13] However, like the provision in the ESA regulations, the NCCPA requires that DFG suspend or revoke a permit, in whole or in part, if the continued take of a covered species would jeopardize its continued existence.

6.3.2 Changed Circumstances

Ecological conditions in the Delta are likely to change as a result of future events and circumstances that may occur during the course of the implementation of the BDCP. The BDCP identifies changes in circumstances that are reasonably foreseeable and that could adversely affect species and natural communities covered by the plan, consistent with the "changed circumstances" provisions of ESA regulations and in the NCCPA.[14] To ensure successful

[10] 69 Fed. Reg. 71723, 71727 (December 10, 2004).

[11] Fish and Game Code section 2820 (f) states "*The department may provide assurances for plan participants commensurate with long-term conservation assurances and associated implementation measures pursuant to the approved plan.*"

[12] DFG bases its determination of the level of assurances on multiple factors. See Fish and Game Code section 2820(f).

[13] Fish and Game Code § 2820(f)(2).

[14] USFWS and NMFS regulations define changed circumstances as "changes in circumstances affecting a species or geographic area covered by a conservation plan that can reasonably be anticipated by plan developers and the [USFWS and NMFS] and that can be planned for…" (50

implementation of the BDCP conservation strategy, the plan further sets out measures designed to respond to these anticipated future changes.

The changed circumstances provisions of the BDCP are intended to address reasonably foreseeable events, both inside and outside of the Delta, that may impede or prevent the BDCP from achieving the biological benefit expected to result from the implementation of the conservation measures in the Plan Area. The BDCP identifies a broad range of potential changed circumstances, including events or conditions that may limit the biological benefits of the conservation measures, such as new invasive species and significant releases of pollutants, or the substantial degradation of habitat functions, from flooding or climate change.

Responses to the changed circumstances provided for in the BDCP will largely be developed and implemented as part of the adaptive management program.[15] For certain specified changed circumstances, measures beyond the scope of the adaptive management program have been developed, as described in this section. The responsive measures set out in the plan reflect approaches that are both practicable and roughly proportional to the impacts of covered activities on covered species and habitat.

Changed circumstances provisions are not intended to remedy events or conditions that are beyond the control of the permittees. Rather, these provisions are intended to protect the plan's operating conservation program in the face of such events. Thus, for example, in the event of changes in water temperatures in the Delta, the BDCP would not provide for actions to moderate such temperature changes. The BDCP, however, would require that the Implementation Office implement responsive actions or contingency plans that provide for a recalibration of habitat restoration strategies or other actions within the context of the defined range of the adaptive management program. Similarly, an occurrence of a major flood event that results in substantial loss of tidal marsh habitat restored under the BDCP would trigger actions under the adaptive management program to restore functions of tidal marsh habitat for covered species.

To address the potential for changed circumstances, the BDCP sets out funding commitments for responsive measures that may be implemented as part of the adaptive management program (Section 3.7, *Adaptive Management*). The BDCP also identifies contingency funding to implement measures to address those changed circumstances not contemplated in the adaptive management program, as described in Chapter 8, *Implementation Costs and Funding Sources*. In the event that changed circumstances occur, the Implementation Office will implement the responsive measures identified in this chapter. However, the BDCP sets out the range of financial commitments of the participating entities, which includes limitations on funding to remediate changed circumstances. As such, responsive measures for changed circumstances will be implemented within the levels of funding set out in the BDCP for these purposes and no

C.F.R. §17.3; 50 C.F.R §222.102). The NCCP Act defines changed circumstances as "…reasonably foreseeable circumstances that could affect a covered species or geographic area covered by the plan." (Fish and Game Code §2805(c)).

[15] See generally, U.S. Fish and Wildlife Service and National Marine Fisheries Service Habitat Conservation Planning Handbook, page 3-28 (November 1996).

additional funding will be required from permittees. [***Note to Reviewers****: The levels of funding for responsive measures have not yet been determined.*]

In the event of such changed circumstances, the BDCP Implementation Office would implement the responsive measures described in this chapter. The following describes the process for identifying the occurrence of changed circumstances, the changed circumstances that would be addressed by the BDCP, and the measures that would be implemented in response to such occurrences.

6.3.2.1 Process to Identify Changed Circumstances

The occurrence of a changed circumstance will generally become apparent to the Implementation Office through information gained from system-wide or effectiveness monitoring, scientific study, or by notification received from another party (e.g., contamination of a terrestrial area reported by a county health agency). Upon an indication that a changed circumstance has occurred, or is likely to occur, the Implementation Office will take immediate steps to investigate and confirm the occurrence of such an event. If a changed circumstance appears to have occurred, the Implementation Office will contact the appropriate fish and wildlife agencies to confirm the changed circumstance. The Implementation Office will notify the BDCP Authorized Entities, relevant Supporting Entities, and the Implementation Committee of the changed circumstance.

For changed circumstances that are anticipated in the BDCP, the Program Manager, in conjunction with the fish and wildlife agencies, will develop thresholds and triggers as appropriate that will be used to signal the onset of change circumstances. After establishing an occurrence of a changed circumstance identified in this chapter, the Implementation Office will determine specific responsive actions that are consistent with the responses described in Section 6.3.2.2, *Changed Circumstances Addressed by the BDCP*, for the particular changed circumstance and develop a schedule for implementation. The Implementation Office will, to the extent necessary, coordinate with the fish and wildlife agencies in the implementation of these responses. For those actions that are to be implemented through the adaptive management program, the decision-making process described in Section 3.7, *Adaptive Management*, will be used. For other responsive actions, the Implementation Office will implement the identified measures after conferring with the relevant fish and wildlife agencies. After implementing responsive actions, the Implementation Office will monitor the effectiveness of the measures and report the associated results and findings.

6.3.2.2 Changed Circumstances Addressed by the BDCP

[***Note to Reviewers:*** *The Steering Committee has initiated discussions of the changed circumstances described in this section and have identified several changed circumstances and topic areas for further discussion, including issues on availability of land, levee failures, failure of water operations facilities, and conflicts with other regulations that might affect water operations.]*

1. Availability of Land Necessary for the Implementation of Habitat Conservation Measures

Nature of the Changed Circumstance

The BDCP Conservation Strategy assumes that sufficient land will be available within the Plan Area to implement the habitat conservation measures set out in the BDCP. In the event that land suitable for these purposes is not available, these changed circumstances will be addressed as set out in this section. A shortfall in available land necessary to implement habitat conservation measures will be deemed to have occurred if land with suitable site conditions and characteristics (e.g., topography, soils, hydrology, proximity to occupied covered species habitats) and in appropriate locations within the Plan Area cannot be reasonably and practicably obtained.

Planned Response

During the course of BDCP implementation, the Implementation Office may determine that land suitable for meeting one or more of the habitat restoration and protection targets are not reasonably and practicably available within the Plan Area. In such instances, the Implementation Office, through the adaptive management process and after consultation with the fish and wildlife agencies, will take all reasonable and practicable steps to: (a) undertake habitat restoration or protection of habitat in areas outside of the BDCP designated Conservation Zone(s), including tidal ROAs, but within the Plan Area, at locations that would benefit the affected covered species, (b) restore or protect habitat in suitable locations outside of the Plan Area, in coordination with local governments, to benefit the associated covered species, or (c) identify and implement alternative conservation measures that would provide equivalent or greater benefits to the affected covered species.

2. Levee Failures

Nature of Changed Circumstance

During the course of BDCP implementation, it is expected that levee failures will occur within the Plan Area, and that such failures may affect benefits to covered species provided by the BDCP. To address such circumstances, the BDCP identifies a range of actions that will be carried out by the Implementation Office to respond to such events. To guide responses to such events, levee failures will be considered a changed circumstance under the BDCP if the failure: (a) diminishes significantly the function of BDCP restored and protected natural communities as habitat for covered species, as jointly determined by the Implementation Office and the fish and wildlife agencies, (b) precludes implementation of habitat conservation measures, and/or (c) impedes the implementation of water operations conservation measures.

Planned Responses

The following sets out several foreseeable scenarios involving the failure of levees that may adversely affect ecological benefits provided by the BDCP, and describes the response that would be provided for under the BDCP.

Failure of levees constructed as part of a BDCP activity result in substantial reduction of the level of benefits to covered species produced by BDCP restored tidal habitat. To reduce the potential for failure of a BDCP levee, BDCP levees will be designed to appropriate standards. However, notwithstanding the integrity of constructed levees, the BDCP Implementation Office may encounter circumstances in which levees constructed pursuant to a BDCP activity subsequently fail. In such an event, the Implementation Office will be responsible for undertaking actions to restore the functions of habitat degraded or lost as a result of the failure. If such restoration of habitat functions is not practicable, the Implementation Office will, through the adaptive management process, restore habitat of comparable biological value elsewhere in the Plan Area or at other locations to replace lost or degraded habitat functions to the extent practicable, as provided for under Changed Circumstance No. 1. The affected habitat may also be replaced at the location of the levee failure site if the breach results in newly created habitat of sufficient value to replace the lost habitat and the new habitat area is or can be made available to the Implementation Office for protection. The Implementation Office will coordinate with appropriate local agencies in developing and implementing the response to the levee failure.

Failure of levees not constructed as part of a BDCP activity reduce the benefits to covered species produced by BDCP tidal habitat restoration and water operations conservation measures. The BDCP Implementation Office is not responsible for repair of failed non-BDCP levees. Following failure of a non-BDCP levee that affects restored BDCP tidal habitat areas, the Implementation Office will determine the extent of effects on the habitat functions for covered species that are supported by the restored habitat. If the intended habitat functions of the restored tidal habitat for covered species are found to be substantially degraded, the BDCP Implementation Office will, to the extent reasonable and practicable, identify and undertake actions through the adaptive management process to adjust implementation of Conservation Measure *CM10: Nontidal Marsh Restoration* to restore or compensate for the degraded or lost habitat. If the failure of a non-BDCP levee affects the implementation of BDCP water operations conservation measures, the Implementation Office will invoke the adaptive management process to determine, in coordination with DWR and Reclamation and the fish and wildlife agencies, appropriate adjustments to water operations or other conservation measures, on a temporary basis and within the established adaptive range of water operations and other conservation measures. Once the circumstances affecting the implementation of the water operations conservation measures have been addressed, the SWP and CVP will resume operations under the parameters that were in place prior to the levee failure.

Failures of levees unrelated to BDCP activities that are not repaired by the responsible flood control entity and inhibit the implementation of water operations conservation measures or reduce the covered species and ecosystem benefits that would be provided by the conservation measure. The BDCP Implementation Office is not responsible for repair of failed non-BDCP levees. Following a determination that a failed non-BDCP levee will not be repaired, the Implementation Office will determine the extent of effects on the aquatic habitat functions for covered species that are supported by the affected water operations. If the intended ecological functions for covered species supported by the water operations are found to be substantially degraded, the BDCP Implementation Office and/or DWR and Reclamation will, through the adaptive management process and subject to the specific circumstances of the event, implement one or more of the following actions to obtain the intended benefits of water operations conservation measures precluded by levee failures: (a) adjust water operations within the permitted adaptive range of water operations to restore benefits to covered species and habitat provided by the measures, to the extent practicable or (b) identify and implement, within the context of the adaptive management program, alternative conservation measures (e.g., additional restoration of physical covered fish species habitats, increase in magnitude of other stressors conservation measures) that will provide similar types and levels of covered species benefits intended by the affected conservation measures. No additional response beyond that contained within the adaptive management program and permit assurances will be required.

Failure of multiple Delta levees substantially alter aquatic conditions such that conservation measures cannot be implemented and/or the covered species habitat benefits provided by conservation measures are substantially reduced as a result of altered aquatic ecosystem conditions or changes in the behavior or distribution of covered fish species. A widespread or catastrophic change in ecological conditions within the Plan Area due to multiple levee failures would be of such magnitude so as to render most responses through the BDCP infeasible. As such, in the event of this changed circumstance, no specific responses would be required under the BDCP; the Implementation Office and DWR and Reclamation, however, will identify and undertake actions to the extent reasonable and practicable within the parameters of the BDCP adaptive management program that would help to moderate the ecological effects of multiple levee failures. Such adaptive management responses would be limited to identifying alternative locations for habitat restoration actions, adjusting water operations within the adaptive management operations range, and adjusting implementation of other stressors conservation measures to more effectively provide benefits for covered fish species under the altered hydrodynamic conditions. The types and extent of potential adjustments in implementation may change over time as Delta conditions evolve towards a new equilibrium.

3. Failure of water operations infrastructure

Nature of Changed Circumstance

For the purpose of this provision, a failure of water operations infrastructure located within the Plan Area will be deemed to have occurred if a malfunction or breakdown of water operations conveyance facilities, including intake and fish screen facilities, pumping facilities, and other appurtenant facilities, and the failure precludes or substantially inhibits the ability to manage water operations within the water operations parameters in effect at the time of the infrastructure failure. Failure of the pipelines, tunnels or canal that comprises the principal conveyance facility are not reasonably foreseeable as a changed circumstance due to the nature of their planned construction.

Planned Response

The water operations infrastructure of the CVP and the SWP are routinely and diligently maintained to greatly reduce the potential for failure. In the unlikely event of such a failure of infrastructure within the Plan Area, the Implementation Office would request that DWR and/or Reclamation repair the affected facilities or make adjustments or modifications to other facilities to restore full operational capacity necessary to implement BDCP conservation measures, as soon as reasonable and practicable, and temporarily adjust water operations within the adaptive range of water operations if such action is deemed necessary to minimize adverse effects on covered species to the extent practicable. Upon completion of facility repairs or alternative modifications to other infrastructure, operations would return to pre-existing levels, parameters and water supply. If the infrastructure failure does not permit operations within the adaptive management range the Implementation Office will operate under the emergency procedures described in Chapter 4, *Covered Activities*.

4. Fire

Nature of Changed Circumstance

Fire is defined as any fire not prescribed by the Implementation Office on BDCP protected lands that removes a sufficient extent of vegetation such that the intended habitat functions of the protected land for covered species is substantially degraded, as jointly determined by the Implementation Office and fish and wildlife agencies.

Fire may substantially degrade the intended habitat functions of natural communities and covered species habitats protected and/or restored under the BDCP. However, the non-aquatic lands within the Plan Area are primarily characterized by intensively managed agriculture, which generally does not provide the conditions for uncontrolled or extensive fire events. Moreover, within the Plan Area, the extensive network of waterways serves as barriers to the rapid spread of fire. While fire is typically a natural component of grassland communities, which represent approximately 8 percent of the Plan Area, most natural communities in the Plan Area, including valley/foothill riparian, wetlands, and agriculture, are typically not prone to fire.

Planned Response

To minimize the risk of fire, the Implementation Office will identify BDCP protected lands that pose a high risk of fire (e.g., grasslands situated near roadways) and carry out a number of preventative measures on those lands. The Implementation Office will ensure that fuel breaks are established and maintained around such lands and that post-fire monitoring plans are developed.

In the event of a fire, the Implementation Office will assess the proportion of the protected habitat area that has burned and its likely effects on habitat use by covered species, will make an initial determination of whether or not a changed circumstance exists, and will notify the fish and wildlife agencies of the fire event. If a changed circumstance is determined to exist, the Implementation Office will implement the appropriate post-fire monitoring plan for a two-year period following the fire. If over the course of the monitoring period it is determined that vegetation is not recovering sufficiently in the burned area to reestablish the original functions of the affected habitat, the Implementation Office will develop and implement through the adaptive management program to the extent practicable a habitat restoration plan to enhance recovery of the affected habitat area. Elements of habitat restoration plans may include provisions for planting and caring for native vegetation and controlling the establishment of invasive plant species.

5. Conflicts related to state or federal environmental laws or regulation

Nature of the Changed Circumstance

In the course of implementing the BDCP, the Implementation Office will seek to obtain various state and federal permits and authorizations necessary to carry out certain conservation actions. The Implementation Office may discover that, in some instances, the implementation of a conservation measure may conflict with the requirements of a state and/or federal law or regulation. The apparent conflict could necessitate changes to the conservation measure or an elimination of the measure altogether.

Planned Response

In the event that it is determined that the implementation of a conservation measure would likely conflict with a state or federal environmental law or regulation, the Implementation Office will pursue one or more of the following actions through the adaptive management process: (a) modify implementation of the conservation measures to ensure compliance with all applicable state and/or federal laws or regulations; (b) identify and implement alternative conservation measures that provide equivalent ecological benefits for the affected covered species. In the alternative, the Implementation Office may also sufficiently reconcile the apparent regulatory conflict in conjunction with the relevant state and/or federal agency and proceed with the implementation of the conservation measure(s).

6. New Species Listings

Nature of the Changed Circumstance

The USFWS, NMFS, or DFG may list additional species as threatened or endangered under the ESA or CESA[16] that occur in the Plan Area that are not BDCP Covered Species. In the event that a fish and wildlife agency lists a species not covered by the BDCP, the provisions of this changed circumstance will be automatically triggered.

Planned Response

Upon a new listing of a species under state or federal endangered species laws, the Implementation Office will undertake the following measures:

[16] A species designated by the State as a "candidate" for listing also receives regulatory protection during the pendency of the candidacy. As such, the provisions set out in this changed circumstance will apply to State-designated candidate species.

- Evaluate the potential impacts of covered activities on the newly-listed species and conduct an assessment of the presence of suitable habitat in areas of potential effect.
- Implement measures to avoid impacts to the newly listed species until such time as the BDCP has been amended to include the newly listed species as a covered species.

In the event that a species not covered by the BDCP becomes listed as threatened or endangered or designated as a candidate species, or is proposed or petitioned for listing, the Implementation Office, on behalf of the Authorized Entities, may request that the appropriate fish and wildlife agency add the species to the relevant take authorizations issued pursuant to the BDCP. In determining whether to seek take coverage for the species, the Implementation Office will consider, among other things, whether the species is present in the Plan Area, if the covered activities could result in the take of the species, and if the existing conservation measures benefit the species and avoid and minimize effects of covered activities on the species. If such take coverage is sought, the BDCP and its authorizations will be amended. Alternatively, the Implementation Office, on behalf of the Authorized Entities could seek new and separate take authorizations. The procedures for Plan modifications and amendments are described in Section 6.4 *Permit Duration and Renewal, Plan Amendments, Permit Suspension and Revocation*.

7. Invasive Species

Nature of Changed Circumstance

A changed circumstance that involves the introduction of an invasive species will be considered to have occurred if the Implementation Office and the fish and wildlife agencies jointly determine that such a species is present and has been established within the Plan Area and that the presence of the invasive species will substantially diminish the benefits to covered species provided by the BDCP conservation measures.

Planned Response

As described in Section 3.6, *Monitoring and Research Plan*, the Implementation Office will take steps to detect, through the monitoring program and through collaboration with other responsible entities, the establishment of new invasive species in the Plan Area. If a new invasive species is discovered, the Implementation Office in coordination with the fish and wildlife agencies will conduct an assessment to determine the possible threats of the invasive species to covered species and the Delta ecosystem. Based on results of the assessment, the Implementation Office will, within the parameters of the adaptive management program, identify and implement, to the extent reasonable and practicable, measures to reduce and/or control the adverse effects of new nonnative species on the functions provided by the conservation measures under the Plan (e.g., control of nonnative plant species in restored tidal marsh that affect food web functions). If methods to adequately reduce and/or control adverse effects of the nonnative species on the functions of restored physical habitats are not available or practicable, the Implementation Office will identify reasonable and practicable alternate design, implementation, and management approaches to future habitat restoration actions within the parameters of the adaptive management program to avoid or minimize potential adverse effects of the invasive species on covered species. If methods are not reasonably and practicably available to reduce and/or control adverse effects of invasive species on water operations, physical habitat, and other conservation measures, the BDCP Implementation Office, within defined adaptive management ranges, will identify and implement alternative conservation measures that provide equivalent or greater benefits to covered species and their habitats to the extent reasonable and practicable.

8. Toxic or Hazardous Spills

Nature of Changed Circumstance

Toxic or hazardous spills will be considered a changed circumstance if the spills of chemicals into Delta waterways or BDCP restored and protected habitats could substantially and adversely affect habitat restored and/or protected through the BDCP, as jointly determined by the Implementation Office and the Fish and Wildlife Agencies.

Planned Responses

The Implementation Office will respond to toxic or hazardous spill events that occur in habitat areas that have been protected, enhanced, or restored through BDCP actions. To minimize the potential effects of a toxic or hazardous spill, the BDCP Implementation Office will develop a toxic and hazardous spill response plan in coordination with responsible regulatory entities (e.g., local, state and federal specialized response teams) to guide its initial responses on detection of a spill event.

For a spill event that is caused by a BDCP action, the BDCP Implementation Office will coordinate its response with DFG's Office for Oil Spill Prevention, the Regional Water Quality Control Board, and other state or federal regulatory entities as appropriate to the nature of the spill event to curtail the immediate spread and minimize the effects of the spill. The Implementation Office will also identify and undertake management measures sufficient to remediate the effects of the toxic substance on covered species and affected habitats (i.e., removal or isolation of the material) and restore the ecological functions of the degraded habitat. If the affected habitat areas cannot be practicably and effectively restored, the Implementation Office, through the adaptive management process, will identify and implement measures to contain the ecological effects of the spill and either compensate for the loss of habitat functions at other locations or implement alternative conservation measures (e.g., expanded or additional contaminant reduction measures) that provide equivalent or greater ecological benefits to the affected covered species.

The BDCP Implementation Office is not responsible for the effects of a spill event that is not the result of a BDCP action. If the spill event is not caused by a BDCP action, the BDCP Implementation Office, would coordinate with responsible regulatory agencies and the party(ies) responsible for the spill event to identity the measures that will need to be funded and/or undertaken by the responsible party(ies) to adequately remediate the effects of the spill and restore the ecological functions of the affected habitat.

9. Climate Change

Nature of Changed Circumstance

The BDCP conservation measures were developed to address the range of predicted effects of climate change on sea level and watershed hydrology over the term of the BDCP using the best scientific information available. Consequently, changes in sea level and watershed hydrology that are of greater magnitude or significance than was assumed during the development of the BDCP conservation strategy are considered a changed circumstance.

Planned Response

In the event changes in sea level and watershed hydrology exceed those used to develop the BDCP conservation strategy, no response is required under the BDCP. The BDCP Implementation Office in coordination with the fish and wildlife agencies, however, may identify and adjust implementation of habitat conservation measures through the parameters of the adaptive management program to the extent such adjustments could be effective at moderating the ecological effects of these hydrological changes. Such adaptive management responses may include expanding the range of environmental gradients to provide for shifting species distributions and habitats. Measures beyond those contemplated by the adaptive management program for habitat conservation measures would likely be impracticable and ineffective given the magnitude and pervasiveness of such changes within Plan Area and, as such, are not provided for under the BDCP.

10. Water Temperature Changes

Nature of Changed Circumstance

Changed circumstances related to water temperature changes are defined as those changes in water temperatures within the Plan Area that exceed the tolerance level for one or more covered fish species, such that one or more of the following conditions occur: (a) a covered fish species no longer inhabits BDCP restored habitats; (b) a covered fish species is no longer present in the Plan Area; (c) a covered fish species no longer accrues benefits from BDCP water operations, habitat restoration, or other stressors conservation measures; and/or (d) a covered fish species' population demonstrates a sustained downward trend in abundance.

Planned Response

Significant changes in water temperature within the Plan Area would likely have widespread, catastrophic impacts on ecological conditions within the Plan Area. As such, the effects of water temperature changes would be of such magnitude as to render any response through the BDCP infeasible and no response to changes in water temperature is required under the BDCP. The BDCP Implementation Office in coordination with the fish and wildlife agencies, however, may identify and implement habitat restoration conservation actions within the parameters of the adaptive management program to the extent such actions could be reasonably and practicably effective at moderating the ecological effects of changed water temperatures. For instance, such adaptive management responses may include identifying alternative locations for implementing habitat restoration actions within the Plan Area such that they create areas of cool water refugia or encourage more rapid passage of covered fish species through areas supporting unsuitable water temperatures for covered fish species.

11. Changes in Ocean Conditions

Nature of Changed Circumstance

Changed circumstances that involve changes in ocean conditions are defined as changes in ocean habitat conditions (e.g., water temperature, upwelling) and ecosystem processes (e.g., food web productivity) that support covered anadromous fish species to a degree that biological goals and objectives cannot be achieved for covered anadromous fish species within the Plan Area. For example, changed ocean conditions could result in lower survival of Chinook salmon in the ocean, resulting in fewer adults returning to spawn upstream of the Delta, which could result in population declines.

Planned Response

Adverse effects on covered anadromous fish species and their habitats resulting from changed ocean conditions could not be reasonably or practicably addressed by the BDCP. Actions to remedy those effects would be well-beyond the capacity of the Implementation Office or the Authorized Entities and no response is required under the BDCP.

12. Long-Term Changes in Precipitation and Temperature

Nature of Changed Circumstance

Long-term changes in precipitation and temperature will be considered a changed circumstance in the event that such changes in the timing and amount of rainfall and ambient air temperature in the Plan Area as a result of climate change are of a magnitude sufficient, as jointly determined by the Implementation Office and Fish and Wildlife Agencies, to diminish the benefit to covered species provided by natural communities restored and protected pursuant to the BDCP conservation measures.

Planned Response

Changes in precipitation and temperature patterns in the Plan Area may affect vegetation composition and structure of BDCP protected, enhanced, and restored habitat areas. In the event of this changed circumstance, the BDCP Implementation Office will identify and implement reasonable and practicable actions within the parameters of the adaptive management program to the extent such actions would help to moderate the ecological effects of changes in precipitation and temperature. Such adaptive management responses may include expanding the range of environmental gradients to provide for shifting species distributions and habitats. Measures beyond those contemplated by the adaptive management program would likely be impracticable and ineffective given the magnitude and pervasiveness of such changes within Plan Area and, as such, are not provided for under the BDCP.

6.3.3 Unforeseen Circumstances

The USFWS and NMFS define unforeseen circumstances as those changes in circumstances that affect a species or geographic area covered by an HCP that could not reasonably have been anticipated by the plan participants during the development of the conservation plan, and that result in a substantial and adverse change in the status of a covered species.[17] Under ESA regulations, if unforeseen circumstances arise during the life of the BDCP, USFWS and/or NMFS may not require the commitment of additional land or financial compensation, or additional restrictions on the use of land, water, or other natural resources other than those agreed to in the Plan, unless the BDCP authorized entities consent.

Within these constraints, USFWS and/or NMFS may require additional measures, but only if: (1) the agencies prove an unforeseen circumstance exists; (2) such measures are limited to modifications of the BDCP's operating conservation program for the affected species; (3) the original terms of the Plan are maintained to the maximum extent practicable; and (4) the overall cost of implementing the BDCP is not increased by the modification. USFWS and/or NMFS bear the burden of demonstrating that unforeseen circumstances exist. A finding of unforeseen circumstances must be clearly documented, based upon the best available scientific and commercial information and made considering certain specific factors.[18] If such a finding is made and additional measures are required, the BDCP authorized entities will work with USFWS and/or NMFS to appropriately redirect resources to address the unforeseen circumstances.

Similarly, unforeseen circumstances are defined in the NCCPA as changes affecting one or more species, habitat, natural community, or the geographic area covered by a conservation plan that could not reasonably have been anticipated at the time of plan development, and that result in a substantial adverse change in the status of one or more covered species.[19] The NCCPA further provides that, in the event of unforeseen circumstances, DFG shall not require additional land, water, or financial compensation or additional restrictions on the use of land, water, or other natural resources without the consent of the plan participants for a period of time specified in the Implementation Agreement. However, such assurances are not applicable in those circumstances in which DFG determines that the plan is not being implemented consistent with the substantive terms of the Implementation Agreement. [20]

[17] 50 C.F.R. §17.3; 50 C.F.R. §222.102

[18] These factors include the following: (1) Size of the current range of the affected species; (2) Percentage of range adversely affected by the conservation plan; (3) Percentage of range conserved by the conservation plan; (4) Ecological significance of that portion of the range affected by the conservation plan; (5) Level of knowledge about the affected species and the degree of specificity of the species' conservation program under the conservation plan; and (6) Whether failure to adopt additional conservation measures would appreciably reduce the likelihood of survival and recovery of the affected species in the wild. 50 C.F.R. §17.22(b)(5)(iii)(C); 50 C.F.R. §222.307(g)(3)(iii).

[19] Fish and Game Code §2805(k)

[20] Fish and Game Code §2820(f)(2)

6.3.4 Applicability of Other Federal Endangered Species Act Issues to the BDCP

6.3.4.1 Future Recovery Plans

Recovery plans under the ESA delineate actions necessary to recover and protect federally listed species. However, these plans are not intended to establish obligations of permittees to undertake specific tasks.

The plan participants, USFWS, and NMFS acknowledge that ESA recovery plans will have no effect on the implementation of the BDCP, except to the extent that they may contribute information to the Adaptive Management Program. Any recovery plan applicable to any Covered Species within the Plan Area that is developed after the approval of the BDCP will:

- Not require any additional water, land, or financial compensation be provided by the Authorized Entities;
- Be finalized only after the USFWS or NMFS has conferred with and requested input from the Implementation Office on the preparation of the recovery plan; and
- In no way diminish the take authorizations provided pursuant to the BDCP, the IA, and the companion biological assessment.

6.3.4.2 Future Section 7 Consultations

The USFWS and NMFS will evaluate the direct, indirect and cumulative effects of the Covered Activities in its internal biological opinion that will be issued in connection with the BDCP and issuance of the Section 10(a) permits and the biological opinion that will be issued to Reclamation. Accordingly, in any consultation under Section 7 that occurs after the approval of the BDCP, the USFWS and NMFS will ensure that any biological opinion issued in connection with the proposed project that is the subject of the consultation is consistent with the BDCP biological opinions. The proposed project must be consistent with the terms and conditions of the BDCP and the IA. Any reasonable and prudent measures included under the terms and conditions of a biological opinion issued subsequent to the approval of the BDCP with regard to the Covered Species and Covered Activities will, to the maximum extent appropriate, be consistent with the measures of the BDCP and the IA. Neither the USFWS nor NMFS will impose measures in excess of those that have been or will be required by the Authorized Entities pursuant to the BDCP, the IA, or the companion biological assessment.

6.4 Permit Duration and Renewal, Plan Amendments, Permit Suspension and Revocation

6.4.1 Permit Duration and Extension

The Plan Participants are seeking take authorizations from the state and federal fish and wildlife agencies with terms of 50 years. The term of the take authorizations issued under the BDCP would begin from the date of their issuance. Prior to their expiration, the authorized entities may apply to the fish and wildlife agencies to renew their take permits. The Permittees will initiate the permit renewal process prior to the expiration of the initial 50-year period and with ample time to allow for the review and processing of the permit renewal.

The proposed 50-year term is necessary to achieve the overall BDCP goals of water supply reliability and ecosystem restoration. Many of the key elements of the BDCP, including the development of substantial new water conveyance infrastructure, restoration of tidal and estuarine habitats, restoration of seasonal floodplain habitat, and establishment and maturation of riparian forest habitat will require substantial commitments of funding and an extended period of time to fully implement. The duration of the permits must be sufficient to justify such expenditures of funds, allow for proper sequencing and effective implementation of the actions contemplated by the Plan, and afford regulatory stability with respect to the operation of the primary water delivery systems for the state of California. A permit term of 50 years provides a practicable time frame in which to carry out the activities that will be authorized under the Plan, including adaptive management strategies, and maximize the benefits of these activities to species and their habitats.

6.4.2 BDCP Administrative Actions That Do Not Require Modification or Amendment

The administration and implementation of the BDCP will require frequent and ongoing interpretation of the provisions of the Plan. Actions taken on the basis of these interpretations that do not substantively change the purpose or intent of the plan provisions will not require modification or amendment of the BDCP or its associated authorizations. Such actions related to the ordinary administration and implementation of the BDCP may include, but are not limited to, the following:

- Clerical corrections to typographical, grammatical, and similar editing errors that do not change the intended meaning; or to maps or other exhibits to address insignificant errors.
- Adaptive management changes to conservation measures, including actions to avoid, minimize, and mitigate impacts, or modifications to habitat management strategies developed through and consistent with the Adaptive Management Program described in Chapter 3.

- Variations in the day-to-day management of reserve system lands, such as adjusting irrigation schedules for created or restored habitat on the basis of observed water needs of planted vegetation;
- Adaptations to the design of directed studies;
- Adjustments to monitoring protocols to incorporate new protocols approved by the Fish and Wildlife Agencies;
- Administration of the Implementation Office;
- Changes in the membership of BDCP advisory committees.

6.4.3 Minor Modifications or Revisions

As part of the process of plan implementation, the Implementation Office will likely need to make minor changes ("Minor Modifications or Revisions") to the BDCP from time to time to respond appropriately to new information, scientific understanding, technological advances, and other such circumstances. Minor Modifications or Revisions will in many instances be technical in nature and will not involve changes that would adversely affect covered species, the level of take, or the obligations of Authorized Entities. The process for implementing Minor Modifications or Revisions is set forth in Section 6.4.3.1 below.

Minor Modifications or Revisions may include, but are not limited to, the following circumstances:

- Minor corrections to land ownership descriptions;
- Changes to survey, monitoring, reporting and/or management protocols that do not adversely affect Covered Species or habitat functions and values;
- Transfers of targeted acreages between ROA consistent with criteria set out in Chapter 3, *Conservation Strategy*;
- Transfers of targeted habitat acreages among BDCP Conservation Zones provided such change does not preclude meeting preserve assembly requirements, significantly increase the cost of the BDCP management or preclude achieving Covered Species and natural community goals and objectives; and
- Extensions of earth moving or ground disturbance outside the rights-of-way limits analyzed in the BDCP for covered activities involving infrastructure development or habitat restoration.
- Updates/corrections to the vegetation or other resource maps and/or species occurrence data.
- Other proposed changes to the Plan that the permitting agencies have determined to be insubstantial and appropriate for implementation as a Minor Amendment

6.4.3.1 Procedures for Minor Modifications or Revisions

The Implementation Office, the Authorized Entities, or the fish and wildlife agencies may propose Minor Modifications or Revisions by providing written notice to the Implementation Office, Authorized Entities, and fish and wildlife agencies. Such notice will include a description of the proposed Minor Modifications or Revisions, an explanation of the reason for the proposed Minor Modifications or Revisions, an analysis of its environmental effects including any impacts to Covered Species, and an explanation of why the effects of the proposed Minor Modifications or Revisions would not:

1. Significantly differ from, and would be biologically equivalent to, the effects described in the BDCP, as originally adopted;
2. Conflict with the terms and conditions of the BDCP, as originally adopted; and
3. Significantly impair implementation of the BDCP Conservation Strategy.

The fish and wildlife agencies and/or the Authorized Entities may submit comments on the proposed Minor Modification or Revision in writing within sixty (60) days of receipt of notice. If any Authorized Entity disagrees with the proposed Minor Modification or Revision for any reason, the Minor Modification or Revision will not be incorporated in the BDCP. If the fish and wildlife agencies do not concur that the proposed Minor Modification or Revision meets the requirements for a Minor Modification or Revision, the proposal must be approved according to the Amendment process. Any Authorized Entity or fish and wildlife agency may institute the informal meet and confer process set forth in the BDCP Implementing Agreement to resolve disagreements concerning a proposed Minor Modifications or Revisions.

If the Authorized Entities are in agreement regarding the proposed Minor Modification or Revision, and the fish and wildlife agencies concur that the requirements for a Minor Modification or Revision have been met and the modification or revision should be incorporated in the Plan, the BDCP will be modified accordingly. If any fish and wildlife agency fails to respond within the 60-day period to the written notice, the agency will be deemed to have approved the proposed Minor Modification or Revision.

6.4.4 Formal Amendment

Under some circumstances, it may be necessary to substantially amend the BDCP. Any proposed changes to the BDCP that do not qualify for treatment under Sections 6.4.2 or 6.4.3 will require Formal Amendment. Formal Amendment to the BDCP will also require corresponding amendment to the Authorizations/Permits, in accordance with applicable laws and regulations regarding permit amendments. The BDCP Implementation Office will be responsible for submitting any proposed Amendments to the fish and wildlife agencies.

Amendments to the BDCP will likely occur infrequently. The process for making Formal Amendments is set forth in Section 6.4.4.1 below. Formal Amendments include, but are not limited to, the following:

- Substantive changes to the boundary of the Plan Area, other than those associated with the acquisition of terrestrial habitat within the surrounding Delta counties, as described in Section 1.4.1, *Geographic Scope of the Plan Area*;
- Additions of species to the Covered Species list;
- Substantial changes in implementation schedules that would have significant adverse effects on the Covered Species;
- Changes in water operations conservation measures or covered water operations that are outside of the ranges established in the Plan for water operations.

6.4.4.1 Process for Formal Amendment

Formal Amendments will involve the same process that was required for the original approval of the BDCP. In most cases, an Amendment will require public review and comment, CEQA/NEPA compliance, and intra-Service Section 7 consultation. Amendments will be subject to review and approval by the Implementation Office and the Permittees. The Fish and Wildlife Agencies will use reasonable efforts to process proposed Amendments within one hundred eighty (180) days.

6.4.5 Suspension of the Federal Permits

Under certain circumstances defined by federal regulation, USFWS or NMFS may suspend, in whole or in part, the regulatory authorizations they issue under the BDCP. However, except where USFWS or NMFS determines that emergency action is necessary to avoid irreparable harm to a Covered Species, it will not suspend an authorization without first (1) attempting to resolve the issue through the informal dispute resolution process set forth in the BDCP Implementing Agreement, and (2) identifying the facts or action/inaction which may warrant the suspension and providing the Implementation Office a reasonable opportunity to implement appropriate responsive actions. Any decision to suspend one or both federal permits must be in writing and must be signed by the Secretary of the Interior and/or the Secretary of Commerce, as the case may be.

6.4.5.1 Reinstatement of Suspended Federal Permit

If USFWS or NMFS suspends a federal permit, as soon as possible but no later than 10 days after the suspension, it will meet and confer with the Implementation Office and Permittees to discuss how the permits can be reinstated. At the conclusion of the meeting, USFWS/NMFS will identify reasonable, specific actions needed to address the suspension. Upon performance or completion of the actions, USFWS and/or NMFS will immediately reinstate the federal permit.

It is the expectation of the BDCP participants that the federal fish and wildlife agencies and the permit holders will strive to reinstate the Federal Permit as soon as possible.

6.4.5.2 Revocation of the Federal Permits

Unless immediate revocation is necessary to avoid the likelihood of jeopardy to a listed species, USFWS and NMFS will not revoke the Federal Permits unless the Authorized Entities fail to fulfill their obligations under the BDCP, and only after (1) completing the informal dispute resolution process described in the BDCP Implementing Agreement, and (2) identifying the actions/inactions that may warrant the revocation and giving the Implementation Office a reasonable opportunity to implement appropriate responsive actions. USFWS and NMFS will revoke or terminate a Federal Permit to avoid the likelihood of jeopardy to a listed species only in accordance with the Federal Permit Revocation Rule as described below. Any decision to revoke one or both Federal Permits must be in writing and must be signed by the Secretary of the Interior and/or the Secretary of Commerce, as the case may be.

6.4.5.3 The Federal Permit Revocation Rule

The No Surprises rule, as promulgated in 1998, did not address circumstances in which a species covered by a permitted HCP experienced significant decline and the continuation of an activity covered by the HCP would contribute to the likelihood of jeopardy to the species. To address such circumstances, the USFWS issued a regulation in 2004, known as the "Permit Revocation Rule," that allows the FWS to nullify regulatory assurances granted under the No Surprises rule and revoke the Section 10 permit only in specified instances, including where continuation of a permitted activity would jeopardize the continued existence of a species covered by an HCP and the impact of the permitted activity on the species has not been remedied in a timely manner.[21]

In the event that such unforeseen circumstances were to arise under the BDCP, the USFWS and/or NMFS would work with the BDCP Implementation Office and the Authorized Entities to obviate the need for such a revocation. The federal Fish and Wildlife Agencies would engage in the following process prior to taking any steps to revoke the BDCP permits:

1. The BDCP Implementation Office and the Fish and Wildlife Agencies would determine, through the adaptive management process, whether changes can be made to the BDCP's operating conservation program to remedy the situation.
2. The USFWS and/or NMFS would determine whether the Fish and Wildlife Agencies or other state and federal agencies can undertake actions that would remedy the situation. It is recognized that the fish and wildlife agencies have available a wide array of authorities and resources that can be used to provide additional protection for the species, as do other state and federal agencies.

[21] 69 Fed. Reg. 71723, December 10, 2004

3. The Implementation Office and the Fish and Wildlife Agencies will determine whether there are additional voluntary conservation actions that the Implementation Office could undertake to remedy the situation.

The USFWS and/or NMFS would only begin the revocation process if no solutions are found and it is determined that the continuation of a BDCP covered activity would appreciably reduce the likelihood of survival and recovery for one or more covered species and that no remedy can be found and implemented. The USFWS and/or NMFS would follow the administrative procedures set out in the BDCP IA and the regulations implementing the Permit Revocation Rule (50 C.F.R. §§ 13.28 & 13.29).

6.4.6 Suspension or Revocation of the State Permit

The NCCPA requires that the implementation agreement include specific terms and conditions that, if violated, result in suspension or revocation of the Section *2835* take permit. Such terms and conditions must include suspension or revocation of the permit if the plan participants fail to provide adequate funding to implement the plan; do not maintain proportionality between impacts on habitats or covered species and conservation measures; adopt or approve changes to the plan that are not consistent with the objectives and requirements of the approved plan without concurrence of the wildlife agencies; or allow the level of take to exceed the permit limits.[22] The DFG must also suspend or revoke a Section 2835 take permit if continued take would result in jeopardy to a species.[23]

If the Authorized Entities violate the terms and conditions of the state permits, or if necessary to avoid jeopardizing the continued existed of a listed species, DFG may suspend or revoke the permits in whole or in part. However, unless immediate revocation is necessary to avoid the likelihood of jeopardy to a listed species or to address rough proportionality (see below), DFG will not suspend or revoke the state permits without first (1) attempting to resolve any disagreements regarding the implementation or interpretation of the BDCP or this Agreement in accordance with the informal dispute resolution process provided in the BDCP Implementing Agreement, and (2) notifying the Implementation Office and permittees of the action/inaction that may warrant the suspension or revocation and providing the Implementation Office and permittees with a reasonable opportunity to take appropriate responsive action. Any decision to suspend or revoke one or both state permits must be in writing and must be signed by the Director of DFG.

6.4.6.1 Failure to Maintain Rough Proportionality

The NCCPA requires revocation of a Section 2835 take permit, in whole or in part, if the plan participants do not maintain rough proportionality between impacts on habitats or covered

[22] Fish and Game Code § 2820(b)(3).
[23] California Fish & Game Code section 2823.

species and conservation measures and do not, within 45 days, remedy such condition or develop a plan with the DFG to provide a remedy.[24]

Rough proportionality will be maintained by implementing the conservation measures substantially in accordance with the agreed upon Plan Implementation Schedule. If DFG determines, after conferring with USFWS, NMFS and the Implementation Office, that rough proportionality is not being maintained, the Implementation Office, permittees, and DFG will meet and confer and, within 45 days of DFG's determination, agree on adjustments to the Implementation Schedule to expeditiously regain rough proportionality. Adjustments to the Implementation Schedule may include any of a variety of commitments or adjustments to BDCP implementation designed to regain rough proportionality, including advancing and/or accelerating plans to acquire, restore, or enhance lands of the appropriate land cover type. The Implementation Office will implement all actions set forth in the agreed upon adjusted Implementation Schedule. As an alternative to the agreement, the Implementation Office may regain rough proportionality within forty-five (45) days by implementing the actions according to the existing Implementation Schedule.

6.4.6.2 State Permit Suspension and Revocation Steps

In the event that such circumstances for permit revocation or suspension were to arise under the BDCP, the DFG would work with the BDCP Implementation Office and the permittees to obviate the need for permit revocation or suspension. The DFG would engage in the following process prior to taking any steps to revoke the BDCP permits:

1. In the event of a failure to maintain rough proportionality, the BDCP Implementation Office will work with DFG to remedy the situation though schedule adjustments as described in Section 6.4.6.1 above and in accordance with the Implementation Agreement. Note that the BDCP monitoring program is designed to identify such issues and that the Implementation Office must report such issues in annual reports.
2. For other situations that could result in permit revocation or suspension or if rough proportionality cannot be regained through schedule adjustments, the BDCP Implementation Office, Permittees, and the DFG would determine, through the adaptive management process, whether other changes can be made to the BDCP's operating conservation program to remedy the situation.
3. The DFG would determine whether the DFG or the federal fish and wildlife agencies or other state and federal agencies can undertake actions that would remedy the situation. It is recognized that the fish and wildlife agencies have available a wide array of authorities and resources that can be used to provide additional protection for the species, as do other state and federal agencies.

[24] Fish and Game Code §-2820(c).

4. The Implementation Office and DFG will determine whether there are additional voluntary conservation actions that the Implementation Office could undertake to remedy the situation.

The DFG would only begin the revocation or suspension process if no solutions are found and it is determined that the continuation of a BDCP covered activity would result in jeopardy to a species or violate any of the terms and conditions for permit revocation or suspension identified in the IA.

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CHAPTER 7. IMPLEMENTATION STRUCTURE

[***Note to Reviewers:*** *This draft of Chapter 7, Implementation Structure, includes revisions to the November 4, 2010 draft provided to the Steering Committee. Prior drafts of this chapter have been reviewed by the Steering Committee on the following dates: October 22, 2009, October 20, 2010, November 4, 2010. The consultant and certain committee members revised the November 4, 2010 draft in response to comments made by the Steering Committee at the November 4, 2010 meeting; these revisions have not been reviewed by the Steering Committee, to date. The chapter reflects input from a wide range of agencies and stakeholders over several years of development. Although certain issues will require further discussion, this draft reflects a general agreement on both the overall approach and many of the specific details related to an implementation structure for the BDCP. While the text of this chapter is subject to change and revision as the BDCP planning process progresses, the chapter has been drafted and formatted to appear as it may in a completed draft HCP/NCCP. Although the chapter includes declarative statements (e.g., the Implementation Office will…), it is nonetheless a "working draft" that will undergo further modification based on input from the BDCP Steering Committee, state and federal agencies, and the public.*]

This chapter describes the institutional structure and organizational arrangements that will be established to govern and implement the BDCP, and sets out the roles, functions, authorities, and responsibilities of the various entities that will participate in plan implementation. The implementation structure is designed to ensure that sufficient institutional expertise, capacity, resources, and focus are brought to bear to accomplish the goals and objectives of the BDCP.

The BDCP implementation structure will help ensure effective and efficient plan implementation and ongoing compliance with the terms and conditions of the plan and its associated regulatory authorizations. This implementation approach will also facilitate the clear delineation of roles and responsibilities among the range of public and private entities participating in the process and help define the nature of their engagement. This approach further reflects the commitment to maintain and encourage ongoing collaboration among the range of public and private parties with interest in the Delta, and to facilitate adaptive and responsive plan implementation, guided by new information and scientific understanding.[1]

The approaches to plan governance set out in this chapter have been designed solely to facilitate the implementation of BDCP actions. If over the course of plan implementation matters arise that are outside the scope of the BDCP, any proposed actions related to those new matters may be implemented through the BDCP only upon appropriate modifications and/or amendments to the Plan.

[1]The BDCP implementing agreement includes additional detail regarding the roles and responsibilities of the authorized entities, the Implementation Office, and the fish and wildlife agencies regarding the implementation of the Plan.

The BDCP implementation structure will be organized around a Program Manager who will direct a new "BDCP Implementation Office" (IO), and have responsibility for plan implementation and oversight (Figure 7-1). The BDCP Program Manager will coordinate implementation actions with the authorized entities (i.e., all entities receiving permits or other authorizations under ESA, NCCPA, and/or CESA), the State and federal contractors, the fish and wildlife agencies, and a range of stakeholders and other interests. The State and federal fish and wildlife agencies will maintain the roles described in this chapter to assure that such implementation is consistent with regulatory authorizations issued pursuant to the BDCP. In addition, a "BDCP Implementation Board" will be established to assist with BDCP implementation, and will consist of representatives of the Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Reclamation), the State and Federal Contractor Water Authority (SFCWA), the State and federal fish and wildlife agencies, and certain other entities as described later in this chapter. Additionally, a "BDCP Stakeholder Committee" will be created to serve as a forum in which other public agencies, non-governmental organizations, interested parties, and the public may offer recommendations regarding BDCP implementation. The Implementation Office will also coordinate with the Delta Stewardship Council, Delta Science Program, Sacramento-San Joaquin Delta Conservancy (Delta Conservancy), and Delta Protection Commission to ensure appropriate engagement and collaboration on matters of common interest. This approach to plan implementation is expected to ensure the timely, efficient, and proper implementation of the commitments reflected in the BDCP.

[***Note to Reviewers*****:** *Additional text will be added to clarify the role of Mirant LLC in the implementation of the BDCP*.]

7.1 Roles and Responsibilities of Entities Involved in BDCP Implementation

The BDCP Program Manager will be selected to oversee and manage the implementation of the BDCP, and to ensure that implementation proceeds in compliance with the Plan, the Implementing Agreement, and the associated regulatory authorizations. The Program Manager will manage the Implementation Office (IO). Various other parties will be integral to the process of shaping decisions and effectuating actions set out in the BDCP. This section describes the roles and responsibilities of the Program Manager, the IO, and of the various other participants in the implementation process.

7.1.1 The BDCP Program Manager and Implementation Office

7.1.1.1 Program Manager: Selection and Designation of Staff

A single BDCP Program Manager will be responsible for BDCP implementation and will direct and oversee the IO. The *"major authorized entities"* will each designate a lead representative from their respective agencies to assist the Program Manager with plan implementation. The Program Manager may fulfill the staffing needs of the IO by drawing from existing personnel at

DWR, Reclamation, SFCWA, and other sources, as appropriate. Staff of the IO, many of whom will be assigned to the IO by DWR, Reclamation, or other entities, will act under the direction of the Program Manager. The engagement of personnel from DWR, Reclamation, and other entities in the IO, however, will not affect or modify the existing authorities of federal, state, and local agencies or non-governmental organizations that pertain to personnel matters

The *major authorized entities* (including DWR and Reclamation) for the BDCP will solicit candidates for the Program Manager position, and will provide their recommendations to the Implementation Board for acceptance. A definition of "*major authorized entities*" is provided in Section 7.1.2 *Authorized Entities*. The *major authorized entities* will, by consensus, select the Program Manager after taking into account the views of other Implementation Board members, and after consulting with the federal and State fish and wildlife agencies. The general qualifications of the Program Manager will have:

- A minimum 10 years experience in the field of natural resources management;
- Familiarity with complex natural resources issues, including water resources issues;
- Experience with State and federal regulatory processes that affect water and other natural resources that fall within the scope of the BDCP;
- Experience with multi-stakeholder processes;
- Experience with the administration or management of large-scale programs or projects; and
- Excellent communication skills.

The specific roles and responsibilities of the Program Manager are described in further detail in Section 7.2, *Implementation Office Administration*, Section 7.3, *Implementation of the Conservation Strategy*, and Section 7.4, *Regulatory Compliance Related to BDCP Implementation*, and Section 7.5, *Public Outreach*.

7.1.1.2 Science Manager: Selection and Function

The Program Manager will select a Science Manager to assist in the implementation of the BDCP and to ensure that such implementation decisions are guided by the best available scientific information. The Program Manager will consult with the Implementation Board in the selection of the Science Manager. The Science Manager will report to the Program Manager. Specifically, the responsibilities of the Science Manager include:

- Assist in the administration and implementation of the adaptive management program;
- Oversee the implementation of the BDCP monitoring and research program, with the assistance of the IEP;
- Oversee the implementation of the BDCP adaptive management program;

- Engage in regular communication and coordination with the Delta Science Program and coordinate with the Independent Science Board as well as other outside scientists to gather independent scientific information and solicit input and review, as needed;
- Support the Program Manager in the preparation of reports and other technical documents; and
- Assist in building sufficient scientific capacity and resources within the IO.

Matters relating to the conduct of scientific reviews and the solicitation of independent scientific advice to assist in the implementation of the BDCP will be conducted by the Science Manager in a manner that ensures their independence and scientific integrity.

Minimum requirements for the Science Manager will be:

- Educational and professional background in relevant scientific discipline,
- At least 10 years experience in the management of large programs,
- Experience managing or senior involvement in large scale research or monitoring programs, and
- Knowledge of issue related to the Delta.

7.1.1.3 Implementation Office: Establishment, Organization, and Functions

The BDCP IO, under the direction of the Program Manager (Section 7.1.1.1), will implement, coordinate, oversee, and report on all aspects of plan implementation. (Figure 7-1). The Program Manager will use the IO staff to assure that the BDCP conservation measures, including those related to protection and restoration of habitat; reduction of ecological stressors; management of conserved habitat; and operation of the water projects, including the development of infrastructure (in its oversight role to ensure plan compliance), are properly implemented throughout the life of the Plan. The Program Manager will use the IO staff to oversee and effectuate the adaptive management program; monitoring, data collection, and scientific research efforts; annual and five-year work plans, budget, and report preparation; and the public outreach process. To ensure that the commitments reflected in the BDCP are carried out in a timely and efficient manner, the Program Manager, through the IO, will institute processes and procedures to adequately address planning, budgeting, sequencing, and scheduling needs related to plan implementation.

The IO may enlist other entities to carry out actions associated with conservation measures or other implementation tasks on behalf of the IO (see "Supporting Entities," below). Notwithstanding the assignment of such responsibilities to other entities to implement projects or actions, the IO will be responsible for ensuring that the work is performed in a manner that complies with the terms and conditions of the BDCP and its associated regulatory authorizations and are properly and fully implemented. As part of that responsibility, the IO will engage and monitor those entities that become involved in aspects of plan implementation. The Program Manager will oversee and coordinate the management of contracts with these other entities to assist in the implementation of the BDCP. Those entities, and the roles and responsibilities they are likely to assume, are generally identified in this chapter and depicted in the organizational framework in Figure 7-1.

The IO will function with a significant level of independence and autonomy from its member entities. The staff of the IO will work closely with these agencies on a range of matters, particularly with respect to actions that affect water operations.

The IO will not be involved in the development or operation of SWP and/or CVP facilities; instead, it will monitor water operations to assemble the information necessary to evaluate and report on compliance with the terms and conditions of the Plan and the authorizations/permits. The BDCP sets out the parameters within which DWR and the Reclamation will carry out CVP and SWP operations and infrastructure development. DWR and Reclamation may chose to operate the projects and develop new infrastructure using their current organizational capacity or by contract with other entities.

The IO will budget for and oversee and coordinate management of the funds and other resources needed to carry out its responsibilities for plan implementation. The authorized entities will dedicate, hold, and release funds and resources necessary for plan implementation, and will not comingle these funds with other funds or resources of the agencies. The authorized entities will be responsible for all appropriated funds and other funds entrusted to them.

The IO will assume responsibility for the implementation of a broad range of actions, including:

- Oversight and coordination of administration of program funding and resources;
- Preparation of annual budgets and work plans;
- Establishment of procedures to implement plan actions;
- Oversight of and engagement in the implementation of conservation measures;
- Management of the monitoring and research and adaptive management programs;
- Implementation of public outreach program; and
- Fulfillment of compliance monitoring and reporting requirements.

The Program Manager will also have responsibility for coordinating with the Delta-wide governance entities (Section 7.2.7. *Coordination with the Delta Stewardship Council, the Delta Science Program, and the Delta Conservancy*) and managers of upstream operations.

The specific roles and responsibilities of the IO are described in further detail in sections 7.2 *Implementation Office Administration*, 7.3 *Implementation of the Conservation Strategy*, and 7.4 *Regulatory Compliance Related to BDCP Implementation*, and 7.5 *Public Outreach*.

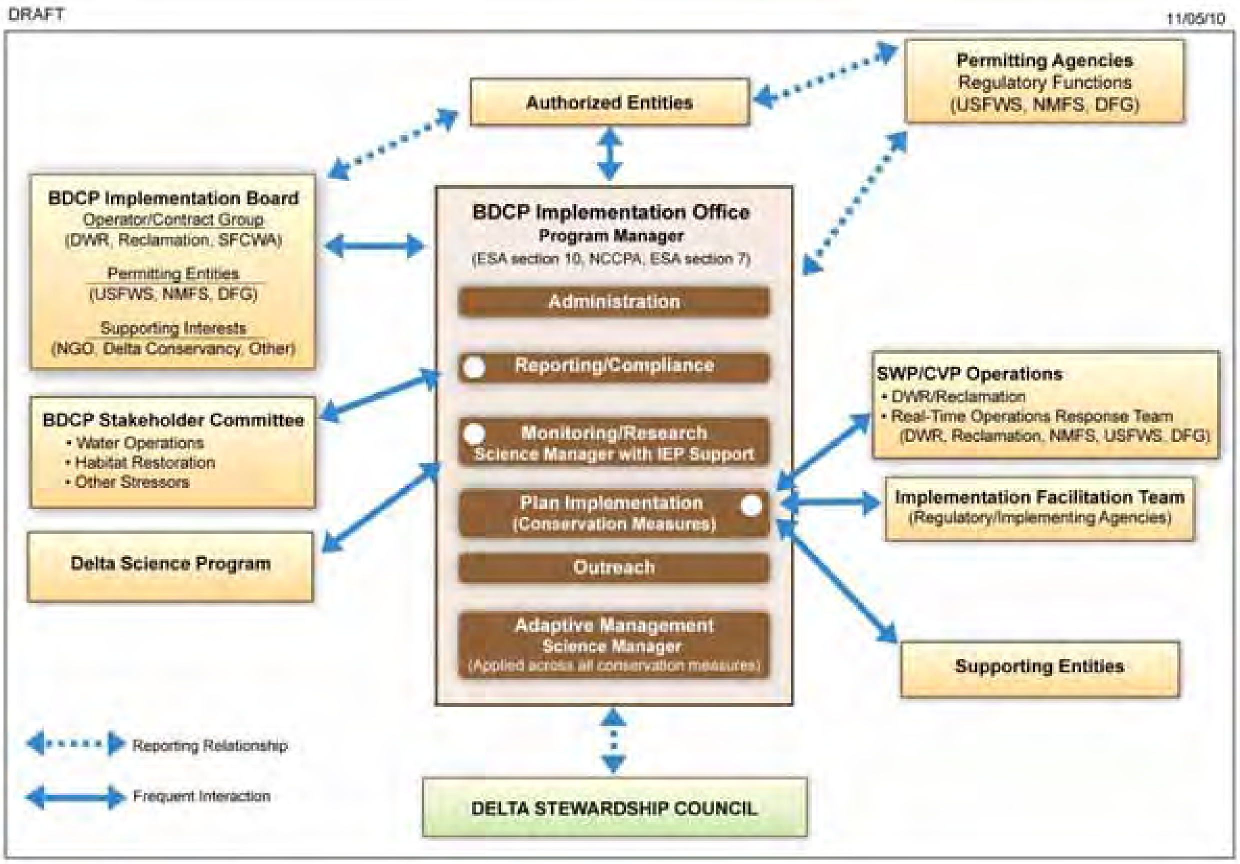

Figure 7-1. BDCP Implementation Structure

7.1.1.4 Assignment of Responsibilities

To effectively implement the BDCP, the Program Manager will be assigned certain responsibilities by DWR and/or Reclamation. DWR and/or Reclamation will provide the Program Manager with sufficient capacity and capability to effectively implement the BDCP and will explicitly define the scope of responsibilities assigned to the Program Manager.

7.1.1.5 No Delegation of Authority

The assignment of responsibility to the Program Manger will not alter or modify existing authorities, mandates, and obligations of the participating State and federal agencies. No general delegation of authority by DWR and/or Reclamation to the Program Manager or one of their employees assigned to the IO will occur, although specific delegation may occur in the event that it is considered by the delegating agency to be beneficial to the efficient operation of the IO. Any such delegation will be conferred, in writing, by the appropriate delegating agency to the appropriate individual within the IO, and will be reviewed by that agency from time to time.

7.1.2 Authorized Entities

[***Note to Reviewer:*** *At this time, a final list of authorized entities under the BDCP has not been developed (i.e., all entities receiving permits or other authorizations under the ESA and the NCCPA). DWR, Reclamation, and Mirant will be authorized entities. In addition, the SFCWA may also be an authorized entity, but this issue is still under consideration. The term "major authorized entities" is used in this chapter, but has not yet been defined. DWR and Reclamation will be included in this category. The SFWCA may be a major authorized entity, but this decision is still under consideration.*]

The BDCP provides the basis for the issuance of regulatory authorizations, under the federal Endangered Species Act (ESA), the California Natural Community Conservation Planning Act (NCCPA) (and potentially the California Endangered Species Act [CESA]), for the incidental take of listed fish and wildlife species that result from Delta water operations and other covered activities (Chapter 4, *Covered Activities).* The entities that receive incidental take authorizations for activities covered under the BDCP are referred to collectively as the "*authorized entities*." Incidental take authorizations will be sought by federal and non-federal entities under the following authorities:

- non-federal entities will seek regulatory coverage pursuant to ESA section 10(a)(1)(B), NCCPA section 2835, and potentially CESA section 2081 or 2080.1 (if applicable), and
- federal agencies will seek regulatory coverage under ESA section 7(a)(2) for federally-listed species.

Each authorized entity will retain full responsibility for proper implementation of the BDCP and compliance with the terms and conditions of the associated regulatory authorizations, regardless of whether another entity is tasked with responsibility for carrying out a required action.

However, the authorized entities and the Program Manager may enter into agreements individually, amongst themselves, or with other entities to designate responsibility for carrying out certain actions under the plan.

The following entities are "authorized entities" for the purpose of the BDCP and its regulatory authorizations. Descriptions of the activities that will be covered under the regulatory authorizations issued to the authorized entities are set out in Chapter 4, *Covered Activities*. The activities identified or described in this document for Federal actions by Reclamation are not "covered activities" for the purposes of the ESA Section 10(a)(1)(b) permit. Reclamation's activities are subject to ESA Section 7 and Reclamation is seeking authorization under ESA section 7 for their actions.

7.1.2.1 California Department of Water Resources

The State of California owns, and DWR manages and operates, the State Water Project's (SWP) existing Delta facilities, including the Clifton Court Forebay and the Banks Pumping Plant. Pursuant to the BDCP, DWR seeks State and federal regulatory authorizations to continue to operate such facilities. The State of California, through DWR, will construct, own, and operate any new diversion and conveyance facilities described in this plan.

7.1.2.2 United States Bureau of Reclamation

The United States owns, and Reclamation operates, the Central Valley Project's (CVP) existing Delta facilities, including the Jones Pumping Plant and the Delta Cross Channel. Consistent with the BDCP, Reclamation seeks federal regulatory authorizations through section 7 consultation for incidental take of listed species from project operations in and upstream of the Delta. Reclamation will likely enter into an agreement with DWR to wheel CVP water through a new conveyance facility.

7.1.2.3 Mirant Corporation

Mirant owns and operates the Pittsburg and Contra Costa Power Plants located in Pittsburg and Antioch. Mirant seeks regulatory permits under ESA section 10 and Fish and Game Code section 2835 for incidental take of listed species from operation of those plants.

7.1.2.4 Major Authorized Entities

DWR and Reclamation will be considered "*major authorized entities*." As *major authorized entities*, DWR and Reclamation will assume a number of specified responsibilities under the

Plan, such as selecting the Program Manager. Mirant[2] will be an authorized entity, but will not be a *major authorized entity*.

7.1.3 Implementation Board

A BDCP Implementation Board will be established to help guide the IO in the implementation of the Plan. Specifically, the Board will provide input to the IO on the proposed Annual Work Plan and Budget, including the anticipated IO actions associated with the adaptive management program and the proposed habitat acquisition and restoration targets. The Board's review of the work plan and budget will focus primarily on the programmatic aspects of the proposed actions. The involvement of the Board in plan implementation is not intended to constrain the Program Manager in day-to-day decision making.

7.1.3.1 Membership

The Implementation Board will consist of approximately 10 members, including DWR, Reclamation, the SFCWA, the State and federal fish and wildlife agencies, and certain other entities (including an NGO and the Delta Conservancy) that will have a significant role in supporting the implementation of the Plan. [***Note to Reviewers:*** *The specific NGO representative, as well as other supporting board members, and the process for future selection of those representatives will be reflected in a later draft of this chapter.*]

7.1.3.2 Function

The Program Manager will organize, convene, and provide support for the Implementation Board and its proceedings.[3] The Implementation Board will receive information from the Program Manager and other sources on the implementation of the BDCP generally, and will have the opportunity to review the proposed Annual Work Plan and Budget, including the targeted acquisitions of land and water interests and the major aspects of anticipated adaptive management actions.

The primary function of the Implementation Board will be to review and concur with the Annual Work Plan and Budget as proposed by the Program Manager. The content of the Annual Work Plan and Budget and the timing of preparation and submission of the document to the Implementation Board are described in Section 6.2 *Compliance and Progress Reporting*. The Annual Work Plan and Budget will be deemed to be "final" once (i) accepted by the Board or (ii) objections to the work plan and budget are resolved through the final decisional authorities (see *Dispute Resolution*, below). The Board will be convened by the Program Manager periodically through the year, as needed, to review issues that arise in the implementation of the annual plan.

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[2] Mirant will be responsible for all of their own operations separate from the operations of the SWP, CVP, and any other entities involved in BDCP implementation. Mirant will be responsible for implementing BDCP actions specifically identified for them in the BDCP. Mirant may become a member of the Stakeholder Committee.

[3] If the Program Manager position is vacant, then DWR and Reclamation will serve this role.

The Program Manager may request that the Board reconvene to consider proposed amendments to the Annual Work Plan and Budget.

The Implementation Board will consider such matters as:

- Candidates for the Program Manager position;
- Annual work plans and budgets; and
- Adaptive management changes.

The Implementation Board will hold a minimum of two meetings per year. The Implementation Board meetings will be public as provided by applicable law.

7.1.3.3 Dispute Resolution

With respect to those matters that are considered by the Implementation Board, it is expected that reasonable efforts will be made to provide input to the Program Manager that reflects acceptance by the members. A board member, however, will have the right to object to any proposal of the Program Manager concerning the annual work plans, budgets, the acquisition of land and water interests, and the major elements of the adaptive management program. Any objections will be made solely on the basis that the proposal (i) will not adequately contribute to achievement of the goals and objectives of the BDCP or (ii) is inconsistent with the requirements of the Plan and/or the permits/authorizations.

The board member may elevate the matter to the regional director(s) of the relevant federal agency, to the director(s) of the relevant state agency, or to other appropriate authorities, as determined by the locus of responsibility for the action (see examples below). A simplified process for considering and responding to such objections in an orderly and timely manner will be established, including a process to elevate appropriate matters for decision to the responsible official, be it a federal or State cabinet-level official or their designee, or another corresponding authority for other locus of responsibility entities, such as a Delta Conservancy, the SFWCA, or a State or federal water contractor. As required by existing law, final responsibility for plan implementation and permit compliance will remain with the holders of those permits and authorizations. The objection procedures and dispute resolution process may not be used to delay the completion and/or implementation of the Annual Work Plan and Budget.

Examples of locus of responsibility:

- DWR would be responsible for actions that affect facilities or operations of the SWP;
- Reclamation would be responsible for actions that affect facilities or operations of the CVP;
- SFCWA would be responsible for actions that would result in changes to costs of conservation measures for which they have provided funding;

- Delta Conservancy would be responsible for projects charged to the Delta Conservancy through future specific State legislation or bond requirements.

*[**Note to Reviewers**: Implementation Board dispute resolution procedures will be developed for the Plan in a later version of this chapter and/or the Implementing Agreement.]*

7.1.4 DWR and Reclamation: Operation of the SWP and CVP

Implementation of the conservation measures related to water facilities and water operations, as described in Chapter 3 *Conservation Strategy*, will be the responsibility of DWR and Reclamation or entities with whom they may contract. DWR and Reclamation will retain their authority to operate the SWP and the CVP within the parameters of the BDCP and other applicable laws and regulations.

The federal and state operators of the CVP and the SWP will prepare coordinated operation strategies for the federal and state Projects, including the Annual Water Operations Strategy as described in as described in Section 6.2, *Compliance and Progress Reporting*. The IO will incorporate the Annual Water Operations Strategy into the BDCP Annual Work Plan and Budget (as described in Section 6.2, *Compliance and Progress Reporting*).

Decisions related to "real time" water operations will be the responsibility of the Real Time Response Team, as described in Section 7.3.2, *Implementation of Water Operations Conservation Measures*.

7.1.5 Permitting Agencies: Fish and Wildlife Agencies

On the basis of the BDCP, the State and federal fish and wildlife agencies (USFWS, NMFS, and DFG) will issue regulatory authorizations to the authorized entities pursuant to the federal ESA and the NCCPA. Consistent with their authorities under these laws, the fish and wildlife agencies will retain responsibility for enforcing the terms and conditions of the permits and regulatory authorizations. The fish and wildlife agencies retain full responsibility to: (i) determine whether implementation of the BDCP is proceeding in compliance with the terms and conditions of the regulatory authorizations, (ii) enforce the terms and conditions of the regulatory authorizations,, and (iii) modify, suspend, or revoke regulatory authorizations, consistent with the terms and conditions of the Plan, the Implementing Agreement, and applicable State and/or federal law.

These agencies will also provide input on a range of implementation actions that will be carried out by the IO. The IO will work closely with these agencies to ensure ongoing compliance with the permits and authorizations.

7.1.5.1 California Department of Fish and Game

DFG is the agency of the State of California authorized to act as trustee for the state's wildlife. DFG administers and enforces CESA, the NCCPA and other provisions of the Fish and Game Code. DFG is authorized to enter into agreements with federal and local governments and other entities for the conservation of species and habitats, to authorize take under CESA and the NCCPA, and to provide statutory assurances under NCCPA. On an ongoing basis, DFG will consult with the IO and the *major authorized entities* on various aspects of plan implementation, including participation in real-time operations decisions, the adaptive management process, and the monitoring and science programs. DFG will also maintain responsibility for plan enforcement, consistent with the NCCPA and other authorities. DFG owns and manages land within the Plan Area, and may, at the request of the IO, enter into agreements whereby it operates and maintains certain habitat areas that are developed through BDCP habitat preservation and restoration actions. DFG is jointly responsible for implementation of the Ecosystem Restoration Program, which was established to advance ecosystem restoration projects in the San Francisco Bay Delta and its tributaries.

7.1.5.2 National Marine Fisheries Service

NMFS is an agency of the United States Department of Commerce authorized by Congress to administer and enforce the ESA with respect to marine mammals and certain fish species (including anadromous fish); to enter into agreements with states, local governments, and other entities to conserve federally threatened, endangered, and other species of concern; to authorize incidental take under ESA; and to provide regulatory assurances in accordance with 50 C.F.R. section 222.307(g). On an ongoing basis, NMFS will consult with the IO and the *major authorized entities* on BDCP implementation, including participation in the real-time operation and adaptive management processes and the monitoring and science programs. NMFS will also maintain responsibility, jointly with USFWS, for plan enforcement consistent with the ESA and other authorities. NMFS is jointly responsible for implementation of the Ecosystem Restoration Program, which was established to advance ecosystem restoration projects in the San Francisco Bay Delta and its tributaries.

7.1.5.3 United States Fish and Wildlife Service

The USFWS is an agency of the United States Department of the Interior authorized by Congress to administer and enforce the ESA with respect to terrestrial wildlife, certain fish species, insects and plants, to enter into agreements with states, local governments, and other entities to conserve threatened, endangered, and other species of concern, to authorize incidental take under ESA, and to provide regulatory assurances in accordance with 50 CFR section 17.22(b)(5) and section 17.32(b)(5). On an ongoing basis, USFWS will consult with the IO and the *major authorized entities* on various aspects of plan implementation, including participation in real-time operations decisions, the adaptive management process, and the monitoring and science programs. USFWS will also maintain responsibility, jointly with NMFS, for plan enforcement consistent with the ESA and other authorities. USFWS may also, at the request of the IO, enter into agreements whereby it operates and maintains certain habitat areas that are developed through BDCP habitat preservation and restoration actions. USFWS is jointly responsible for implementation of the Ecosystem Restoration Program, which was established to advance ecosystem restoration projects in the San Francisco Bay Delta and its tributaries

7.1.6 Other Regulatory Agencies

The BDCP has been developed as a conservation plan pursuant to the ESA and the NCCPA. To implement the BDCP, certain conservation actions will need to conform to the requirements of various other State and federal laws and regulations not specifically addressed by the Plan. Prior to the implementation of many of the conservation actions set out in the BDCP, regulatory authorizations and approvals will need to be obtained from State and federal agencies under applicable laws. To facilitate compliance with these laws and regulations, the IO will work closely with the appropriate regulatory agencies to plan in advance of future permitting needs and establish processes to expedite such authorizations.

In addition, certain Important Related Actions (IRAs) have been identified that fall within the jurisdictional responsibility of other State and/or federal regulatory agencies. The USFWS, NMFS, DFG, and the IO will work with these regulatory agencies to encourage the implementation of the IRAs. To the extent appropriate, the IO will seek to integrate IRAs into the BDCP Conservation Strategy. [***Note to Reviewers:*** *The approach to Other Stressor Conservation Measures indentified as IRAs is currently under evaluation and changes to this text will be made as the approach is formulated in Chapter 3 Conservation Strategy*.]

It is expected that the actions set out in the BDCP are likely to involve some or all of the following statutes: California Water Code sections 1000 *et seq*. (water rights), Water Code sections 13000 *et seq*. (water quality), California Fish and Game Code sections 1600 and 5900 *et seq*. (channel modification, fish screens), Clean Water Act section 401 (water quality) and section 404 (placement of dredge and fill), Rivers and Harbors Act section 408 (work on levees), Rivers and Harbors Act section 10 (navigation), the Migratory Bird Treaty Act (migratory birds), and the Federal Energy Regulatory Act implemented by the Federal Energy Regulatory Commission.

7.1.7 Implementation Facilitation Team

An “Implementation Facilitation Team” will be established and directed by the Program Manager. The Facilitation Team will include the State and federal fish and wildlife agencies and, as appropriate, Supporting Entities and other State and federal regulatory agencies and other entities involved in the implementation of the BDCP. The Facilitation Team will work closely with the IO and supporting entities to facilitate the process of regulatory compliance under various authorities. The purpose of the Facilitation Team is to ensure regular communication and coordination between the IO, Supporting Entities, and those agencies that have regulatory responsibility for actions that will be implemented under the BDCP. The Facilitation Team will work to address issues that may arise with respect to these regulatory processes, including those related to technical and logistical matters, and will help facilitate the efficient and timely implementation of conservation measures. The role of this team will be limited to technical issues; it will not engage in matters related to the program oversight or management.

7.1.8 Supporting Entities

The Program Manager may assign specific implementation tasks to other entities, referred to as "Supporting Entities," that have the authority, resources, and expertise to successfully and timely complete the task. Where specific tasks are so assigned, the Program Manager will ensure that that tasks and associated responsibilities are carried out properly and in coordination with other BDCP actions. Supporting entities may include, among others:

- DWR.
- Reclamation.
- SFCWA or individual SWP and CVP contractors. It is anticipated that the SFCWA will be substantially involved in the implementation of the BDCP, and will likely assume responsibility for implementing a number of BDCP actions.
- The Delta Conservancy. The Delta Conservancy has been designated by statute as a primary State agency to implement ecosystem restoration in the Delta.
- Sponsors of regional conservation planning programs, including those engaged in NCCP and/or HCP development or implementation, or of other similar conservation programs, that overlap or are adjacent to the Plan Area.
- State and federal regulatory agencies, including USFWS, NMFS, and DFG. In addition to acting in their regulatory roles, these entities may act as supporting entities.
- Other public agencies and private entities that have authority, capacity, or expertise to implement actions described in the conservation strategy in a cost-effective, reliable, and timely manner.

The Program Manager will oversee each supporting entity's performance of its responsibility for carrying out a specific task. Decisions by the Program Manager to engage another entity in the implementation of specific plan elements or actions will be accomplished by written contract and will be based on the entity's jurisdictional authority, level of expertise, and its capacity to carry out the element or action in a timely and successful manner. The Program Manager may terminate a supporting entity's role in plan implementation in the event that the supporting entity does not perform a task adequately.

The take authorizations that will be issued pursuant to the BDCP will provide regulatory coverage under the ESA and the NCCPA for all activities covered by the Plan. As such, no additional take authorizations will be required to implement these activities, regardless of whether the action is carried out by the IO or a Supporting Entity.

7.1.9 BDCP Stakeholder Committee

A BDCP Stakeholder Committee will be established by the Program Manager to provide a forum through which interested public and private entities will consider and discuss matters related to Plan implementation.

7.1.9.1 Membership

The Stakeholder Committee will comprise a broader membership than the Implementation Board and consist of a range of entities and organizations with an interest in BDCP-related issues or engaged in BDCP matters.

Members of the Committee will at a minimum include but not be limited to:

- Members of the BDCP Steering Committee, serving as of the authorization date of the BDCP;
- Representative of the SFCWA
- Representatives of Delta counties and other local Delta government agencies; and,
- Other stakeholders whose assistance will increase the likelihood of the success of plan implementation.

7.1.9.2 Function

The Program Manager will convene and facilitate the Stakeholder Committee periodically to exchange information and provide input to the Program Manager concerning the current significant issues at hand. Stakeholders will have opportunity to inquire about implementation matters, be apprised by the Program Manager of issues of interest, and make recommendations concerning pending decisions. Stakeholder Committee meetings will be open to the public. At least two Stakeholder Committee meetings will be held each year.

For the benefit of the Stakeholder Committee members and the general public, the Program Manager will provide information and briefings regarding plan implementation. In addition, to further facilitate access to information and promote transparency in decision-making, the IO will maintain a public, on-line data base of key documents and information, such as annual implementation reports, work plans, and budgets (Section 6.2, *Compliance and Progress Reporting*).

The Stakeholder Committee will develop its own internal organization and process by committee consensus to best coordinate with the various aspects of BDCP implementation. The Stakeholder Committee process will complement, but not substitute for, ongoing collaboration and communication between stakeholders and the IO, authorized entities, the Implementation Board, and the fish and wildlife agencies. The IO will organize, help convene, and provide support for the Stakeholder Committee and its proceedings.

7.1.10 The General Public

The BDCP implementation process will provide for ongoing and frequent engagement and participation of the public. Other entities that have interests in the conservation of Delta resources, may participate in BDCP implementation through the public outreach process coordinated by the IO (Section 7.5 *Public Outreach*) or through the BDCP Stakeholder Committee, if eligible for membership. Stakeholder Committee meetings will be open to the public and specific times made available for public comment.

7.2 Implementation Office Administration

The Program Manager direct, oversee, and select staff for the IO. The IO, which will not be a legal entity authorized to enter into contracts directly or hold property in its own name, but will instead administer the implementation of the BDCP under the existing authorities of the authorized entities. By relying on the legal authorities of the authorized entities, the IO will be equipped with the resources and capacity necessary to carry out BDCP implementation tasks for which it will be responsible. This structure also contemplates that DWR and the Reclamation will maintain their historic roles as owners and operators of the SWP and CVP, but provides flexibility for changing those roles if so directed by Congress, the California Legislature, or through administrative processes.

Proper implementation of the Plan will require a skilled and expert team consisting of administrators, policy-makers, scientists, engineers, data analysts, and regulatory specialists, capable of working together in a cohesive and unified manner. In addition, effective implementation will necessitate adequate financing of and support for the IO. The BDCP includes funding assurances (Chapter 8 *Implementation Cost and Funding*) that the IO will have such capacity to carry out the responsibilities described in this chapter.

The Program Manager may assign specific implementation tasks to other entities that have the authority, resources, and expertise to successfully complete the task in a timely manner. These other entities can, at the discretion of the Program Manager, include an authorized entity, a regulatory agency, a supporting entity, or any combination thereof. Where specific tasks are so assigned, the Program Manager will ensure that that tasks and associated responsibilities are carried out properly and in coordination with other BDCP actions. The entity selected will be responsible, subject to oversight by the Program Manager, for entering into the necessary contracts and acquiring title to interests in real and personal property, acquiring permits, and taking all other steps needed to complete the implementation task.

The IO's primary functions and responsibilities are described in the following subsections.

7.2.1 Establishing Administrative Capacity

The Program Manager will manage the IO. The Program Manager will enter into an employment relationship with one of the *major authorized entities*. However, the Program Manager will be responsive to all of the *major authorized entities*.

The Program Manager will arrange for and equip the IO office space, hire a staff of sufficient size, and enter into contracts (through the authorities of DWR, Reclamation, and/or other *major authorized entities*) to build capacity to become fully functional and operational.

The Program Manager, with the consent of and pursuant to agreements with any affected agencies, may enlist current employees of the Implementation Board's member agencies, as well as employees of other State, federal, or local agencies, who possess the expertise and experience necessary to carry out the tasks associated with BDCP implementation. The specific staffing needs of the IO will be determined by the Program Manager. All IO staff, including staff from entities that are members of the Implementation Board will work at the direction of the Program Manager.

7.2.2 Preparing Budgets and Managing Expenditures

The Program Manager will develop, propose, and administer budgets for general program administration for acceptance by the Implementation Board pursuant to the dispute resolution process (Section 7.1.3.3 *Dispute Resolution*). The Program Manager will establish systems and processes to centralize oversight of implementation budgets and related expenditures. The Program Manager will also generally oversee budgets and expenditures related to implementation actions carried out by authorized or supporting entities.

7.2.3 Contracting for Services

The IO, through the appropriate entity, may contract for services as necessary to implement the BDCP, including for professional services related to:

- Acquisition and protection of habitat;
- Habitat restoration and management;
- Monitoring and scientific research;
- Legal and regulatory matters;
- Environmental and technical services;
- Engineering and construction (e.g., conservation facilities, water facilities, levees);
- Funding and grant agreements pertaining to state and federal programs and executing sub-grants to third-parties to conduct specific actions; and
- Operations and maintenance.

The Program Manager shall administer such contracts.

7.2.4 Securing, Holding, and Managing Funds to Support Implementation Actions

The IO will coordinate the expenditure of funds from State, federal, and other sources that have been dedicated to the implementation of the BDCP. At least one State and one federal agency member of the Implementation Board will serve as the fiscal agents, consistent with existing agency authorities, for the expenditure of funds by the IO, from both public and private sources, to support implementation actions. The IO will not be authorized to manage the expenditure of funds related to design, construction, operation and maintenance of water diversion and conveyance facilities which are or will be elements of the SWP or CVP.

7.2.5 Coordinating with the Authorized Entities and Supporting Entities

The Program Manager will convene meetings and facilitate communication with the authorized entities and supporting entities. The Program Manager will maintain frequent contact with these entities and provide regular updates concerning implementation matters, including progress in meeting BDCP timetables, dissemination of information, and maintenance and availability of BDCP records and reports.

7.2.6 Coordinating with Regulatory Agencies – Facilitation Team

The USFWS, NMFS, DFG, and other regulatory agencies will coordinate and collaborate through the Facilitation Team with the IO on matters potentially affecting compliance with the terms and conditions of the BDCP and its regulatory authorizations. The Program Manager will coordinate and lead Facilitation Team meetings.

7.2.7 Coordinating with the Delta Stewardship Council, Delta Science Program, and Delta Conservancy

The Program Manager will facilitate and monitor the effective and efficient incorporation of the BDCP into the Delta Stewardship Council's Delta Plan (Delta Plan).[4] The Program Manager will report, at least annually, to the Delta Stewardship Council on the progress of BDCP implementation, including the status of monitoring programs and adaptive management, as required by Water Code section 85320(f). The IO will also respond to questions or concerns raised by the Delta Stewardship Council regarding the implementation of the BDCP.

The IO, lead by the Science Manager, will coordinate with the Delta Science Program and, as necessary, the Delta Independent Science Board, [5] regarding scientific assistance in the

[4] Water Code § 85320.

[5] Water Code § 85280

formulation and implementation of monitoring activities and research efforts to support the BDCP adaptive management process.

The IO will coordinate with the Delta Conservancy concerning implementation of ecosystem restoration projects carried out pursuant to the BDCP Conservation Strategy and other programs being carried out by the Delta Conservancy.

7.2.8 Coordinating with Local Governments, Delta Protection Commission, and Other Public Agencies

The Program Manager will serve as the main point of contact for local, State, and federal agencies interested or engaged in BDCP implementation issues. The Program Manager will prepare, publish, and distribute general information about the BDCP to those agencies and serve as representative of the BDCP in public meetings convened by cities, counties, and other public agencies with jurisdiction within the Delta. The Program Manager will encourage local government participation on the BDCP Stakeholder Committee.

Where regional conservation plans overlap with or adjoin the Plan Area, the IO will collaborate and coordinate with the sponsors of those regional conservation plans on the acquisition and management of habitat lands to be preserved and/or restored within areas common to both plans. The Program Manager will, as appropriate, enlist sponsors of those regional conservation plans and local governments to serve as BDCP supporting entities to assist in the acquisition and/or management of conservation lands. Where mutually beneficial, the IO will encourage joint acquisitions of land with local government plan sponsors to realize economies-of-scale and to secure large, contiguous blocks of habitat. The IO will explore opportunities to fund early conservation actions (i.e., habitat acquisition and/or restoration) that may benefit both the BDCP and other regional conservation plans.

7.2.9 Coordinating with Flood Control Agencies

In the design and implementation of conservation actions that could affect flood control capabilities, the IO will coordinate with agencies responsible for flood control in the Plan Area, including USACE, DWR, Central Valley Flood Protection Board, and local flood control agencies.

7.2.10 Protecting and Defending Against Legal Challenges

The IO, in coordination with the Implementation Board, supporting entities, fish and wildlife agencies, and other appropriate public agencies, will help direct efforts to defend against legal challenges to the BDCP or its associated State and federal authorizations. As necessary, the IO may also provide funding for legal counsel to address the range of legal issues associated with implementation, including: defense against litigation related to the BDCP, liability associated with land acquisition and related matters, disputes arising out of contractual agreements, and general, routine in-house legal matters.

7.2.11 Overseeing Plan Amendments

In the event that an amendment to the BDCP and its authorizations is necessary, the IO will compile information and prepare documentation necessary to support such an amendment and will seek to obtain approvals from the applicable fish and wildlife agencies.

7.2.12 Implementing Mitigation Measures Identified in BDCP-related Environmental Documentation under NEPA and CEQA

Subject to the approval of the NEPA and CEQA lead agency(ies) conducting the environmental review under NEPA and/or CEQA and the Program Manager, the IO will implement the mitigation measures identified in the final environmental documents on behalf of the lead agency(ies). Such mitigation measures must be associated with either the EIS/EIR prepared for the BDCP or environmental documents necessary for the implementation of an action set out in the BDCP.

7.2.13 Undertaking Other Responsibilities

The IO will institute a program to monitor compliance with the BDCP and the BDCP EIR/EIS (as per agreements with NEPA/CEQA lead agencies) and provide the fish and wildlife agencies, on a mutually-agreed upon time-frame, with reports on the results of the monitoring program (Section 6.2 *Compliance and Progress Reporting* and Section 7.3, *Implementation of the Conservation Strategy*). The IO will also obtain other regulatory authorizations and permits necessary to implement BDCP conservation actions (Section 7.4, *Regulatory Compliance Related to BDCP Implementation*) and will engage in public outreach and education (Section 7.5, *Public Outreach*)

7.3 Implementation of the Conservation Strategy

The Program Manager will be responsible for planning, overseeing, and conducting actions set out in the BDCP Conservation Strategy (Chapter 3, *Conservation Strategy* and Chapter 6, *Plan Implementation*). The Program Manager will be afforded sufficient flexibility to use supporting entities and the fish and wildlife agencies to undertake certain actions that will enhance the overall effectiveness of the Conservation Strategy and yield greater efficiencies in plan implementation. The following sets out the tasks and responsibilities of the IO regarding the implementation of the Conservation Strategy.

7.3.1 Implementation of the Habitat Protection and Restoration Conservation Measures

The IO will take actions directly or through the supporting entities to implement conservation measures related to the protection of existing habitat and the enhancement and restoration of habitat within the identified restoration opportunity areas (ROAs) and conservation zones, as well as within other areas in the Plan Area, as described in Chapter 3, *Conservation Strategy*. These measures will primarily involve actions to acquire lands, restore or improve habitat conditions, and manage and maintain conservation lands. The IO will work with, and may contract with the Delta Conservancy or the supporting entities to carry out the conservation measures associated with habitat protection and restoration.

Acquisition and/or Lease of Property Interests. Pursuant to the authorities of DWR, Reclamation, and/or other *major authorized entities*, the IO may acquire interests in real property to facilitate the implementation of a habitat protection and/or restoration conservation measure. Similarly, under the direction of the IO, other entities that have been selected to implement such conservation measures may also acquire interests in real property, as described in Chapter 3 *Conservation Strategy*. The tasks related to the acquisition of fee interest and/or conservation easements, for the purpose of habitat protection, restoration, and creation, will include, among other things:

- Routine "due diligence" review of real property;
- Biological "due diligence" to assess habitat/restoration values;
- Appraisal of property, including oversight of the appraisal process;
- Negotiation and execution of the transaction; and
- Receipt of title or easement to lands.
- Select appropriate mechanism or instrument to ensure the protection of conservation lands.

The selected entity will also acquire or lease lands or facilities, or, with the consent of the Program Manager, contract with the Delta Conservancy or other appropriate entities to do so, for the purpose of conducting scientific research and monitoring, housing administrative offices and equipment, and undertaking other activities as necessary to administer and implement the measure.

Management of Land. The IO will oversee the management and maintenance of lands acquired for conservation, as described in Chapter 3 *Conservation Strategy*, and will select entities that will be responsible for carrying out such management and maintenance. Tasks associated with land management will generally include:

- Habitat management;
- Invasive species control;
- Security patrol;
- Liaison with neighboring landowners;
- Mosquito abatement;

- Management of vegetation on flood control facilities to maintain flood flow capacity;
- Species and habitat monitoring;
- Public access management;
- Research activities;
- Educational services; and
- Agricultural lease management.

Maintenance of Facilities and Improvements. The IO will oversee the maintenance of all related facilities and improvements, such as buildings, fences, levees, roads, as described in Chapter 3, *Conservation Strategy* and necessary for support and protection conservation lands

Funding of Activities of Other Entities. The IO may provide funding to other entities (such as local governments engaged in regional conservation planning processes), subject to appropriate conditions and oversight, to implement habitat and species conservation efforts, both inside and outside the Plan Area, that help advance the biological goals and objectives of the BDCP, as described in Chapter 3, *Conservation Strategy*.

7.3.2 Implementation of Water Operations Conservation Measures

7.3.2.1 Operations of Water Facilities

Implementation of water facilities and water operations conservation measures as described in Chapter 3 *Conservation Strategy* will be the responsibility of DWR and Reclamation, or entities with whom they may contract, consistent with their existing responsibilities and authorities.

7.3.2.2 Real Time Operations Response Team

To enhance the effectiveness of the water operations conservation measures, a "Real Time Operations Response Team" (Response Team) will be established. The Response Team will consist of representatives from DFG, USFWS, NMFS, DWR, and the Reclamation.

7.3.2.2.1 Role of the Real Time Operations Response Team

The Response Team will be assigned the responsibility to make real-time operational recommendations based on covered fish species needs, within the boundaries established by the BDCP CM1 *Water Facilities and Operations* (Chapter 3, *Conservation Strategy*), other applicable regulatory constraints, and the Annual Water Operations Strategy (Section 6.2, *Compliance and Progress Reporting*). The fish and wildlife agencies will make a determination that the proposed real time operational actions are consistent with the biological needs of the covered fish species, within the boundaries established by the BDCP CM1 *Water Facilities and Operations* (Chapter 3, *Conservation Strategy*), other applicable regulatory constraints, and the

Annual Water Operations Strategy (Section 6.2, *Compliance and Progress Reporting*). DWR and Reclamation will implement the real time action.

The Response Team will make recommendations in real time (e.g., hourly/daily/weekly) regarding operations of the SWP and the CVP Delta facilities to achieve the purposes specified above.

Real-time water operations actions will be designed to increase fish benefits while recognizing the importance of meeting the water supply target in the Annual Water Operations Strategy as revised in the Seasonal Operations Strategies as well as to meet other operational requirements. The Response Team's recommendations will take into account upstream reservoir operations and other SWP and CVP operational requirements as well as the allocation, amount, and timing of water delivered, including surplus water that may be available, to the CVP or SWP customers within any water year. [***Note to Reviewers****: Standard for allowable impact on water supply and the real time operation decision making process are under review and development.*]

Notwithstanding the role of the Response Team, the Authorized Entities will retain ultimate legal responsibility for water operations conservation measures and compliance with the Plan and the regulatory authorizations. Similarly, the fish and wildlife agencies will retain legal authority to oversee, enforce, modify, or revoke such authorizations, as described in Chapter 6, *Plan Implementation*, under applicable laws and regulations.

7.3.2.2.2 Coordination between the Program Manager and the Response Team

The Program Manager will coordinate with the Response Team and retain responsibility for overseeing, monitoring, and reporting on the implementation of the water operation conservation measures. The Program Manager will also establish processes to ensure that recommendations made by the Response Team regarding the implementation of water operations conservations measures are transparent and understandable. Water operations will be described each year in a water operations report. Review and reporting requirements on water operations are described in Section 6.2, *Compliance and Progress Reporting*.

7.3.2.2.3 Responsibility of the Response Team to Balance Conservation and Water Supply Goals

The Response Team will be required to take into account the effect of its operational recommendations on water supply. While the Response Team's primary role will be to enhance the effectiveness of the water operations conservation measures, it will make real time recommendations in a manner that considers water supply and timing of delivery from that which would have occurred without variations from the expected operations set forth in the Annual Water Operations Strategy. [***Note to Reviewers****: Standard for allowable impact on water supply is under development.*]

7.3.2.2.4 Informational Resources Available to Support Decisions of the Response Team

In making real-time recommendations regarding the implementation of operations-related conservation measures, the Response Team will utilize data, information, and analysis generated from fisheries and operational technical groups and, where appropriate, outside scientific experts. Specifically, the Response Team will take into account real-time data derived from work conducted by the following groups (or their successors or equivalents, if any), including current fish surveys, flow and temperature information, and determinations regarding salvage or loss at the project facilities; and information about public health, safety, and water supply reliability:[6]

- **The Sacramento River Temperature Task Group (SRTTG):** The SRTTG is a multiagency group formed pursuant to SWRCB Water Rights Orders 90-5 and 91-1, and the NMFS biological opinion, to assist with improving and stabilizing Chinook populations in the Sacramento River. Annually, Reclamation develops temperature operation plans for the Shasta and Trinity divisions of the CVP. Reclamation considers impacts on winter-run and other ESUs of Chinook salmon, and associated project operations. The SRTTG meets initially in the spring to discuss biological, hydrologic, and operational information, objectives, and alternative operations plans for temperature control. Once the SRTTG has recommended an operation plan for temperature control, Reclamation then submits a report to the SWRCB, generally on or before June 1st each year. After implementation of the operation plan, the SRTTG may perform additional studies and commonly holds monthly meetings, as needed through the summer and into fall, to develop revisions based on updated biological data, reservoir temperature profiles and operations data. Updated plans may be needed for summer operations protecting winter-run, or in fall for fall-run spawning season. If there are any changes in the plan, Reclamation submits a supplemental report to SWRCB and to NMFS for review and concurrence.
- **Smelt Working Group (SWG):** The SWG evaluates biological and technical issues regarding delta smelt and develops recommendations for consideration by the USFWS. Since the longfin smelt became a state candidate species in 2008, the Working Group has also developed for DFG recommendations to minimize adverse effects to longfin smelt. USFWS chairs the group which consists of representatives from USFWS, DFG, DWR, EPA, and Reclamation. The SWG compiles and interprets the latest near real-time information regarding state- and federally-listed smelt, such as stages of development, distribution, and salvage. If they agree that a protection action is warranted, the SWG submits their recommendations in writing to USFWS and DFG. The Delta Smelt Risk Assessment Matrix (DSRAM) outlines the conditions when the Working Group will

[6] Additional working groups have been created and governed by SWRCB orders and NMFS and USFWS biological opinions. These work groups are listed here for informational purposes and are not necessary to the implementation of the BDCP

convene to evaluate the necessity of protective actions and provide FWS with a recommendation. This generally occurs weekly during the months of January through June, when smelt salvage at CVP and SWP has occurred historically. However, the SWG may meet at any time at the request of USFWS. Further, with the State listing of longfin smelt, the group will also convene based on longfin salvage history at the request of DFG.

- **Delta Operations for Salmon and Sturgeon (DOSS) Group:** NMFS chairs this working group, which consists of biologists, hydrologists and other staff with relevant expertise from Reclamation, DWR, DFG, and USFWS and may include USGS, EPA, and Regional Water Quality Control Board participation. The DOSS provides recommendations for real-time management measures to reduce adverse effects to salmonids and green sturgeon by coordinating Delta Cross Channel (DCC) gate operations, fishery protection closures, water releases, and/or export reductions. Inputs such as fish life stage and size development, current hydrologic events, fish indicators (such as catch indices), salvage at the export facilities, and current and projected Delta water quality conditions are some of the factors used to make recommendations. The DOSS will coordinate with the SWG and other technical teams to maximize benefits to all listed species.
- **American River Group (ARG):** In 1996, Reclamation established a working group for the Lower American River, known as ARG. Although open to the public, the ARG meetings generally include representatives from several agencies and organizations with on-going concerns and interests regarding management of the Lower American River. The formal members of the group are Reclamation, USFWS, NMFS, and DFG. The ARG convenes monthly or more frequently if needed, with the purpose of providing fishery updates and reports for Reclamation and NMFS to help manage Folsom Reservoir for fish resources in the Lower American River.
- **San Joaquin River Technical Committee** (SJRTC): The SJRTC meets to plan and implement the Vernalis Adaptive Management Plan (VAMP) each year, and oversees two subgroups: Biology and Hydrology. These two subgroups are charged with certain responsibilities, and must also coordinate their activities within the San Joaquin River Agreement (SJRA) Technical Committee. VAMP was officially initiated in 2000 as a 12-year experimental/management program under the SJRA and SWRCB Decision-1641.

7.3.2.3 Annual Reporting and Planning for Water Operations

Planning and reporting requirements for the IO, DWR, Reclamation, and the Response Team are set out in Section 6.2, *Compliance and Progress Reporting*.

7.3.3 Implementation of All Other Conservation Measures

The Program Manager, through the IO, will be responsible for the implementation of the other conservation measures described in Chapter 3, *Conservation Strategy*. The IO may undertake conservation actions directly or arrange for funding to support actions carried out by supporting entities, as described in chapter 3 *Conservation Strategy*. The funds provided to supporting entities will likely be for the purpose of implementing conservation measures that address the adverse effects of other stressors, such as toxic contaminants, nonnative predatory species, low dissolved oxygen zones, and entrainment unrelated to covered activities.

7.3.4 Management of Biological Monitoring, Scientific Research, and Reporting Programs

The Science Manager will be responsible for the overall management and oversight of the BDCP biological monitoring and research program, including the implementation of monitoring-related activities, as described in Chapter 3 *Conservation Strategy* (Section 3.6 *Monitoring and Research Program*).

The Science Manager will identify technical staffing needs and requirements necessary to adequately implement the biological monitoring program. The Science Manager will utilize the Interagency Ecological Program (IEP) to assist in the monitoring program. The Science Manager will oversee the development and implementation of the monitoring program and related scientific activities, with the assistance of the IEP agencies and in coordination with the Delta Science Program. The Science Manager will establish the framework for the monitoring program (*e.g.*, scope, methodologies, and protocols), in coordination with IEP and the fish and wildlife agencies, Delta Science Program, and supporting entities, The Science Manager, in collaboration with these entities, will develop and implement a process for compiling, evaluating, and synthesizing the results of monitoring activities, and will maintain databases and the results of data analysis, obtained through the monitoring program and expand on that currently developed by IEP.

The Science Manager will also manage the BDCP research program, as described in Chapter 3 *Conservation Strategy* (Section 3.6 *Monitoring and Research Program*), in coordination with the IEP agencies and the Delta Science Program. The research program will include establishing research goals and priorities and administering a process to select and coordinate researchers who will be involved in the program. The Science Manager will be responsible for the compilation and synthesis of the results of studies and analysis undertaken by other entities and organizations that are of interest and assistance to BDCP implementation. The Science Manager will also coordinate BDCP funding for research by other entities and organizations, as described in Section 3.6 *Monitoring and Research Program*.

The Program Manager will look to the Delta Science Program and Independent Science Board for science support and review. As appropriate, the Science Manager will seek and obtain input and advice from independent scientists through the Delta Science Program. Matters relating to the conduct of scientific reviews, and the acquisition of independent scientific advice to assist in the implementation of the BDCP, shall be conducted in a manner that ensures their independence and scientific integrity. The Science Manager will work with the Chief Scientist for the Delta

Science Program and IEP Lead Scientist in making sure BDCP science activities, reporting, and reviews are coordinated with other science activities being conducted in the Delta.

The Program Manager will track plan implementation actions and comply with the reporting requirements of the Plan, as described in Section 6.2 *Compliance and Progress Reporting*. Reports prepared by the IO will include, among other things, the results of monitoring and research, an assessment of overall plan performance, and an accounting of the distribution and expenditures of funding by the various entities engaged in plan implementation activities. See Section 6.2 *Compliance and Progress Reporting* for specifics on reporting requirements.

The Program Manager may contract with one or more of the authorized entities, supporting entities, or consultants when appropriate to ensure completion of required monitoring, data analysis, and scientific research.

7.3.5 Management of the Adaptive Management Program

The Science Manager will manage the BDCP adaptive management program, as described in Chapter 3 *Conservation Strategy* (Section 3.7 *Adaptive Management Program*). The Science Manager will establish and chair an Adaptive Management Team to assemble, synthesize, and analyze the results of BDCP monitoring efforts and integrate the results of new and relevant scientific research and studies conducted by other parties, including the Delta Science Program. Based on this information, the Science Manager will facilitate and coordinate discussion and consideration of adaptive management issues among the various participating entities, including the Implementation Board, the fish and wildlife agencies, and the Stakeholder Committee as part of the process of making decisions based on the adaptive management program.

The decision-making process for adaptive management changes, including the roles and responsibilities of the various entities in the BDCP implementation structure, is described in Section 3.7 *Adaptive Management Program*

7.3.6 Implementation of Measures in Response to Changed Circumstances

The Program Manager, through the IO, will be responsible for recognizing and responding to those changed circumstances identified in the plan, and for implementing those responses set out in the BDCP to address those changed circumstances, as described in Section 6.3 *Regulatory Assurances and Changed Circumstances and Unforeseen Circumstances*. The Program Manager will establish a process to ensure timely engagement of the Implementation Board, authorized entities, fish and wildlife agencies, and the Stakeholder Committee in the identification and response to such changed circumstances.

[***Note to Reviewers:*** *This process for ensuring timely engagement of these entities will be included in a future draft of the Plan*]

7.4 Regulatory Compliance Related to BDCP Implementation

The Program Manager, through the IO, will be responsible for ensuring that the BDCP is properly implemented, including ongoing compliance with the elements of the Plan and the terms and conditions of the associated regulatory authorizations. The IO will also identify, seek, and obtain from State and federal agencies any other regulatory permits or authorizations that are necessary to effectuate Plan implementation.

7.4.1 Maintaining Permits/Authorizations and Obtaining Amendments

The Program Manager will establish a process to ensure compliance with all permits and authorizations related to BDCP implementation. If amendments or modifications to any of these permits or authorizations become necessary, the Program Manager and the authorized entities will work with the applicable agency to develop the necessary documentation and obtain the amendment.

7.4.2 Obtaining Additional Regulatory Authorizations

[***Note to Reviewers:*** *Certain specific regulatory authorizations (e.g. water rights) will need to be completed prior to implementation of the BDCP. Other regulatory authorizations will be acquired as necessary during BDCP implementation. This section describes those authorizations that happen during BDCP implementation*.]

The Program Manager will identify and seek regulatory authorizations necessary to implement BDCP actions. The EIR/EIS for the BDCP will provide sufficient environmental review and analysis of the proposed adoption of the Plan by DWR, CVP-related actions undertaken by Reclamation, and of the proposed issuance of take authorizations by the State and federal fish and wildlife agencies pursuant to the Plan, and may provide sufficient environmental review to support other anticipated federal and State regulatory authorizations. However, additional NEPA and CEQA review, as well as compliance with other environmental laws, will be necessary for a number of BDCP-related actions.

The IO will oversee the likely need of supporting entities to obtain permits or authorizations, or conduct environmental review, under the following State and federal laws, regulations, or processes prior to the implementation of certain conservations measures:

- Sections 404 and 401 of the Clean Water Act;
- Sections 10 (33 USC 403) and 14 (33 USC 408) of the Rivers & Harbors Act of 1899;
- Section 1602 of the California Fish and Game Code (Streambed and Lakebed Alteration Agreements);

- Section 106 of the National Historic Preservation Act;
- Encroachment permits from the Central Valley Flood Protection Board and reclamation districts to conduct work on levees;
- Federal Energy Regulatory Act compliance through the Federal Energy Regulatory Commission; and
- The National Environmental Policy Act and the California Environmental Quality Act, as necessary for certain project-related actions.

This list is not intended to be comprehensive and the Program Manager would be responsible for compliance with any additional regulations necessary for Plan implementation.

7.5 PUBLIC OUTREACH

The Program Manager, through the IO, will implement a public outreach and education program to promote public awareness and provide opportunities for public input on matters concerning plan implementation. General objectives of the outreach program will be to:

- Promote public awareness of and understanding about the plan's purpose, specific conservation measures and their implementation;
- Provide streamlined and timely access to information;
- Provide contact with decision-makers; and
- Maintain a transparent process for understanding, clarifying and addressing public input and comments.

Particular emphasis will be placed on outreach efforts focused on the following stakeholders: Delta residents, including landowners, farmers, and business owners; environmental community; agricultural community; boaters; commercial fishing interests; recreational anglers; local governments; reclamation districts; irrigation districts; public utilities; public and private landowners adjacent to BDCP conservation areas; and Native American tribes.

The public outreach and education program will include, at a minimum:

Informational Material. The preparation and distribution of general information materials such as reports, quarterly electronic newsletters, and issue-specific fact sheets in timely manner so as to facilitate public understanding and meaningful public input.

Interactive Website. Development and maintenance of an interactive website that provides real-time access to information, updates regarding implementation activities, and expanded opportunities for public engagement and input. Visual elements such as maps and webcasts will be used to further aid information sharing and public understanding.

Speakers Bureau. Presentation of BDCP implementation information to various groups and at public meetings that occur throughout the state, as well as targeted audiences including Delta communities, Tribes, and specific statewide stakeholder interests.

Annual Public Workshops. Commitment to annual public workshops and others as needed to provide timely opportunities for public dialogue, input and comment regarding a wide range of implementation issues.

Environmental Justice. An environmental justice outreach program will be integrated into overall outreach activities described above to provide minority and low-income communities with access to information about the plan's implementation and opportunities for input. Outreach techniques include dedicated multilingual web page, availability of translation services at public workshops and community presentations, and outreach to ethnic media outlets.

CHAPTER 8. IMPLEMENTATION COSTS AND FUNDING SOURCES

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CHAPTER 8. IMPLEMENTATION COSTS AND FUNDING SOURCES

[Note to Reviewers: *This chapter will ultimately address both estimated BDCP implementation costs and sources of funding that will be relied upon to cover these costs. This draft provides descriptions of the assumptions used to develop cost estimates associated with the implementation of the BDCP conservation measures, program administration, and other Plan related actions. Cost estimates presented in this chapter are preliminary. Cost estimates are dependent on the consultant's assumptions about how individual actions will be designed and constructed and could change significantly as these assumptions are reviewed and revised by the BDCP Steering Committee and the project applicants. Readers should note that cost estimates include budget contingencies of twenty to fifty percent due to uncertainty regarding the elements of each proposed action. The cost estimates set out in this chapter will also be adjusted as conservation measures are added, deleted, or modified and when more detailed cost information becomes available. Costs for some parts of the Conservation Strategy (e.g., the monitoring and research program) have not been estimated at this time as there is need for additional specific cost information or additional information or refinement to the actions. Section 8.11, Funding Sources and Assurances, will not be prepared until the total cost estimate has been completed, and hence funding needs can be ascertained and a funding plan developed.*

No agreement has been reached on the apportionment of funding of the various components of this plan beyond the state and federal contractors' commitment to funding the new conveyance and related mitigation costs. Substantial public and other sources of funding are expected to contribute to the cost of implementing the other elements of the Plan.

The BDCP Steering Committee members have submitted comments to various drafts of this chapter during development, which may or may not have been incorporated into this November 18, 2010 draft. While the text of this chapter is subject to change and revision as the BDCP planning process progresses, the chapter has been drafted and formatted to appear as it may in a completed draft HCP/NCCP. Although the chapter includes declarative statements (e.g., the Implementation Office will…), it is nonetheless a "working draft" that will undergo further modification based on input from the BDCP Steering Committee, state and federal agencies, and the public.]

8.1 INTRODUCTION

This chapter outlines estimates of the costs associated with implementation of the Bay Delta Conservation Plan (BDCP) over the proposed 50-year term of the Plan, including the costs related to each of its primary components. The Endangered Species Act (ESA) requires that habitat conservation plans specify "the funding that will be available to implement" conservation actions that minimize and mitigate impacts on covered species.[1] The Natural Community Conservation Planning Act (NCCPA) requires that natural community conservation plans

[1] U.S.C. section 1539(a)(2)(A)

contain "provisions that ensure adequate funding to carry out the conservation actions indentified in the Plan."[2] Based on the estimated costs for BDCP implementation, this chapter identifies the sources of funding that will be relied upon for plan implementation and the mechanisms that will be utilized to secure such funds, and describes the basis for the assurances provided by the Plan Participants that adequate funding will be available to support the implementation of the Plan.

*[**Note to Reviewers**: "Sources and assurances of funding" will be described in a subsequent draft of this chapter.]*

8.1.1 Scope and Purpose of the Cost Analysis

The BDCP identifies a range of actions that will be implemented over the term of the Plan to meet the biological goals and objectives described in the Conservation Strategy and to comply with the requirements of the federal ESA and the NCCPA. Among those actions are measures to avoid, minimize, and mitigate the effects of activities covered by the BDCP on species and natural communities addressed by the Plan and to provide for the conservation of those species. In addition, the BDCP establishes commitments of the Plan Participants to carry out an adaptive management and monitoring program for the species covered by the Plan and to take identified steps to respond to changed circumstances. The BDCP also establishes specific obligations of the Plan Participants regarding Plan implementation.

The cost analysis conducted for the BDCP quantifies both the overall cost of the BDCP and the cost of specific plan components. These estimates were used to establish the funding requirements for plan implementation over the course of a 50-year term and to guide decisions regarding the allocation of funding responsibilities among the Plan Participants.

Specifically, the analysis addresses costs related to the following components of the BDCP:

- **Conservation Measures**
    - **Water Facilities Construction and Operations.** This category covers those conservation measures related to water facilities and water operations. The costs associated with these measures include the development of new water conveyance and other water management facilities that will be located both within and around the Delta. This category also includes actions associated with the operations of both existing and new facilities. These actions were described in Chapter 3, *Conservation Strategy*.
    - **Physical Habitat Restoration and Protection.** This category includes conservation measures associated with the preservation, restoration, and protection of habitat. Specifically, the cost analysis considered actions related to the restoration of 65,000 acres of tidal wetland and associated estuarine habitat, 5,000 acres of riparian habitat, 2,000 acres of grassland, 400 acres of nontidal wetlands and associated aquatic habitat, 200 acres of vernal pool complex, up to 5,000 acres of managed wetlands,

[2] Cal. Fish and Game Code section 2820(a)(10)

and 10,000 acres of floodplain habitat; the enhancement of 20 linear miles of channel margin habitat; and the protection of existing 8,000 acres of grassland, 400 acres of nontidal wetlands, 300 acres of vernal pool complex, 400 acres of seasonal alkali wetland complex, up to 2,000 acres of managed wetlands, and up to 32,640 acres of agricultural land. The analysis also covers costs related to the mitigation of impacts to terrestrial habitat that are expected to occur as a result of certain covered activities. These measures are described in Chapter 3, *Conservation Strategy*.

- **Other Stressors.** This category covers conservation measures designed to reduce the direct and indirect adverse effects of various stressors on ecological functions, covered species, and natural communities. Such stressors include toxic contaminants and other factors affecting water quality, nonnative species, harvest, hatcheries, diversions unrelated to the State Water Project (SWP) or the Central Valley Project (CVP), predators, and migration barriers and other impediments to movement. The range of conservation measures that address other stressors are described in Chapter 3, *Conservation Strategy*.

- **Monitoring and Adaptive Management**. This category includes the start-up and on-going costs of the monitoring, research, and adaptive management programs, including expenses related to research and data collection, management, and analysis. The BDCP monitoring and adaptive management programs are described in Chapter 3, *Conservation Strategy*.
- **Changed Circumstances.** This category covers the cost of implementing measures to respond to changed circumstances. Those measures are set forth in Chapter 6, *Implementation Plan*.
- **Program Administration**. This category consists of expenditures necessary to administer the BDCP. It includes the start-up cost of establishing the BDCP Implementation Office and the ongoing costs of administration, including expenses associated with personnel, offices and other facilities, equipment, vehicles, contracted services, and other overhead and related expenses. A description of the approach to the administration of the BDCP is described in Chapter 7, *Implementation Structure*.

The cost analysis includes sections describing how funding needs were estimated for each plan component, including the assumptions and data used to determine the level and timing of funding needed over the course of plan implementation. Many of the cost estimates are based on conceptual and engineering designs for water facilities and habitat restoration projects available at the time of plan formulation.

This chapter also identifies the sources of funding to implement the BDCP and sets out assurances that adequate funding will be available to perform the terms and conditions of the Plan, consistent with the ESA and the NCCPA. Both the ESA and the NCCPA require that conservation plans include provisions that ensure adequate funding to carry out identified conservation actions. The nature of the BDCP assurances of funding for each of the primary components of the Plan, including actions associated with conservation measures, adaptive management and monitoring, and plan administration, is described in this chapter.

8.1.2 Organization of Chapter

The remainder of this chapter is organized as follows:

- Section 8.2 describes common assumptions used to estimate BDCP implementation costs.
- Sections 8.3 to 8.7 describe the methods, data, and specific assumptions used to estimate implementation costs related to conservation measures, monitoring, research, adaptive management, plan administration, and mitigation.
- Section 8.8 provides the costs of mitigation measures identified in the BDCP EIR/EIS.
- Section 8.9 summarizes the overall implementation costs for the Plan.
- Section 8.10 provides an analysis of net costs of BDCP implementation.
- Section 8.11 identifies the sources of funding for the BDCP and describes how such funding will be assured by the Plan participants.

Appendix J, *Implementation Costs Supporting Materials* provides additional detail on the data and assumptions used to estimate costs presented in this chapter.

8.2 COMMON ASSUMPTIONS FOR COST ESTIMATION

Certain common assumptions were applied to all cost estimates developed for the BDCP. These common assumptions are described in the following subsections.

8.2.1 Cost Periods

Cost estimates are described within 5-year periods, commencing with the first year in which regulatory authorizations have been issued by the fish and wildlife agencies, and concluding at the expiration of the permit's term. The cost estimation assumes that the initial 5-year period covers 2012 to 2016 and the final 5-year period covers 2057 to 2061. Every cost estimate has a temporal dimension, reflecting when those costs are expected to be incurred over the term of the BDCP. The timing of Plan implementation costs are based on the schedule of implementation presented in Chapter 6.

8.2.2 Cost Ranges

Low and high cost estimates are presented for the habitat and other stressor conservation measures. In most cases the low and high estimates reflect different assumptions in project design and/or unit costs. In cases where this was not possible, the low is assumed to be 10 percent less than the estimated cost and the high is assumed to be 10 percent more than the estimated cost.

8.2.3 Cost Contingency

The American Association of Cost Engineers define contingency as a specific provision for unforeseeable elements of cost within the defined project scope. Cost uncertainties may result from incomplete design, unforeseen and unpredictable conditions, or uncertainties within the defined project scope. The amount of contingency will depend on the status of design, procurement, and construction; and the complexity and uncertainties of the component parts of the project. For planning studies, standard contingencies typically range from 20 and 30 percent, but may be as high as 50 percent for experimental or special conditions. Cost estimates developed for major plan elements, such as water facilities, tidal habitat creation, and Yolo Bypass improvements, include various contingencies as specific cost line items. In those cases where cost contingency has not been explicitly factored into a cost estimate, a 20 percent contingency is added.

8.2.4 Financial Assumptions

In cases where present values were calculated or capital costs were amortized, a nominal discount rate of 4.375 percent and a long-term inflation rate of 2.1 percent are assumed. The discount rate was selected to match the fiscal year (FY) 2010 rate that the U.S. Army Corps of Engineers (USACE) and the U.S. Bureau of Reclamation (USBR) are required to use for developing and evaluating proposed plans for water project plan formulation and evaluation.[3] The long-term inflation rate is based on the spread between nominal and inflation-indexed 30-year Treasury notes, as published in Appendix C of Office of Management and Budget (OMB) Circular No. A-94 (revised January 2008).

Costs are reported in constant 2010 dollars.[4] Historical costs have been converted to 2010 dollars using various price indices, including consumer price indices published by the Bureau of Labor Statistics and civil works construction cost indices published by the USACE.

8.2.5 Delta Real Estate Values

Interests in land for the purpose of physical habitat restoration actions, resource protection, and water facilities development may be obtained through the acquisition of fee title or through easement. Estimated costs of acquiring land in fee or by easement to facilitate physical habitat restoration within ROAs in the Delta are based on the per acre land values shown in Table 8-1. Estimated costs of acquiring Delta land in fee or by easement for terrestrial land conservation and water facilities construction are based on the per acre land values shown in Table 8-2. Average land values within the ROAs are expected to be lower than for the broader Delta due to differences in land use and quality.

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[3] The published rate of 4.0 percent (rounded) does not include any adjustment that may be needed to show the maximum rate of change of ¼ of one percent per year. The FY 2009 rate was 4.625 percent, hence the adjusted FY 2010 rate cannot be less than 4.375 percent.

[4] This means the costs presented in this chapter have been adjusted to reflect 2010 price levels and dollar purchasing power. Adjusting costs for inflation in this way allows for a more accurate comparison of costs over time.

<u>ROA Land Values:</u> Existing agricultural and native vegetation land uses in each ROA were grouped into the following categories:[5] (1) field and pasture crop production, which includes pasture, hay, grain, and other field crops; (2) vegetable crop production; (3) orchard; (4) vineyard; and (5) native vegetation. Land value data published by the California Chapter of the American Society of Farm Managers and Rural Appraisers (CSFMRA 2009) was used to estimate typical land values for agricultural land uses in each ROA. Values for Cache Slough, Suisun Marsh, and Yolo Bypass ROAs were based on data for field crop land (Class II/III), vegetable crop land (Class I/II), pear orchard, vineyards, and rangeland in CSFMRA Region I, South Sutter, Western Placer, Solano and Yolo Counties. Values for Cosumnes/Mokelumne, South Delta, and West Delta ROAs were based on data for Delta cropland, cherry orchard, vineyards, and rangeland in CSFMRA Region III, San Joaquin County. For each agricultural land use, the likely ROA value was set to the average of the low and mid CSFMRA valuation. Values for native vegetation land uses were based on parcel-level county assessment data.[6] The land values shown in Table 8-1 are an acreage-weighted average value based on the mix of land uses in each ROA.

Table 8-1. ROA Land Value Assumptions

ROA	*Avg. Fee Title Value [1] ($/Acre)*
Cache Slough	$4,100
Cos./Mokelumne/East Delta	$5,600
South Delta	$5,500
Suisun Marsh	$3,600
West Delta	$3,200
Yolo Bypass	$4,200

[1] Avg. fee value is the acreage-weighted average value based on the hypothetical tidal habitat restoration footprints used to cost Conservation Measure 4 (CM4), except in the case of Yolo Bypass, where it is the acreage-weighted average value for the entire bypass.

<u>Broader Delta Land Values:</u> A similar procedure was used to estimate typical land values for agricultural and native vegetation land uses for the broader Delta. In the case of Delta land uses outside of the ROAs, the expected value was set to the mid-point CSFMRA value to reflect the greater extent of higher quality agricultural land that may be acquired by BDCP. Table 8-2 shows the land values for specific land use categories used to estimate the cost of land acquisition for terrestrial conservation measures and water facilities. Note that by itself Table 8-2 does not indicate the expected cost of land acquisition for terrestrial conservation measures or water facilities. For a given conservation measure, the expected cost of land acquisition depends

[5] California Department of Water Resources (DWR) land use survey data at the Detailed Analysis Unit (DAU) level were used to classify existing ROA land uses. The DWR Land and Water Use Program collects land use data and develops water use estimates used in statewide water planning. It accomplishes this by conducting surveys of agricultural, urban and environmental land uses, and developing annual estimates of land uses on a regional basis. Since 1986, DWR has compiled land use survey data into georeferenced digital maps. The smallest level of resolution for these maps is the DAU, the smallest study area used by DWR, generally defined by hydrologic features or boundaries or organized water service agencies. In the major agricultural areas, a DAU typically includes 100,000 to 300,000 acres.

[6] Parcels with assessments made between 2000 and 2009 and having at least two-thirds of their land uses classified as native vegetation were used to estimate the average value of land classified as native vegetation in the ROAs. Assessed values were adjusted using USDA's California land value index for non-irrigated farmland to reflect changes in rural land values since the time of the assessment.

upon the mix of existing land uses on the acreage that will be acquired. Those costs are presented later in this chapter.

Table 8-2. Broader Delta Land Value Assumptions

County	*$/Per Acre*					
	Native Veg.	**Field Crop**	**Truck Crop**	**Orchard**	**Vineyard**	**Rangeland**
Contra Costa	$1,500	$5,900	$5,900	$17,800	$16,800	$5,100
Sacramento	$1,500	$7,000	$8,400	$9,200	$20,400	$3,100
San Joaquin	$1,500	$5,900	$5,900	$17,800	$16,800	$5,100
Solano	$1,500	$7,000	$8,400	$9,200	$20,400	$3,100
Yolo	$1,500	$7,000	$8,400	$9,200	$20,400	$3,100

Easement Costs: Easement values in the Delta vary widely, depending on type of easement and restrictions placed on land use. Expressed as a percent of fee title value, surface easement costs may range between 10 and 90 percent while subsurface easements may range between 30 and 50 percent (Davis, per. comm.). For cost estimation, it was assumed surface easements would average 60 percent of fee title value and subsurface easements would average 40 percent of the fee title value.

8.2.6 Transaction Costs Associated with the Acquisition of Interests in Land

Purchases of interests in land, either through fee title or through easements, for the purpose of carrying out habitat restoration actions, ensuring the protection of resources, and undertaking construction of water facilities, are assumed to involve transactional costs in addition to the price paid for that property interest. These transaction costs are likely to consist of: (1) the cost of conducting due diligence, and (2) the cost of undertaking pre-acquisition boundary and habitat surveys. The common assumptions used for computing due diligence and pre-acquisition survey costs are set forth in Table 8-3 and Table 8-4, respectively. Transactional costs are based on the average parcel size and boundary length computed for each BDCP Conservation Zone (CZ), Restoration Opportunity Area (ROA), floodplain region, and water facility right-of-way.[7]

Table 8-3. Land Acquisition Due Diligence Cost Assumptions

Due Diligence Multiplier [1]	1.25
Appraisal Cost ($/Parcel)	$5,300
Preliminary Title Report ($/Parcel)	$530
Phase 1 Site Assessment ($/Parcel)	$6,900
Legal Description ($/Parcel)	$4,300
Boundary Survey ($/Linear Foot of Boundary)	$0.48
Monumentation ($/Linear Foot of Boundary)	$0.37

[1]Applied to the number of acquired parcels to account for the number of parcels considered for purchase but ultimately not purchased.

[7] Transaction costs assumptions based on real estate due diligence and survey costs in *Final East Contra Costa County Habitat Conservation Plan and Natural Community Conservation Plan*. Direct and indirect costs for staff and legal assistance supporting BDCP land acquisition are included as part of the BDCP Implementation Office cost estimate.

Table 8-4. Pre-Acquisition Survey Cost Assumptions

Survey Multiplier [1]	1.25
Land Cover Type Survey (hrs/100 acres)	12
Covered Species Habitat Survey (hrs/100 acres)	16
Covered Plant Habitat Survey (hrs/100 acres)	32
Covered Wildlife Survey (hrs/100 acres)	28
Contractor Cost ($/hr)	$130

[1]Applied to the number of acquired acres to account for the number of acres surveyed for purchase but ultimately not purchased.

8.2.7 Employee Salary Costs and Benefits Multiplier

Plan administration costs include salary costs (Section 8.4, *Plan Administration*). The BDCP Implementation Office will build a staff to oversee or carry out the actions outlined in the BDCP (Chapter 7, *Implementation Structure*). The salary cost estimates associated with these personnel needs are based on proposed FY 2008-09 salary scales for reference positions within various departments of the California Natural Resources Agency, as reported by the California Department of Finance.[8] While federal employees may also be involved in the BDCP Implementation Office, differences between federal and state salaries are expected to be small and inconsequential with respect to overall BDCP administrative costs.

The cost analysis includes a benefits multiplier to account for certain assumed benefits, such as paid leave, health, retirement and other employee benefits, that would be provided to employees of the BDCP Implementation Office. A benefits multiplier of 1.35 was applied to all staff salary costs associated with the BDCP Implementation Office, except in cases where the estimated staffing cost accounted for employee benefits.[9]

8.3 COST ESTIMATE FOR CONSERVATION MEASURES

This section describes the data, methods, and assumptions used to estimate the cost of implementing the BDCP conservation measures. Different costing approaches were used for different conservation measures, depending on the conceptual and engineering design and cost information available at the time of Plan formulation. The approach taken for each conservation measure and the sources of data and other information used for the analysis are described in the following subsections.

8.3.1 CM1: Water Facilities and Operation

*[**Note to Reviewers**: In the main text, the mid-point construction cost estimate is presented for the all pipeline/tunnel conveyance facility option. Because a preferred project has not been selected at this time, the preliminary cost estimate for the eastern alignment option for the conveyance facility is also presented at the end of this section. For the pipeline/tunnel alignment,*

[8] www.dof.ca.gov/budget/historical/2008-09/salaries_and_wages/index.htm

[9] The multiplier is based on average benefits paid by state and local governments as a percent of total employee compensation in 2009, as reported by the U.S. Bureau of Labor Statistics.

the mid-point estimate is the average of the Delta Habitat Conservation and Conveyance Program (DHCCP) PTO Rev. 1 September 2010 construction cost estimate and the 5RMK Independent February 2010 construction cost estimate (escalated using same percentage as DHCCP Rev. 1). Costs are in 2010 dollars. Water facility mitigation costs for non-biological resources, other than property tax revenue replacement, are still being developed and are not included in this draft of chapter 8.]

Cost estimates are presented for the following components of water facilities construction and operation:

- Design, project management, construction management;
- Intake and conveyance construction costs;
- Construction cost contingency;
- Land acquisition;
- Annual operation, maintenance, power, and capital replacement; and
- Local Property Tax and Assessment Revenue Replacement.

Facility features are summarized in Table 8-5. . The mid-point cost estimates for design, project management, construction, contingency and land acquisition are shown in Table 8-6. Operation, maintenance, power, and capital replacement costs are summarized in Table 8-7.

8.3.1.1 Design, Project Management, and Construction Management Costs

Design, project management and construction management costs are assumed to be 18 percent of construction cost. This percentage was derived from comparing historical data from previous programs.

8.3.1.2 Direct Construction Costs

Direct construction costs are based on the Conceptual Engineering Report – All Tunnel Option (now called the Pipeline/Tunnel Option), dated March 2010 as modified by Addendum in August 2010.

The Association for the Advancement of Cost Estimating (AACE International) classifies cost estimates using guidelines identified in Recommended Practice No. 17R-97. Cost estimates are generally classified using several characteristics, the most significant being level of project definition, end usage and methodology.

- **Project Definition (Primary Characteristic) -** These reports are generally considered to be at an approximately 10 percent design level. The cost estimates would therefore fall into the Class 4 or Class 3 Estimate Class.

- **End Usage (Secondary Characteristic) –** These cost estimates are expected to be used for Feasibility or Budget purposes, which would also fall into the Class 4 or Class 3 categories.
- **Methodology –** These estimates were created using a mix of Stochastic and Deterministic methods (primarily Stochastic), which indicates a Class 3 category.

The construction cost estimates developed for the Plan are considered to be in the Class 3 Estimate Class and should have an expected accuracy range of +50 percent / -25 percent.

The estimates are based on a combination of stochastic and deterministic cost estimation methodologies, but primarily stochastic.

Stochastic methodology is defined in this case as involving the probability that an activity will result in a specific cost. This involved researching similar activities from previous projects and reconciling them to the current situation (quantity, year performed, site and market conditions, etc.). These costs were then sorted and a representative unit price selected. This was done without a bottoms-up review of labor, equipment, and materials, etc. The process resulted in a database of "unit prices" that were then applied to activities in the current estimate.

Deterministic methodology is defined in this case to mean a more bottoms-up approach to estimating the cost of an activity. An activity is broken down into its component parts and each part is assigned a set of resources (labor, equipment, materials, etc.) and a production rate (x cubic yards of soil excavated per hour) and the cost is determined.

The construction cost estimates were created using a combination of unit prices developed for similar work in various locations around the United States; historical unit prices compiled over time by the DHCCP estimating staff members; average unit prices recorded by the State of California Department of Transportation in the Contract Cost Data guide; budgetary vendor pricing; and bottoms-up estimates developed specifically for portions of work by the DHCCP estimators. Unit prices were converted to 2010 dollars using United States Bureau of Reclamation (USBR) cost index charts or other methods.

For all activities that required bottoms-up (or deterministic) methods of estimation – e.g., labor, equipment and materials - resource costs were identified as follows:

- **Labor –** General prevailing wage determinations made by the Director of Industrial Relations for Northern California and Sacramento, San Joaquin, Yolo, Solano and Contra Costa counties. Employer cost as well as overhead was calculated and special shift arrangements were factored for overtime.
- **Equipment –** Project rates were developed using USACE, Region VII "Construction Equipment and Operating Expense Schedule," the State of California Department of Transportation "Labor Surcharge and Equipment Rental Rates," and quotes from Northern California equipment rental companies.

- **Materials –** Material quotes were received from various Northern California material vendors. Pumping plant equipment quotes from major national and international suppliers (pumps, valves, etc.) were used**.**

Contingencies were added to the various facility construction costs. In the case of all tunneling work, a contingency of 35 percent was added. For all other work, a contingency of 25 percent was added.

At this stage of project planning, certain assumptions were necessarily made in the creation of the estimate:

- It was assumed that land would be acquired which would be sufficient to "borrow" soil from to construct each facility (canal and forebay embankments, pumping plant pads, etc). These borrow sites will be within a 5-mile haul (one way, using off-highway equipment).
- All excess or unsuitable soil will be deposited (spoiled) within a 1-mile haul from the facility (one-way, using off-highway equipment).
- It is assumed that the soil can be dewatered effectively.
- Installation of sheet pile cofferdams is planned to occur during the allowable windows, however once cofferdams are in place, work within the cofferdam will be allowed to occur year round.
- Tunneling work may continue 24/7; all other work is expected to be performed on five-day, ten-hour shift basis with two shifts per day.
- For the Isolated Conveyance Facility (ICF) East Option, it is assumed that certain sloughs can be completely diverted to allow for complete box culvert siphon construction.

Construction Cost Decomposition: the cost estimate for each conveyance option was decomposed into a logical division of work such as river intake structures, pumping plants, conveyance pipelines, canals, culvert siphons, tunnels, bridges, utilities, forebays, controls and communications, and power supply and grid connections. Major project components were further decomposed into subcomponents which were distinguishable. Decomposition continued until a discreet activity could be identified and either "unit prices" or a detailed estimate could be applied. The following is an example of this decomposition for pumping plants:

- Intake Pumping Plants
- Intermediate Pumping Plant
    - Mobilization/Site Prep/Temporary Facilities
    - Clearing and Grubbing
    - Pumping Plant Excavation and Backfill

- o Approach from Forebay
  - Excavation and Export
  - Excavation and Stockpile
  - Place Stockpiled Material as Backfill
  - Construct Concrete Approach
  - Rebar for Concrete Approach

Activity costs were then summarized at the facility level and all facility costs were summarized for a total alternative cost estimate.

Table 8-5. Summary of Intake and Conveyance Facility Features

Item	*Quantities*			
Intake Capacity	15,000 CFS			
Intake Pumping Plants	5 @ 3,000 CFS each			
Intermediate Pumping Plant Capacity	15,000 CFS			
Gravity Bypass Capacity	Up to 7,000 CFS			
Installed Power Demand	210 MW			
Surge Towers	5 each			
Conveyance Pipeline	8 miles (twin 16 ft diameter)			
Tunnels	2 ea 33 ft dia at 33.5 miles, 1 ea 29 ft dia at 5.2 miles			
Canals	1 mile			
Box Culvert Siphons	None			
Forebay Total Acreage	1,400 acres			
Existing Utilities Affected	70 primary conflicts			
New Bridges	none			
Estimated Privately Owned Acreage Required for Facility, Staging and Borrow Site Footprints, by Land Use and County				
Surface Acreage	***Alameda/Contra Costa***	***Sacramento***	***San Joaquin***	***Yolo***
Ag – Field Crop	744	2,284	738	88
Ag – Truck Crop	0	268	368	46
Ag – Orchard	0	431	0	120
Ag – Vineyard	299	709	0	107
Semiagricultural	65	184	67	68
Urban	11	61	5	38
Native	281	384	98	177
Total Surface Acreage	1400	4,321	1276	644
Subsurface Acreage	***Alameda/Contra Costa***	***Sacramento***	***San Joaquin***	***Yolo***
Ag – Field Crop	31	354	510	
Ag – Truck Crop	28	31	13	
Ag – Orchard		113		
Ag – Vineyard		16		
Semiagricultural	7	28	17	
Urban	3	18	6	
Native	14	72	123	
Total Subsurface Acreage	83	632	669	

CFS = cubic feet per second. MW = megawatts

Table 8-6. Water Conveyance Capital Cost

Capital Cost Items	***Mid-Point Cost Estimate[1] (in millions)***
PM/CM/Final Design and Construction	**$9,602.1**
Contingency	$2,932.2
Total Cost of Conveyance Facility, including Contingency	**$12,534.3**
Land Acquisition	**$130.4**
Contingency	$26.1
Total Cost of Land Acquisition, including Contingency	**$156.5**
Total Capital Costs	**$12,690.8**

[1]Mid-point construction cost estimate is the average of the DHCCP PTO Rev. 1 September 2010 construction cost estimate and the 5RMK Independent February 2010 construction cost estimate (escalated using same percentage as DHCCP Rev. 1). Estimated land acquisition costs based DHCCP Revision 7b Engineering GIS data (8/6/2010).

Table 8-7. Water Conveyance Annual Operations Cost

Annual Operations Cost Items [1]	***Mid-Point Cost Estimate [2] (in millions)***
SWP Power	$14.3/Yr
CVP Project Power	$3.5/Yr
Operations & Maintenance	$18.9/Yr
Capital Replacement	$45.9/Yr
Property Tax Revenue Replacement[3]	$1.9/Yr

[1]Annual SWP Power, CVP Project Power, and Operations & Maintenance costs assumed to commence by the 11th year of the permit period. Annual Capital Replacement costs assumed to commence by the 21st year of the permit period.
[2] Mid-point annual operations cost estimate is the average of the low and high DHCCP PTO Rev. 1 September 2010 operations cost estimate.
[3]While state agencies such as DWR are statutorily prohibited from making payments in lieu of taxes, recently passed legislation requires payment in lieu of taxes for land used in mitigation of new Delta conveyance facilities. The land acquisition cost estimate includes a provision for payments in lieu of taxes, but does not assign those costs to any specific party.

8.3.1.3 Land Acquisition Costs

Data from DWR land use surveys for Delta counties were combined with hypothetical facility, staging, and borrow site footprints to estimate facility land acquisition and easement requirements.[10] Land acquisition costs were estimated using the per acre fee title, surface easement, and subsurface easement cost assumptions presented in Section 8.2. Transaction costs are approximately 10 percent of fee title value and a 20 percent contingency was added to account for market uncertainties.

8.3.1.4 Facility Operation Costs

Estimated power requirements were based on simulated operations of each of the five intakes and the intermediate pumping plant using output from CALSIM II at 15 minute intervals from

[10] Acreage amounts are reflective of the DHCCP Revision 7b Engineering GIS data (8/6/2010).

October 1974 through September 1991 for a total of 17 years of hydrologic record. Diversion flows were dynamically simulated using operating rules in DSM2. Results were used to characterize typical diversion volumes during wet, normal, and dry year hydrologic conditions. Power requirements for pumping were estimated as a function of the pumping flow rate, total dynamic head, and combined efficiency of the pumps and motors. Pumping power requirements were then increased by 15 percent to account for all other project power uses (e.g. Heating, Ventilating, and Air Conditioning [HVAC], general operations and maintenance, lighting, etc.).

Annual power costs are based on a combination of Western Area Power Administration (WAPA) unit energy costs, estimates of bulk power purchased in northern California, and an estimate of CVP Project Power, with CVP Project Power supplying power for 40 percent of pumped water. The 15-minute model outputs were used to estimate on-peak and off-peak power purchases for typical diversion volumes in wet, normal, and dry year hydrologic conditions. The resulting costs for each hydrologic year were averaged to produce the average annual power cost shown in Table 8-7.[11]

General operations and maintenance (O&M) costs were based on estimated staffing requirements for facility operations and maintenance of the proposed conveyance facilities. Unit staffing costs were based on salary and wage rates, including benefits and overhead, for existing SWP operations.

In addition to general O&M and power costs, annual operating costs include contributions to a reliability and replacement fund to cover costs of major repairs and replacement of major capital equipment (e.g. pumps, motors, high voltage switchgear) over the permit period. For purposes of cost estimating, it is assumed that between $43 and $48 million is contributed to the fund annually starting in the 21st year of the permit period.

8.3.1.5 Property Tax and Assessment Revenue Replacement

New Delta conveyance facilities are required under the California Water Code to offset impacts to property tax or assessments levied by local governments or special districts.[12] Publicly available parcel-level local tax assessment data were combined with the proposed footprint of the conveyance facility to estimate potential impacts on local tax revenues. The average cost of property tax and assessment revenue replacement over the 50-year permit period for private lands acquired for conveyance was estimated to range between $1.5 and $2.3 million per year. While state agencies such as DWR are statutorily prohibited from making payments in lieu of taxes, recently passed legislation requires payment in lieu of taxes for land used in mitigation of new Delta conveyance facilities. The land acquisition cost estimate includes a provision for payments in lieu of taxes, but does not assign those costs to any specific party.

[11] Hydrologic year classifications are established by California Department of Water Resources and are primarily based on annual precipitation and unimpaired flow in the Sacramento River watershed.
[12] California Water Code Section 85088 (2009 Nov SB 1).

[Eastern Alignment Surface Canal Conveyance Option Cost Estimate]

*[**Note to Reviewers**: Because a preferred project has not been selected the preliminary cost estimate for the eastern alignment conveyance facility is presented in the following tables. Estimated construction costs from DHCCP PTO Rev. 1 September 2010 construction cost estimate, including cost of on-bank intake structures. Estimated land acquisition costs are based DHCCP Revision 7b Engineering GIS data (8/6/2010).]*

Table 8-A. Summary of Features for the East Canal Conveyance Option

Item	***East Canal Conveyance***
Intakes with Pumping Plants	*5@3,000 CFS*
Conveyance Pipeline	*5.9 miles (twin 16' diameter)*
Intermediate Pumping Plant	*15,000 CFS*
Intake Capacity	*15,000 CFS*
Canals	*40 miles*
Tunnels	*4 each (2.1 miles)*
Box Culvert Siphons	*8 each*
Forebay Total Acreage	*630 acres*
Bridges	*18 bridges*
Utilities	*150 conflicts*
Gravity Bypass	*none*
Installed Power Demand	*95 MW*
Surge Towers	*none*

Assumptions made for estimating East Canal Conveyance costs and schedule include:

- *All import borrow will be available at an average 5-mile haul using off-highway equipment.*
- *All excess dirt can be spoiled at an average 1-mile haul using off-highway equipment.*
- *No import borrow royalty payment is included.*
- *No allowance for upgrading the existing roadways and/or bridges to accommodate the required number of highway truck trips is included.*
- *The soil can be dewatered effectively.*
- *Certain sloughs can be completely diverted to allow for complete box culvert siphon construction.*
- *For construction of the North Delta Intake facility, once sheet pile cofferdams are in place, work can continue year-round in water.*
- *Work would proceed on a ten-hour day, six-days per week schedule with potentially two shifts per day. All required permits would be in place prior to start of construction.*
- *Real estate acquisition would not delay the construction schedule.*

Table 8-B. East Canal Capital Cost

Capital Cost Items	Cost Estimate [1] *(in millions)*
PM/CM/Final Design and Construction	**$6,334.2**
Contingency	$1,680.6
Total Cost of Conveyance Facility, including Contingency	**$8,014.8**
Land Acquisition	**$344.5**
Contingency	$68.9
Total Cost of Land Acquisition, including Contingency	**$413.4**
Total Capital Costs	**$8,428.2**

[1]DHCCP PTO Rev. 1 September 2010 construction cost estimate. Includes cost for on-bank intakes. Estimated land acquisition costs based DHCCP Revision 7b Engineering GIS data (8/6/2010).

Table 8-C. East Canal Annual Operations Cost

Annual Operations Cost Items [1]	*Cost Estimate [2] (in millions)*
Project Power	$33.6/Yr
Operations & Maintenance	$17.9/Yr
Capital Replacement	$45.9/Yr
Property Tax Revenue Replacement[3]	$2.2/Yr

[1]Annual SWP Power, CVP Project Power, and Operations & Maintenance costs assumed to commence by the 11th year of the permit period. Annual Capital Replacement costs assumed to commence by the 21st year of the permit period.
[2]DHCCP December 2009 operations cost estimate, updated to 2010 dollars.
[3]While state agencies such as DWR are statutorily prohibited from making payments in lieu of taxes, recently passed legislation requires payment in lieu of taxes for land used in mitigation of new Delta conveyance facilities. The land acquisition cost estimate includes a provision for payments in lieu of taxes, but does not assign those costs to any specific party.

8.3.2 CM2: Yolo Bypass Fisheries Enhancements

This conservation measure provides for the implementation of physical modifications within the Yolo bypass to enhance floodplain habitat for spawning and rearing splittail and rearing habitat of juvenile Sacramento River salmonids, as described in Chapter 3, *Conservation Strategy*. The measure includes development of a Yolo Bypass Fishery Enhancement Plan (YBFEP) to determine the best approaches for achieving biological objectives. The key features of the major facilities identified in the conservation measure were used for cost estimating purposes and are summarized below.

1. **Fremont Weir Fish Ladder Replacement**. The existing Fremont Weir Denil fish ladder will be removed and replaced with new salmonid passage facilities. Specific design criteria of the ladder have not yet been determined. This facility will incorporate monitoring technologies to allow for collection of information to evaluate its efficacy at passing adult fishes.

2. **Experimental Sturgeon Ramps**. One or more experimental ramps will be constructed at the Fremont Weir to allow for the effective passage of adult sturgeon and lamprey. Specific design criteria of ramps have not yet been determined. This facility will incorporate monitoring technologies to allow for collection of information to evaluate its efficacy at passing adult fishes.

3. **Deep Fish Passage Gates and Channel**. To enhance adult fish passage through the Fremont Weir, as part of modifications to the Fremont Weir (see action #8, below), a deep fish passage notch will be cut through a much smaller section of the Fremont Weir to an elevation of 11.5 feet (NAVD88). This notch will be fitted with operable "fish passage gates" that will allow controlled flow into the Yolo Bypass. A "fish passage channel" will be excavated to convey water from the Sacramento River to the new fish passage gates, and from the fish passage gates to the Tule Canal.

4. **Stilling Basin Modification**. Modifications will be made to the existing Fremont Weir stilling basin to ensure that the basin drains sufficiently into the deep fish passage channel.

5. **Sacramento Weir Improvements**. Modifications will be made to reduce leakage at the Sacramento Weir and therefore reduce attraction of fish from the Yolo Bypass to the weir. For comparative analysis purposes, YBFEP will review the benefits and necessity of constructing fish passage facilities at the Sacramento Weir to reduce juvenile fish stranding and improve upstream adult fish passage. This action may require excavation of a channel to convey water from the Sacramento River to the Sacramento Weir and from the Sacramento Weir to the Toe Drain, construction of new gates at a portion of the weir, and minor modifications to the stilling basin of the weir to ensure proper basin drainage. Specific design criteria of ramps would need to be determined. The low cost estimate assumes Sacramento Weir improvements are not needed, while the high cost estimate assumes they are.

6. **Tule Canal/Toe Drain and Lisbon Weir Improvements**. The YBFEP will include physical modifications to passage impediments, including road crossings and agricultural impoundments in the Tule Canal/Toe Drain to improve fish passage and survival. The cost estimate assumes the replacement of three existing structures at the northern end of the Tule Canal with bridges or other structures to allow adult fish passage. Lisbon Weir will be redesigned to improve fish passage while maintaining or improving water capture efficiency for irrigation.

7. **Lower Putah Creek Improvements**. The cost estimate assumes a realignment of Lower Putah Creek to improve upstream and downstream passage of Chinook salmon and steelhead in Putah Creek and floodplain habitat restoration to provide benefits for multiple species on existing public lands.

8. **Fremont Weir Modification**. The cost estimate includes engineering designs to physically modify the Fremont Weir to manage the timing, frequency, and duration of inundation of the Yolo Bypass with Sacramento River flows. It was assumed a section of the Fremont Weir will be lowered to 17.5 feet (NAVD88) and fitted with operable gates that will allow for controlled flow into the Yolo Bypass when the Sacramento River stage at the weir exceeds 17.5 feet. New flood channels would be excavated to connect the Sacramento River to the new gate structure and to connect the new gate structure to the Yolo Bypass.

9. **Yolo Bypass Modification**. Grading, removal of existing berms, levees, and water control structures, construction of berms or levees, re-working of agricultural delivery channels, and earthwork or construction of structures to reduce Tule Canal/Toe Drain channel capacities will be conducted to the extent necessary to improve the distribution (e.g., wetted area) and hydrodynamic characteristics (e.g., residence times, flow ramping, and recession) of water moving through the Yolo Bypass. The YBFEP will include modifications that will allow water to inundate in certain areas of the bypass to maximize biological benefits and keep water away from other areas to reduce stranding of covered fish species in isolated ponds, minimize impacts to terrestrial covered species, including giant garter snake, and accommodate other existing land uses (e.g., wildlife, public, and agricultural use areas). If necessary, lands will be acquired, in fee-title and through conservation or flood easements.

10. **Westside Option**. The YBFEP will include a feasibility study and evaluation of a gated channel to provide flows into Yolo Bypass along the west side. Potential flow sources are the Sacramento River, Colusa Basin Drain or Sacramento River flows through Knights Landing Ridge Cut, or augmentation of other western tributaries. Some modification of the existing configuration of the discontinuous channels along the western edge of the Yolo Bypass may also be required. If effective at meeting biological objectives, this option could be included in the implementation of the conservation measure. The low cost estimate assumes a gated channel is not constructed. The high cost estimate assumes it is constructed.

8.3.2.1 Yolo Bypass Improvement Options

The preferred design of Yolo Bypass improvements has not been determined. For purposes of cost estimation, two alternative design options were considered. These are as follows:

- **Option 1:** *Fremont Weir and All Fish Passage Improvements*. This option includes extensive improvements to Fremont Weir, as well as improvements to Lisbon Weir, Tule Canal/Toe Drain, Lower Putah Creek, Los Rios Creek, Yolo Bypass Modification, and some improvements to Sacramento Weir (to reduce stranding juvenile fish). It may optionally include a Westside Option. The high cost estimate for this option includes an allowance for a Westside Option, while the low estimate does not.
- **Option 2:** *Sacramento Weir and Lisbon Weir, Los Rios, and Putah Fish Passage Improvements*. This option includes extensive improvements to Sacramento Weir, as well as improvements to Lisbon Weir, Tule Canal/Toe Drain, Lower Putah Creek, Los Rios Creek, and Yolo Bypass Modification, and some improvements to Fremont Weir fish passage structures to prevent stranding juvenile fish. It does not include a Westside Option.

8.3.2.2 Estimated Construction Costs

[**Note to Reviewers:** *Yolo Bypass improvement options and costs are being reviewed and may be revised by DHCCP-Engineering. It also should be noted that it may be possible to cost-share* *improvements for Fremont and Sacramento Weir with State flood agencies, which would result in a lower overall cost for this conservation measure than estimated below.]*

The estimated construction costs for the two options are summarized in Table 8-8. Construction costs are based on the *Yolo Bypass Construction Cost Estimate*, dated September 14, 2010, prepared by DHCCP-Engineering. The construction cost estimates developed for the Plan are considered to be in the Class 4 Estimate Class and should have an expected accuracy range of +120 percent / -60 percent. Costs were estimated using the same cost estimation methodology used to estimate costs for Conservation Measure 1, *Water Facilities and Operations*. Low and high cost estimates for each option are presented. Costs for Option 1 are used in the BDCP cost summaries presented in Section 8.9 because this option provides a more conservative basis for Plan cost estimation.

Table 8-8. Yolo Bypass Improvement Options Construction Costs

Construction Element		***Low Cost Estimate (in millions)***	
Fac #	Description	Option 1	Option 2
1-4,8	Fremont Weir Fish Facilities	$141.4	$9.0
1-4,8	Other Civil/Site Work near Fremont Weir	$12.0	$0.0
1-4, 6, 8	Other Civil/Site Work for Fremont Weir	$20.0	$0.0
5	Sacramento Weir	$47.6	$192.7
6	Lisbon Weir	$23.3	$23.3
6	Los Rios Check Structure	$16.8	$16.8
7	Putah Creek - Gate Structure	$16.8	$16.8
7	Putah Creek Realignment	$6.6	$6.6
10	Westside Option	$0.0	$0.0
	Total Direct Cost	$284.6	$265.3
	Planning, Preliminary Engineering & Permitting at 8%	$22.8	$21.2
	Contingency at 50%	$142.3	$132.6
	Subtotal	$449.6	$419.1
	PM/CM/Final Design at 18%	$76.8	$71.6
	Total Construction Cost, including Contingency	$526.4	$490.8
Construction Element		***High Cost Estimate (in millions)***	
Fac #	Description	Option 1	Option 2
1-4,8	Fremont Weir Fish Facilities	$168.6	$9.0
1-4,8	Other Civil/Site Work near Fremont Weir	$41.4	$0.0
1-4, 6, 8	Other Civil/Site Work for Fremont Weir	$20.0	$0.0
5	Sacramento Weir	$47.6	$192.7
6	Lisbon Weir	$23.3	$23.3
6	Los Rios Check Structure	$16.8	$16.8
7	Putah Creek - Gate Structure	$16.8	$16.8
7	Putah Creek Realignment	$16.7	$16.7
10	Westside Option	$58.3	$0.0
	Total Direct Cost	$435.3	$275.3
	Planning, Preliminary Engineering & Permitting at 8%	$168.6	$22.0
	Contingency at 50%	$41.4	$137.7
	Subtotal	$687.8	$435.0
	PM/CM/Final Design at 18%	$168.6	$74.3
	Total Construction Cost, including Contingency	$805.3	$509.4

8.3.2.3 Estimated Costs for Flowage and Levee Easements

Flowage easement costs are expected to depend on the incremental changes in flood frequency and duration in the bypass. Bypass acreage was categorized as minimally, moderately, or significantly impacted by incremental flows caused by the weir and other modifications to the bypass. Flowage easements on minimally impacted acreage were assumed to cost 12.5 percent of fee value. Flowage easements on moderately impacted acreage were assumed to cost 25 percent of fee value. Flowage easements on significantly impacted acreage were assumed to cost 37.5 percent of fee value. The fee values for Yolo Bypass described in Section 8.2 were used to calculate easement costs.

The low cost estimate assumed new flowage easements would be required for 21,500 acres within the eastern part of the bypass.[13] It assumed one-third of this acreage would be minimally impacted, one-third moderately impacted, and one-third significantly impacted.

The high cost estimate assumed western tributary flows would cause land within the central and western part of the bypass to also be affected. The high cost estimate assumed new flowage easements would be required for up to 48,000 acres.[14] It assumed 42.5 percent of this acreage would be minimally impacted, 42.5 percent moderately impacted, and 15 percent significantly impacted.[15]

A lump sum allowance of $5 million for levee easements to offset land encroachments for levee widening and other levee modifications to address potential scour and underseepage was also added to the estimate.

Estimated costs for flowage and levee easements are summarized in Table 8-9.

Table 8-9. Yolo Bypass Flowage and Levee Easement Costs

Cost Items	*Low Estimate (in millions)*	*High Estimate (in millions)*
Flowage Easements		
Affected Acreage	21,500	48,000
Easement Cost	**$25.1**	**$48.0**
Contingency at 20%	$5.0	$9.6
Easement Cost, including Contingency	**$30.1**	**$57.6**
Allowance for Levee Easements	**$5.0**	**$5.0**
Total Easement Cost	**$35.1**	**$62.6**

[13] This is based on the estimated extent of flooded acreage given a flow of 6000 cfs over Fremont Weir, per Table 2 of *Technical Study #2: Evaluation of North Delta Migration Corridors: Yolo Bypass*, Updated April 2009.

[14] The estimated extent of flooded acreage under very high Fremont Weir flows, per Table 3 of *Technical Study #2: Evaluation of North Delta Migration Corridors: Yolo Bypass*, Updated April 2009, is used as a proxy of the amount of potentially impacted acreage.

[15] Percentages were calculated by assuming the same distribution of impacted acreage within the eastern part of the bypass as the low cost estimate, and that half the additional 26,500 acres impacted within the central and western parts of the bypass would be minimally impacted, and half would be moderately impacted.

8.3.3 CM3: Natural Communities Protection

This conservation measure provides for the establishment of a preserve system to protect and enhance areas of existing natural communities and covered species habitat, protect and maintain occurrences of selected plant species with very limited distributions, provide sites suitable for restoration of natural communities and covered species habitat, and provide habitat connectivity among the various BDCP conservation land units in the preserve system. Costs were estimated for land acquisition, habitat creation, and nonnative weed control during the plant establishment period.

Land acquisition costs are based on the Terrestrial Habitat Restoration Land Base Requirements (SAIC, 2010). The assumed schedule of land acquisition is shown in Table 8-10. Assumptions for land acquisition and habitat construction cost by type of terrestrial habitat are as follows:

- *Vernal Pool Complex Terrain* – Land acquisition costs are based on acquiring fee-title interest in 300 acres of rangeland in the Conservation Zones listed in Table 8-10. Land costs are based on the land value assumptions presented in Section 8.2 and include allowances for transaction costs and contingency. Vernal pool habitat construction costs are based on costs for comparable restoration projects occurring in and around the Delta (Gause, per. comm.). Costs for vernal pool creation were estimated to range between $25,000 and $40,000 per acre of pool built. Vernal pools were assumed to occupy 45 acres, or 15 percent, of the 300 acre vernal pool complex. The other 255 acres were assumed to be supporting grassland habitat. Costs for grassland habitat restoration were estimated to range between $1,000 to $1,400 per acre. Ten to 20 percent of complex acreage is expected to require weed management each year during the establishment period. Weed management costs were estimated to range between $150 and $500 per treated acre, depending on type of management protocol.
- *Alkali Seasonal Wetland Complex* – Costs are based on acquiring fee-title interest in 400 acres of rangeland in the Conservation Zones listed in Table 8-10 to preserve existing alkali seasonal wetland complex. Land costs are based on the land value assumptions presented in Section 8.2 and include allowances for transaction costs and contingency.
- *Grassland* – Land acquisition costs are based on acquiring fee-title interest in 8,000 acres of rangeland in the Conservation Zones listed in Table 8-10. Land costs are based on the land value assumptions presented in Section 8.2 and include allowances for transaction costs and contingency. Costs for grassland habitat restoration were estimated to range between $1,000 to $1,400 per acre (Gause, per. comm.). It was assumed weed management would be required during the habitat establishment period at a cost of $200 to $400 per acre, depending on type of management protocol (Gause, per. comm.).
- *Cultivated (ag) Habitat* – Costs are based on acquiring fee-title interest in approximately 9,800 acres and securing conservation easements on an additional 22,800 acres of agricultural lands in the Conservation Zones listed in Table 8-10. Fee-title and easement

costs are based on the land value assumptions presented in Section 8.2 and include allowances for transaction costs and contingency.

Estimated costs to preserve natural communities are summarized in Table 8-11.

Table 8-10. Land Acquisition Schedule for CM3 Preserve System

Vernal Pool Complex Terrain											
Conservation Zone	**Acres Acquired by Period**										***Total Acreage***
	1-5	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**31-35**	**36-40**	**41-45**	**46-50**	
1	44	23	31	16							114
8	43		31	17							91
11	44	20	31								95
Total	131	43	93	33	0	0	0	0	0	0	300
Alkali Seasonal Wetland Complex											
Conservation Zone	**Acres Acquired by Period**										***Total Acreage***
	1-5	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**31-35**	**36-40**	**41-45**	**46-50**	
1	10		89	50							149
8	5	8	89								102
11	10		89	50							149
Total	25	8	267	100	0	0	0	0	0	0	400
Grassland											
Conservation Zone	**Acres Acquired by Period**										***Total Acreage***
	1-5	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**31-35**	**36-40**	**41-45**	**46-50**	
1	500		443	500	750	744	900	1,000			4,837
8	1,000		307								1,307
11	500		250	500	250	256	100				1,856
Total	2,000	0	1,000	1,000	1,000	1,000	1,000	1,000	0	0	8,000
Agricultural Lands											
Conservation Zone	**Acres Acquired by Period**										***Total Acreage***
	1-5	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**31-35**	**36-40**	**41-45**	**46-50**	
1	473	481	308	308	309	309	309	308			2,805
2	1,720	1,752	1,123	1,123	1,123	1,123	1,123	1,123			10,210
4	1,654	1,684	1,079	1,079	1,079	1,080	1,080	1,080			9,815
7	1,653	1,683	1,079	1,079	1,079	1,079	1,079	1,079			9,810
Total	5,500	5,600	3,589	3,589	3,590	3,591	3,591	3,590	0	0	32,640

Table 8-11. Estimated Costs to Establish Natural Communities Land Preserve

Land Acquisition		***Estimated Cost (in millions)***
Vernal Pool Complex		$1.0
Alkali Seasonal Wetland Complex		$1.4
Grassland Complex		$35.7
Cultivated Habitat		$259.8
Subtotal Land Acquisition		**$297.9**
Contingency at 20%		*$59.6*
Land Acquisition, including contingency		**$357.5**
Habitat Construction	***Low Estimate (in millions)***	***High Estimate (in millions)***
Vernal Pool Complex	$1.4	$2.3
Grassland Complex	$14.4	$24.0
Subtotal Habitat Creation	**$15.8**	**$26.3**
Contingency at 20%	*$3.2*	*$5.3*
Construction Cost, including contingency	**$19.0**	**$31.6**
Total Cost to Create Preserve System	**$376.5**	**$389.1**

8.3.3.1 Property Tax and Assessment Revenue Replacement

Foregone property tax and assessments levied by local governments or special districts on private lands converted to terrestrial habitat will be offset by the BDCP. The annual cost of these offsets was estimated to range between three-quarters and one percent of the estimated market value of the converted private acreage.[16] The average cost of property tax and assessment revenue replacement over the 50-year permit period for private lands converted for the preservation of natural communities was estimated to range between $0.6 and $0.8 million per year. While state agencies such as DWR are statutorily prohibited from making payments in lieu of taxes, recently passed legislation requires payment in lieu of taxes for land used in mitigation of new Delta conveyance facilities. The land acquisition cost estimate includes a provision for payments in lieu of taxes, but does not assign those costs to any specific party.

8.3.4 CM4: Tidal Habitat Restoration

Tidal habitat restoration cost estimates are based on the extent and location of hypothetical tidal habitat restoration footprints for the near-term (Plan Year 10), early long-term (Plan Year 15), and late long-term (Plan Year 40) time periods. Table 8-12 shows the amount to tidal restoration that was assumed to have occurred by the end of each plan phase.[17] Chapter 5, *Effects Analysis*, provides a description of how the hypothetical habitat restoration designs were developed. This section presents the estimated costs for tidal habitat land acquisition, county tax revenue replacement, and habitat construction.

[16] Property tax and assessment burdens on parcels within the conveyance facility footprint were calculated to determine the average tax and assessment burden as a percent of estimated market value. Annual burden rates varied by county, but generally ranged between 0.75 and 1.0 percent of estimated market value, which is used to estimate forgone tax and assessment revenue for land converted to tidal and terrestrial habitat.
[17] The acreage foot prints were derived from RMA modeling conducted for the BDCP effects analysis.

Table 8-12. Tidal Habitat Restoration Acreage

Plan Phase	*Acres*	*Cumulative Acres*
Near-Term (Plan Year 10)	14,000	14,000
Early Long-Term (Plan Year 15)	11,000	25,000
Late Long-Term (Plan Year 40)	40,000	65,000

8.3.4.1 Tidal Habitat Restoration Land Acquisition Costs

Spatial data from DWR land use surveys, county parcel maps, and the tidal habitat footprints were combined to determine the number of parcels and amount of acreage by land use classification that would need to be acquired in each ROA.[18] Costs for land acquisition were calculated by multiplying this acreage by the average ROA land values listed in Table 8-1. Estimated transaction costs and contingency were then added to the estimate. Land acquisition costs for tidal habitat are summarized in Table 8-13.

Table 8-13. Tidal Habitat Land Acquisition Costs

ROA	*Estimated Cost (in millions)*
Cache Slough	$106.6
Cosumnes/Mokelumne	$21.9
South Delta	$151.2
Suisun Marsh	$31.9
West Delta	$10.4
Subtotal Land Acquisition	**$322.1**
Contingency at 20%	*$64.4*
Land Acquisition, including contingency	**$386.5**

8.3.4.2 Property Tax and Assessment Revenue Replacement

Foregone property tax and assessments levied by local governments or special districts on private lands converted to tidal habitat will be offset by the BDCP. The annual cost of these offsets was estimated to range between three-quarters and one percent of the estimated market value of the converted private acreage.[19] The average cost of property tax and assessment revenue replacement over the 50-year permit period for private lands converted to tidal habitat was estimated to range between $1.3 and $1.8 million per year. While state agencies such as DWR are statutorily prohibited from making payments in lieu of taxes, recently passed legislation requires payment in lieu of taxes for land used in mitigation of new Delta conveyance facilities. The land acquisition cost estimate includes a provision for payments in lieu of taxes, but does not assign those costs to any specific party.

[18] Parcels were counted only if at least 10 percent of their acreage was included in the footprint in order to avoid counting parcels just touching the footprint or having very little acreage in it.

[19] Property tax and assessment burdens on parcels within the conveyance facility footprint were calculated to determine the average tax and assessment burden as a percent of estimated market value. Annual burden rates varied by county, but generally ranged between 0.75 and 1.0 percent of estimated market value, which is used to estimate forgone tax and assessment revenue for land converted to tidal and terrestrial habitat.

8.3.4.3 Tidal Habitat Construction Cost Estimates

Tidal habitat restoration will involve a broad range of construction activities, as described in Chapter 3, *Conservation Strategy*. Mass grading and construction of temporary and permanent flood-protection levees will account for most of the construction cost. Low and high construction cost estimates were developed, which differ in terms of the extent of mass grading necessary. Two scenarios were assessed because the extent to which surface grading will be used to adjust the mix of intertidal (mainly marsh plain) and subtidal (mainly estuarine aquatic) habitat has not been determined. The estimated intertidal and subtidal habitat acreages for the low and high cost scenarios are summarized in Table 8-14. Acreages in the table are based on the hypothetical tidal habitat footprint and phasing assumptions used for the effects analysis, with minor modifications in the West Delta ROA.[20]

Table 8-14. Tidal Habitat Restoration Area Estimates by Scenario

	Habitat Area (acres)			
	Tidal Marsh	**Subtidal**	**Other**	**Total**
Low Cost Estimate	14,500	33,000	17,500	65,000
High Cost Estimate	29,000	26,500	9,500	65,000

The acreage footprints are derived from hydrodynamic modeling for a July 2002 base period. Tidal habitat is defined as the area between mean lower low water (MLLW) and mean higher high water (MHHW). Subtidal habitat is defined as the area below MLLW. Other habitat includes areas which are currently within intertidal elevations, but would be above high tides, based on the modeling predictions, once restoration is complete. The tidal ranges and associated acreages shown in the table do not account for long-term forecasts of sea level rise.

Large areas within the ROAs have subsided to a degree that natural sedimentation processes alone will not increase intertidal elevations to levels necessary to support the establishment of vegetation. To establish suitable elevations for intertidal marsh restoration, fill will need to be placed (mechanically or hydraulically) in subsided areas or biomass accumulation (also referred to as subsidence reversal) will need to occur prior to levee breaching. Because the extent to which grading will be needed to achieve the desired mix of intertidal and subtidal habitat has not been determined, cost estimates were developed for two conceptual mass grading scenarios. For each scenario, fill settlement has been taken into account in the volume calculations as a function of fill height and approximate depth of underlying peat soils.

The low cost grading scenario assumes 4.9 million cubic yards (MCY) of fill placement would be used to raise grades to suitable intertidal marsh elevations in parts of the West Delta ROA. The high cost grading scenario assumes an additional 13.7 MCY of grading and fill placement would be used to expand the intertidal area in the West Delta, Cache Slough, South Delta, and Cosumnes-Mokelumne ROAs.

Cost estimates were based on the following mass grading assumptions for each ROA.[21]

[20] Due to substantial fill and grading requirements in the West Delta ROA under the original hypothetical footprint, the footprint assumed for the cost analysis was reconfigured slightly to avoid tidal habitat construction in the most subsided parts of the ROA.

[21] It should be noted that alternative methods for converting subtidal habitat to intertidal marsh, such as bioaccumulation (subsidence reversal) and more extensive dredged material fill placement, have not been included in the cost estimates. Bioaccumulation involves planting and

Suisun Marsh: The cost estimate assumed no mass grading would be required. Suisun Marsh has a relatively high potential for estuarine deposition to raise elevations from subtidal to intertidal compared to the Delta ROAs. In addition, because of the regional geomorphic setting of Suisun Marsh, the tide signal is not expected to be as compressed as modeled in the long term, resulting in a relatively high extent of intertidal habitat area created without fill placement.

West Delta: The low cost scenario assumed restoration areas on subsided West Delta islands would be filled with hydraulically-placed dredged material to create a mix of approximately 20 percent intertidal and 80 percent subtidal habitat in all except the most deeply subsided areas (deeper than approximately 9 feet below mean low low-water (MLLW). The high cost scenario assumed these same restoration areas would be filled to create 100 percent intertidal habitat, again with the exception of the most deeply subsided areas. Both cost scenarios assumed the Dutch Slough site mass grading would consist of land-based fill placement (from local borrow and the Ironhouse Sanitary parcel), per the current DWR restoration plan (PWA 2006). Both scenarios assumed existing artificial fill above intertidal elevations would be removed at no cost to the project. West Delta fill costs were based on estimated costs of placing dredged material and the planning-level cost estimate for Dutch Slough.

Cache Slough, South Delta, and Cosumnes-Mokelumne: For these ROAs, the low cost scenario assumed no mass grading is required. The high cost scenario assumed some land-based cut and fill. To estimate the volume of fill required, it was assumed that lands with elevations up to one foot above mean high high-water (MHHW) would be lowered to the MHHW elevation. The cut material would then be placed in shallow subtidal areas to raise them up to the MLLW elevation. Additionally, mass grading costs for the Cache Slough ROA are based on the assumption that earthmoving would be phased over several decades, requiring interim stockpiling of fill material on one or more parcels. Cut and fill areas were broadly categorized based on anticipated haul distances, and the need for interim stockpiling. Unit costs for grading and fill were based on grading and fill costs for a sample of regional tidal marsh restoration projects.

Flood protection levees would be necessary to protect adjacent developed and other lands that have not been protected for tidal habitat restoration. Levee cost estimates were based on a total of 44 miles of permanent levees along the upland edges of the ROAs, 32 miles of permanent levees on subsided areas in the interiors of the ROAs, and 50 miles of temporary levees that would need to be breached or removed as restoration progresses. Estimated levee heights and unit volumes for each type of levee, by ROA, are shown in Table 8-15.

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controlled flooding of marsh vegetation (e.g., tules, cattails) to allow for the accumulation of organic material over time to increase surface elevations. Allowing bioaccumulation to occur over a period of 20-30 years prior to breaching could increase grades by approximately three feet relative to the tides, assuming an accretion rate of one foot every six years. Bioaccumulation is most applicable to late long term restoration actions because of the time needed to increase surface elevations. To use this approach, the rate of land acquisition set out in the BDCP would need to be accelerated to provide sufficient opportunities for bioaccumulation to occur.

Table 8-15. Estimated Levee Heights and Unit Volumes by ROA

ROA	FEMA Base Flood Elevation (ft NAVD)	Temporary Levees		Permanent Levee (subsided areas)		Permanent Levee (upland edge)	
		Total Height* (ft)	Unit Volume (cy/lf)	Total Height* (ft)	Unit Volume (cy/lf)	Total Height* (ft)	Unit Volume (cy/lf)
Cache Slough	17.0	19.8	62.4			12.1	26.3
Suisun Marsh	10.0	10.8	21.4	9.3	16.7	-	-
Cosumnes-Mokelumne	20.0	-	-	22.5	79.0	-	-
West Delta	9.0	-	-	18.0-26.0	53-105	-	-
South Delta	14.0			20.2	64.9	10.7	21.2

* Total levee height includes allowance for settlement, future sea level rise, and freeboard.

The typical levee height for permanent levees was calculated as the difference between the Federal Emergency Management Agency (FEMA) 100-year flood elevation and a typical ground elevation, plus an allowance for settlement, freeboard and future sea level rise. Typical ground elevation was estimated by ROA and by levee type. Settlement was estimated for each levee type within an ROA as a function of levee height and approximate depth of underlying peat soils. A crest width of 16 feet was assumed for all levees, with average side slopes of 5:1 and 2:1 (horizontal:vertical) on the outboard and inboard sides, respectively.

Unit costs were derived from per cubic yard costs based on similar constructed projects. Unit costs ranging from $5 to $30 per cubic yard, depending on anticipated soil strength and distance of fill material source, were applied. It was assumed that the fill necessary for levee construction would be obtained from sources within the ROA. For island levees, it was assumed that material would be imported from offsite locations by barge and conveyor system.

A unit cost of $3,600 per acre was applied to the acreages shown in Table 8-14 to account for restoration elements other than mass grading and flood protection levees. This unit cost is based on costs for typical, large-scale tidal marsh restorations that have been completed (or are in final stages of design) in the San Francisco Bay: Napa Salt Ponds, South Bay Salt Ponds (multiple sites), Eden Landing Ecological Reserve, Bahia Wetlands, Petaluma Marsh, Cooley Landing, Outer Bair Island and Blacklock Marsh (Suisun Bay). Projects located in San Francisco Bay were used as analogues because of the lack of large-scale tidal habitat restoration projects within the Delta to serve as reference sites.

There are several challenges and limitations associated with estimating construction costs for the tidal habitat restoration. Consequently, estimates of construction costs and of the expected outcomes regarding the extent of habitat acreages created may ultimately be low or high. The uncertainties potentially affecting cost estimates are largely related to the following factors:

- Few, if any, examples of large-scale, planned tidal habitat restoration projects exist in the Delta to serve as reference sites.
- Flexible restoration footprints within the ROAs.
- Flexible sequencing of restoration projects.

- Future determinations regarding desired mix of intertidal marsh and subtidal habitat and therefore relative emphasis on using mass grading and fill to expand intertidal areas.
- Future evaluation of site specific features (e.g., utilities), conditions (e.g., weak soils, degraded levees), and adjacent land uses that may require additional design effort and construction costs.
- Future assessment of actual (versus modeled) changes to tide range over time due to phased restoration actions, geomorphic evolution, and sea level rise.

Each restoration site will have its own unique characteristics, causing actual construction costs to differ from the estimates set out in this chapter. Factors that may affect actual costs include: relocation of existing utilities, improvements necessary for site access, and accommodation for a phased approach to construction. The precise cost of restoration projects will not be known until site-specific designs are completed. A 35 percent contingency was applied to estimated construction costs to account for these unknowns.

Low and high construction cost estimates for tidal habitat restoration are summarized in Table 8-16.

Table 8-16. Total Construction Costs for Tidal Habitat Restoration

Construction Costs	*Low Estimate (in millions)*	*High Estimate (in millions)*
Restoration Costs	$232.2	$235.7
Mass Grading Costs	$36.0	$234.5
Long-term Levee Costs	$307.7	$307.7
Temporary Levee Costs	$241.0	$241.0
Subtotal Construction Costs	**$816.9**	**$1,018.9**
Contingency at 35%	*$285.9*	*$356.6*
Total Construction Costs	**$1,102.9**	**$1,375.5**
Related Costs		
Permitting, Survey & Design at 20%	$220.6	$275.3
Construction Administration at 7%	$77.2	$96.3
Vegetation Establishment at 3%	$33.1	$41.3
Subtotal Related Costs	**$330.9**	**$412.9**
Total Tidal Habitat Construction Costs	**$1,433.7**	**$1,788.4**

8.3.5 CM5: Seasonally Inundated Floodplain Restoration

*[**Note to Reviewers**: At this point in time, cost estimates are presented for two floodplain restoration cost sharing options in order to support deliberations on selection of a preferred option. Once the selection of a preferred option has been made, Chapter 8 will be revised to present the cost estimate for just that option.]*

This conservation measure provides for the creation of 10,000 acres of seasonally inundated floodplain habitat along the San Joaquin River downstream of Vernalis and along Old and/or Middle rivers. The locations identified in this analysis were used solely to estimate costs. The

BDCP floodplain restoration conservation measures provide flexibility for restoration actions to occur along any major channel in the north, east, and south Delta. For cost estimation, it was assumed that floodplain habitat will be created by setting back existing levees, approximately 1,000 feet on each side of a channel. For areas along the San Joaquin River between Vernalis and French Camp Slough, it was assumed that 7,000 acres of floodplain habitat will be created through the relocation of approximately 29 miles of existing levees. It was assumed an additional 3,000 acres of floodplain habitat will be created along Old and/or Middle rivers by moving approximately 12 miles of existing levees.

The assumed schedule of setback levee construction and floodplain habitat creation over the term of the BDCP is shown in Table 8-17.

Table 8-17. Miles of Setback Levees and Acres of Created Floodplain Habitat

Miles of Setback Levees	***Cost Period***									
	1-5	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**31-35**	**36-40**	**41-45**	**46-50**
San Joaquin R.	-	0.9	2.0	5.2	5.2	5.2	5.2	5.2		
Old/Middle R.	-	0.4	0.9	2.2	2.2	2.2	2.2	2.2		
Total Miles	-	1.3	2.9	7.4	7.4	7.4	7.4	7.4	-	-
Running Total	***-***	***1.3***	***4.2***	***11.6***	***19.0***	***26.4***	***33.8***	***41.3***	***41.3***	***41.3***
Acres of Floodplain	-	300	700	1800	1800	1800	1800	1800	-	-
Running Total	**-**	**300**	**1,000**	**2,800**	**4,600**	**6,400**	**8,200**	**10,000**	**10,000**	**10,000**

Setback levees for both project and non-project levees[22] were assumed to be constructed to the PL84-99 (Delta Specific) Standard. Levees along the San Joaquin River were assumed to already meet this standard, while levees along Old and Middle rivers were assumed to be non-project levees that do not meet this standard. The average levee height was assumed to be 20 feet, with a 5:1 interior slope, a 2:1 exterior slope, and a 16-foot wide crest. It was also assumed a graded, sloping bench to provide opportunities for both passive and active establishment of riparian vegetation will be added to the water-side of the levee.

Floodplain development costs were grouped as follows: (1) land acquisition costs for floodplain habitat and setback levee footprint; (2) planning, design, engineering, and permitting costs; (3) construction management costs; (4) construction costs; and (5) contingency costs.

8.3.5.1 Floodplain Habitat Land Acquisition

Land requirements for floodplain development are summarized in Table 8-18. Floodplain development is expected to involve land acquisition through fee title and easements. Land for graded benches and other habitat features on the water-side of the setback levees are expected to require fee-title acquisition. This accounts for approximately 80 percent of the acreage listed in

[22] Project levees are part of the Sacramento Flood Control Project, which was completed by USACE in 1960. Non-project levees are not part of a federal flood control project. Non-project levees are maintained by local districts with financial assistance from the state.

Table 8-18. It is assumed the remaining 20 percent can be secured through easements. Land acquisition costs are summarized in Table 8-19.

Table 8-18. Flood Plain Habitat Land Requirements

Flood Plain Land Acquisition	***Plan Year***									
	1-5	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**31-35**	**36-40**	**41-45**	**46-50**
Cumulative Flood Plain Created (Acres)	-	300	1,000	2,800	4,600	6,400	8,200	10,000	10,000	10,000
Cumulative Easement/Purchase (Acres)	-	348	1,160	3,248	5,336	7,424	9,512	11,600	11,600	11,600

Table 8-19. Flood Plain Land Acquisition Costs

Cost Items	***Low Estimate (in millions)***	***High Estimate (in millions)***
Land Acquisition		
Fee Title Purchases	$58.1	$71.0
Easements	$9.5	$11.6
Subtotal Land Acquisition	**$67.6**	**$82.6**
Contingency at 20%	*$13.5*	*$16.5*
Land Costs, including Contingency	**$81.1**	**$99.1**

8.3.5.2 Property Tax and Assessment Revenue Replacement

Foregone property tax and assessments levied by local governments or special districts on private lands converted to floodplain habitat will be offset by the BDCP. The annual cost of these offsets was estimated to range between three-quarters and one percent of the estimated market value of the converted private acreage. The average cost of property tax and assessment revenue replacement over the 50-year permit period for private lands converted to floodplain habitat was estimated to range between $0.2 and $0.3 million per year. While state agencies such as DWR are statutorily prohibited from making payments in lieu of taxes, recently passed legislation requires payment in lieu of taxes for land used in mitigation of new Delta conveyance facilities. The land acquisition cost estimate includes a provision for payments in lieu of taxes, but does not assign those costs to any specific party.

8.3.5.3 Setback Levee Construction Costs

Levee construction cost estimates for setback levees were taken from levee cost studies done for Delta Visions (Betchart, 2008). Cost estimates were updated to 2010 dollars using USACE's Civil Works Construction Cost Index for levees and floodwalls. It was assumed upgrading existing levees to the PL84-99 (Delta-specific) standard will cost from $1.5 to $2.1 million per mile. It was assumed setting back levees will cost $2.3 million per mile, while creating the water-side benches for habitat development will cost between $1.2 million and $2.3 million per mile.[23] Based on these estimates, the construction costs to set back levees and create water-side benches for habitat were assumed to be $4.5 million per mile for project levees and $6.8 million per mile for non-project levees. The cost estimate assumed fill will be obtained locally. If fill needs to be imported, costs per mile will increase. The cost estimate includes allowances for mobilization (10 percent), surveys, design, construction management and administration (30 percent), and contingency (10 percent). Low and high costs for levee construction are summarized in Table 8-20.[24]

8.3.5.4 Low and High Cost Share Estimates

*[**Note to Reviewers:** cost estimates are presented for two floodplain restoration cost sharing options in order to support deliberations on selection of a preferred option. Once the selection of a preferred option has been made, Chapter 8 will be revised to present the cost estimate for just that option.]*

Some costs of floodplain development are expected to be funded by state flood management programs. The BDCP cost summaries in Section 8.9 assume that state flood management programs will cover a portion of the setback levee costs. The low cost estimate assumes BDCP will pay for half the incremental levee setback costs, all the habitat development costs, and half the land acquisition costs, while state flood programs will pay for half the setback and land acquisition costs plus upgrading non-project levees to the P.L.84-99 (Delta-specific) standard. The high cost estimate assumes BDCP will pay for all incremental levee setback cost, all habitat development costs, and all land acquisition costs, while state flood programs will pay for upgrading non-project levees to the P.L.84-99 (Delta-specific) standard. These assumptions result in a 50 to 75 percent BDCP cost share. BDCP costs are summarized in Table 8-21.

Table 8-20. Estimated Cost of Setback Levee Construction

Construction Costs	*Low Estimate (in millions)*	*High Estimate (in millions)*
Planning/Design/Permitting	$85.3	$104.3
Direct Construction	$284.3	$347.5
Construction Contingency at 10%	*$28.4*	$34.8
Construction Costs, including Contingency	**$398.0**	**$486.6**

Table 8-21. Low and High Cost Sharing Estimates for Floodplain Habitat

BDCP Cost Share	*Low Estimate (in millions)*	*High Estimate (in millions)*
Land Acquisition and Construction	$239.6	$439.3

[23] The cost ranges cited here are in 2010 dollars. The cost estimates reported in Betchart (2008) were developed by the Delta Risk Management Strategy (DRMS)/URS Levee Optimization workgroup. The estimates are based on a basic estimating system using assumed material quantities and unit prices and are considered to be first-order planning level estimates. Actual costs for constructing levee setbacks would be subject to substantial variation based on local conditions, availability of fill material, and changes in other construction assumptions.

[24] Low and high estimate are +/- 10 percent of the estimated costs for levee construction.

8.3.6 CM6: Channel Margin Habitat Enhancement

This conservation measure provides for the enhancement of 20 linear miles of channel margin habitat in the Delta.[25] For the cost analysis, it was assumed that channel margin habitat enhancement will entail creating low benches that support emergent vegetation and higher elevation benches that support riparian vegetation along existing levees. Large woody material (e.g., tree trunks and stumps) may be anchored into constructed low benches or in existing riprapped levees to provide similar habitat functions.

Channel margin enhancement cost estimates are based on conceptual design cross sections and budget-level cost estimates for 95 USACE bank stabilization project sites (approximately 76,000 linear feet) along the Sacramento River and its tributaries (USACE, 2009). Only bank stabilization projects that included channel margin habitat enhancements for species that are covered under the BDCP were considered for the BDCP cost analysis.

Line item cost estimates for each project were obtained from USACE. Cost items included expenditures for: (1) soil cover, (2) in-stream woody material, (3) fascines, (4) landscape materials, and (5) wetlands construction. Across the 95 projects, the cost of channel margin enhancements averaged $538 per linear foot. This estimate includes the cost of planning, engineering and design (at 12 percent of construction cost), construction management (at 8 percent of construction cost), and contingency (at 20 percent of construction cost). USACE assumed channel margin enhancement projects would not require land purchases or easements, though in some cases construction was assumed to require land-side access to target sites. The BDCP cost estimate adopted the same assumptions.

Estimated costs of channel margin enhancements are presented in Table 8-22.[26]

Table 8-22. Estimated Costs of Channel Margin Improvements by Cost Period

Construction Costs	***Low Estimate (in millions)***	***High Estimate (in millions)***
Planning/Design/Permitting	$4.5	$5.5
Direct Construction	$40.2	$49.1
Construction Contingency at 20%	*$8.9*	$10.9
Construction Costs, including Contingency	**$53.6**	**$65.5**

8.3.7 CM7: Riparian Habitat Restoration

This conservation measure provides for the establishment of 5,000 acres of riparian forest and scrub within areas of restored tidal marsh, floodplain, and channel margin. Establishment of riparian habitat will rely on both natural recruitment and active planting. Nonnative vegetation in riparian restoration areas will be controlled during the first three years of native riparian

[25] This could increase to up to 40 linear miles if adaptive management results in the deobligation of funds from other conservation measures.

[26] Low and high estimate are +/- 10 percent of the estimated costs for channel margin enhancement.

establishment. Assumptions used to estimate the costs of this conservation measure are as follows.

Natural Recruitment in Tidal Marsh Restoration Areas: Natural recruitment of riparian forest and scrub was assumed to occur above the tidal range from MHHW to MHHW +2.5 feet at sites that support suitable soils. Natural recruitment was assumed to take place in up to 20 percent of areas with generally suitable soils, and in up to 40 percent of areas with more fluvial disturbance (e.g., portions of the Cosumnes-Mokelumne ROA), where there is more potential for fluvial inundation and scour to refresh soil surfaces.

Active Planting in Tidal Marsh Restoration Areas: Active planting of riparian forest and scrub was assumed to occur in areas adjacent to naturally recruited vegetation in order to increase riparian patch size and enhance riparian habitat quality. It was assumed that active planting acreage would equal 30 percent of natural recruitment acreage in each ROA. A plant density of 170 plants per acre was assumed, which is consistent with an "over-planting" approach designed to rapidly establish native riparian species and reduce the need for replanting. A 70 percent survivorship rate was assumed over the three-year establishment period. Active planting was estimated at $4,000 per acre, including management, field preparation, irrigation installation, and planting costs. The unit cost assumption is based on riparian establishment costs for comparable projects in the Central Valley. A 20 percent cost contingency was added to the estimate.

Management of Riparian Vegetation in Tidal Marsh Restoration Areas: Control of nonnative vegetation during the three-year establishment period will be required. Control of nonnative vegetation will take place in both natural recruitment and active planting areas. It was assumed that control will occur on 100 percent of active planting areas and 50 percent of natural recruitment areas. Annual control cost in areas of active planting was estimated at $1,300 per acre. The unit cost assumption is based on nonnative vegetation control costs for comparable projects in the Central Valley. Control of nonnative vegetation in natural recruitment areas was assumed to cost 40 percent more than in active planting areas to account for more varied and difficult nonnative control conditions. A 20 percent cost contingency was added to the estimate.

Active Planting in Floodplain and Channel Margin Restoration Areas: The amount of active planting acreage in floodplain and channel margin restoration areas was based on the difference between targeted riparian acreage and estimated tidal marsh riparian acreage for the near-term, early long-term, and late long-term periods of the BDCP. Establishment of riparian habitat within restored floodplain was assumed to occur primarily in the South Delta ROA along the San Joaquin, Old, and Middle Rivers. Natural recruitment in floodplain areas and along channel margins was not assumed to contribute to riparian target acreage because of the likelihood native species composition and density would not result in quality riparian habitat.[27] Active planting

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[27] Some funds for active planting in floodplain and channel margin restoration areas could be shifted to other conservation measures if subsequent monitoring shows that natural recruitment in these areas creates good riparian habitat.

cost assumptions in floodplain and channel margin restoration areas are the same as for tidal marsh restoration areas.

Management of Riparian Vegetation in Floodplain and Channel Margin Restoration Areas: Nonnative vegetation control costs per acre during the three-year establishment period in floodplain and channel margin restoration areas were assumed to be the same as for tidal marsh restoration areas.

Estimated riparian establishment costs over the term of the BDCP are summarized in Table 8-23.[28]

Table 8-23. Estimated Costs of Riparian Habitat Restoration

Plant Establishment	*Low Estimate (in millions)*	*High Estimate (in millions)*
Active Planting	$12.1	$14.8
Nonnative Control during Establishment	$15.7	$19.2
Subtotal Riparian Establishment	**$27.8**	**$34.0**
Contingency at 20%	*$5.6*	$6.8
Riparian Establishment Cost, including Contingency	**$33.4**	**$40.8**

8.3.8 CM8: Grassland Communities Resotration

This conservation measure provides for the restoration of 2,000 acres of grassland habitat within Conservation Zones 1, 8, and/or 11 (Figure 3.6). Costs were estimated for land acquisition, habitat creation, and on-going weed management during the establishment period.

8.3.8.1 Grassland Communities Land Acquisition Cost

Spatial data from DWR land use surveys and county parcel maps were combined to estimate the expected number of parcels and amount of acreage by land use classification in each Conservation Zone that would need to be acquired, per the acquisition schedule shown in Table 8-24. Costs for land acquisition were calculated by multiplying the acreage in each land use category by the land values listed in Table 8-2. Estimated transaction costs and contingency were then added to the estimate. Land acquisition costs for tidal habitat are summarized in Table 8-25.

Table 8-24. Land Acquisition Schedule for Grassland Habitat

Land Acquisition by CZ	**Acres Acquired by Period**										*Total Acres*
	1-5	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**31-35**	**36-40**	**41-45**	**46-50**	
1	250	250	125	125	125	125					1,000
8		250									250
11	250		125	125	125	125					750
Total	**500**	**500**	**250**	**250**	**250**	**250**					**2,000**

[28] Low and high cost estimates are +/- 10 percent of the riparian establishment cost estimate.

Table 8-25. Grassland Communities Land Acquisition Cost

Cost Items	Cost Estimate *(in millions)*
Land Acquisition	
Fee Title Purchases	$6.9
Subtotal Land Acquisition	**$6.9**
Contingency at 20%	*$1.4*
Land Costs, including Contingency	**$8.3**

8.3.8.2 Property Tax and Assessment Revenue Replacement

Foregone property tax and assessments levied by local governments or special districts on private lands converted to grassland habitat will be offset by the BDCP. The annual cost of these offsets was estimated to range between three-quarters and one percent of the estimated market value of the converted private acreage. The average cost of property tax and assessment revenue replacement over the 50-year permit period for private lands converted to grassland habitat was estimated to range between $0.04 and $0.05 million per year. While state agencies such as DWR are statutorily prohibited from making payments in lieu of taxes, recently passed legislation requires payment in lieu of taxes for land used in mitigation of new Delta conveyance facilities. The land acquisition cost estimate includes a provision for payments in lieu of taxes, but does not assign those costs to any specific party.

8.3.8.3 Grassland Habitat Establishment Costs

Grassland habitat construction costs were based on costs for comparable restoration projects occurring in and around the Delta (Gause, per. comm.). Grassland restoration was estimated to cost $1,000 to $1,400 per acre for grading, disking, and seeding, and seed stock. Annual cost of weed management over the establishment period is expected to range between $200 and $400 per acre.[29] Grassland habitat establishment costs are summarized in Table 8-26.

Table 8-26. Estimated Costs to Restore Grassland Habitat Restoration

Plant Establishment	***Low Estimate (in millions)***	***High Estimate (in millions)***
Active Planting	$2.0	$2.9
Weed Control during Establishment	$1.6	$3.3
Subtotal Grassland Establishment	**$3.6**	**$6.2**
Contingency at 20%	*$0.7*	$1.2
Grassland Establishment Cost, including Contingency	**$4.3**	**$7.4**

8.3.9 CM9: Vernal Pool Complex Restoration

This conservation measure provides for the restoration of 200 acres of vernal pool complex habitat within Conservation Zones 1, 8, and/or 11 (Figure 3.6). Costs were estimated for land

[29] Herbicide choice and type of weeds can greatly affect price. If the sites can be pre-treated for weeds prior to planting using a combination of cultural and chemical control methods the costs for future weed control may be reduced by half.

acquisition, habitat creation, and on-going weed management during the establishment period for the vernal pool complex terrain.

8.3.9.1 Vernal Pool Complex Land Acquisition Cost

Spatial data from DWR land use surveys and county parcel maps were combined to estimate the expected number of parcels and amount of acreage by land use classification in each Conservation Zone that would need to be acquired, per the acquisition schedule shown in Table 8-27. Costs for land acquisition were calculated by multiplying the acreage in each land use category by the land values listed in Table 8-2. Estimated transaction costs and contingency were then added to the estimate. Land acquisition costs for 200 acres of vernal pool complex are summarized in Table 8-28.

Table 8-27. Land Acquisition Schedule for Vernal Pool Complex

Land Acquisition by CZ	**Acres Acquired by Period**										*Total Acres*
	1-5	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**31-35**	**36-40**	**41-45**	**46-50**	
1	40		22								62
8	27			22							49
11	20	29	20	20							89
Total	**87**	**29**	**42**	**42**	**0**	**0**	**0**	**0**	**0**	**0**	**200**

Table 8-28. Vernal Pool Complex Land Acquisition Cost

Cost Items	*Cost Estimate (in millions)*
Land Acquisition	
Fee Title Purchases	$0.7
Subtotal Land Acquisition	**$0.7**
Contingency at 20%	*$0.1*
Land Costs, including Contingency	**$0.8**

8.3.9.2 Property Tax and Assessment Revenue Replacement

Foregone property tax and assessments levied by local governments or special districts on private lands converted to vernal pool habitat will be offset by the BDCP. The annual cost of these offsets was estimated to range between three-quarters and one percent of the estimated market value of the converted private acreage. The average cost of property tax and assessment revenue replacement over the 50-year permit period for private lands converted to vernal pool complex was estimated to range between $4 and $5 thousand per year. While state agencies such as DWR are statutorily prohibited from making payments in lieu of taxes, recently passed legislation requires payment in lieu of taxes for land used in mitigation of new Delta conveyance facilities. The land acquisition cost estimate includes a provision for payments in lieu of taxes, but does not assign those costs to any specific party.

8.3.9.3 Vernal Pool Complex Establishment Cost

Vernal pool habitat construction costs are based on costs for comparable restoration projects occurring in and around the Delta (Gause, per. comm.). Costs for vernal pool creation were estimated to range between $25,000 and $40,000 per acre of pool built. Vernal pools were assumed to occupy 30 acres, or 15 percent, of the 200 acre vernal pool complex. The other 170 acres were assumed to be supporting grassland habitat. Costs for grassland habitat restoration were estimated to range between $1,000 to $1,400 per acre. Ten to 20 percent of complex acreage is expected to require weed management each year during the establishment period. Weed management costs were estimated to range between $150 and $500 per treated acre, depending on type of management protocol. Vernal pool complex establishment costs are summarized in Table 8-29.

Table 8-29. Estimated Vernal Pool Complex Establishment Cost

Vernal Pool Establishment Costs	Low Estimate *(in millions)*	High Estimate *(in millions)*
Vernal Pool Construction	$0.8	$1.2
Grassland Establishment	$0.2	$0.2
Weed Control during Establishment	$0.0	$0.1
Subtotal Vernal Pool Establishment	**$1.0**	**$1.5**
Contingency at 20%	*$0.2*	$0.3
Vernal Pool Complex Cost, including Contingency	**$1.2**	**$1.8**

8.3.10 CM10: Nontidal Marsh Restoration

This conservation measure provides for the restoration of 400 acres of nontidal freshwater marsh within Conservation Zones 2 and 4 (Figure 3-1). Restored habitat will be distributed in patches of at least 25 acres and associated with occupied giant garter snake habitat within the proposed 1,000-acre giant garter snake preserves designed to enhance the Caldoni Marsh/White Slough and the Yolo Basin/Willow Slough giant garter snake populations. Costs were estimated for land acquisition, habitat creation, and a backup water supply.

8.3.10.1 Nontidal Freshwater Marsh Land Acquisition Cost

For purposes of cost estimation, it was assumed 200 acres of agricultural land within Conservation Zone 4 would be acquired by year 5 of the Plan and an additional 200 acres of agricultural land within Conservation Zone 2 would be acquired by year 10 of the Plan. Spatial data from DWR land use surveys and county parcel maps were combined to estimate the expected number of parcels and amount of acreage by land use classification in each Conservation Zone that would need to be acquired. Costs for land acquisition were calculated by multiplying the acreage in each land use category by the appropriate land values listed in Table 8-2. Estimated transaction costs and contingency were then added to the estimate. Land acquisition costs for 400 acres of nontidal freshwater marsh are summarized in Table 8-30.

Table 8-30. Nontidal Freshwater Marsh Land Acquisition Cost

Cost Items	Cost Estimate *(in millions)*
Land Acquisition	
Fee Title Purchases	$4.4
Subtotal Land Acquisition	**$4.4**
Contingency at 20%	*$0.9*
Land Costs, including Contingency	**$5.3**

8.3.10.2 Property Tax and Assessment Revenue Replacement

Foregone property tax and assessments levied by local governments or special districts on private lands converted to nontidal freshwater marsh will be offset by the BDCP. The annual cost of these offsets was estimated to range between three-quarters and one percent of the estimated market value of the converted private acreage. The average cost of property tax and assessment revenue replacement over the 50-year permit period for private lands converted to vernal pool complex was estimated to range between $0.04 and $0.05 million per year. While state agencies such as DWR are statutorily prohibited from making payments in lieu of taxes, recently passed legislation requires payment in lieu of taxes for land used in mitigation of new Delta conveyance facilities. The land acquisition cost estimate includes a provision for payments in lieu of taxes, but does not assign those costs to any specific party.

8.3.10.3 Nontidal Freshwater Marsh Establishment Cost

Estimated costs for nontidal freshwater marsh habitat establishment are based on costs for comparable restoration projects occurring in and around the Delta (Gause, per. comm.). Construction of nontidal freshwater marsh habitat, including permitting, project management, monitoring, grading, seeding, and other planting was estimated to cost between $4,600 and $8,100 per acre. This assumes two-thirds of the acreage is converted to aquatic habitat and one-third to upland habitat. The cost estimate also includes allowances for two wells for backup water supply. Well costs were estimated to range between $125,000 and $150,000 per well. Estimated costs for nontidal freshwater marsh establishment are summarized in Table 8-31.

Table 8-31. Nontidal Freshwater Marsh Establishment Cost

Nontidal Freshwater Marsh Establishment Costs	Low Estimate *(in millions)*	High Estimate *(in millions)*
Marsh Construction	$1.8	$3.3
Wells	$0.3	$0.3
Subtotal Freshwater Marsh Establishment	**$2.1**	**$3.6**
Contingency at 20%	*$0.4*	*$0.7*
Freshwater Marsh Cost, including Contingency	**$2.5**	**$4.3**

8.3.11 CM11: Natural Communities Enhancement and Management

*[**Note to Reviewers**: Preserve land management costs are preliminary and subject to revision.]*

This conservation measure provides for the development and implementation of management plans for all conservation lands. This management will provide for the maintenance of the habitat functions of protected existing habitat and restored habitats described in CM3, CM4, CM5, CM6, CM7, CM8, CM9, CM10, and CM11.

Management Costs During Permit Period: Habitat management costs for BDCP conservation lands were based on operating budgets for western U.S. National Wildlife Refuges (NWR) managed by the U.S. Fish and Wildlife Service (USFWS) (USFWS 2007). Data on operating budgets and acreage under management were used to estimate unit costs for habitat management. Estimation details are provided in Appendix J, *Implementation Costs Supporting Materials*.

Habitat acreage was assumed to come under management in the period following the one in which existing habitat was acquired or new habitat restored. Tidal marsh, floodplain, and terrestrial/nontidal wetlands acreage were treated as separate management units and separate unit cost assumptions were applied to these acreages. Unit costs shown in the table are averages across all habitat types.

Non-Wasting Endowment Funding Costs: A non-wasting endowment is expected to be established to pay for the costs of land management following the 50-year permit period. The endowment would be funded over the 50-year permit period. Interest from the fund would be used to pay for on-going land management costs following the end of the permit. This would require contributions of approximately $2 million per year (in 2010 dollars), resulting in a fund balance of approximately $182 million (in 2010 dollars) by the end of the permit period.

Annual costs for land management and endowment funding are summarized in Table 8-32.[30]

Table 8-32. Annual Cost of Preserve Management and Endowment Funding

Preserve Management and Endowment Costs	***Low Estimate*** *(in millions)*	***High Estimate*** *(in millions)*
Preserve Management [1]	$3.1/Yr	$3.8/Yr
Contingency at 20%	$0.6/Yr	$0.8/Yr
Subtotal Preserve Management	**$3.7/Yr**	**$4.6/Yr**
Endowment Funding	*$2.0/Yr*	$2.0/Yr
Total Preserve Management, including Contingency and Endowment	**$5.7/Yr**	**$6.6/Yr**

[1]Annual cost for fully established preserve system.

8.3.12 CM12: Methylmercury Management

BDCP actions to minimize the potential for bioaccumulation of mercury that could occur in areas of restoration actions (CM12) include (1) site characterization of mercury prior to acquisition, (2) restoration design modification to address unacceptable concentrations of mercury in substrate,

[30] Low and high estimated costs are +/- 10 percent of the estimated costs for land management and endowment funding. Note that Table 8-32 is representing the annual management cost once the preserve system is fully established. Annual management costs will increase to this level over the permit period as land is added to the preserve system.

(3) long-term monitoring and (4) adaptive management. This cost estimate addresses actions (1) and (2); costs associated with actions (3) and (4) are included in costs for specific habitat measures (e.g., tidal habitat restoration, CM4). The mercury sampling results described in this section will inform site selection and habitat restoration design for tidal and floodplain habitat (CM 4 and 5, respectively). Costs associated with modified site selection and habitat design fall within the contingencies for those two conservation measures, and therefore are not shown here. Costs for ongoing monitoring of mercury methylation within BDCP habitat are subsumed within the cost estimate for Monitoring, Research, and Adaptive Management. This section describes the assumptions used to estimate the incremental costs associated with soil sampling that will be used to identify mercury hot spots within the restoration opportunity areas.

Pre-Acquisition Site Characterization: Pre-acquisition surveys for mercury, grain size and total organic content would be conducted for proposed tidal habitat areas (CM4; 65,000 acres) and floodplain restoration (CM5; 10,000 acres). The 4,000 acres of West Delta tidal restoration acreage can be eliminated from pre-acquisition surveys because these areas will be extensively filled to attain the targeted elevations, resulting in a total of 71,000 acres to be surveyed. For costing purposes the lower end of a range of sample densities from regional surveys (Heim et al., 2010) is used, 1 sample per 300 acres. Consideration is given to the fact that some sites may require an increased sample density, reflected in a high-end cost estimate that assumes one-quarter of the total restoration acreage would be sampled at a density of 1 sample per 50 acres. Survey costs are based on an estimate of $200,000 for a two-week survey to collect, analyze and provide report of results for 175 samples.

Project Design Surveys: More detailed mercury surveys may be required for designing specific restoration plans. Approximate acreages that may require project design surveys are based on the low-end and high-end scenarios described for tidal habitat restoration, CM4, in Section 8.4.4. For a low end cost estimate, project design surveys for mercury would be conducted for approximately 46,100 acres of restoration area at 1 sample per 300 acres. For the high end cost estimate, sampling density would be increased to 1 sample per 50 acres and would include collection and analysis of composite samples representing the 0 to 12-inch depth interval and on a more limited basis the12-inch to 14 or 16-inch depth interval.

Low and high cost estimates for methylmercury site characterization and project design surveys are summarized in Table 8-33.

Table 8-33. Methylmercury Site Characterization and Project Design Surveys

Methylmercury Survey Cost	*Low Estimate (in millions)*	*High Estimate (in millions)*
Site Characterization Surveys	$0.3	$0.8
Project Design Surveys	$0.3	$1.5
Subtotal Methylmercury Survey Cost[1]	**$0.5**	**$2.3**
Contingency at 20%	*$0.1*	$0.5
Methylmercury Survey Cost, including Contingency	**$0.6**	**$2.8**

[1] Subtotal may not reflect sum of survey costs due to rounding.

8.3.13 CM13: Nonnative Aquatic Vegetation Control

This conservation measure provides for the control of Brazilian waterweed (*Egeria densa*), water hyacinth (*Eichhornia crassipes*), and other nonnative submerged and floating aquatic vegetation (SAV and FAV) in BDCP tidal habitat restoration areas. To implement this conservation measure, the BDCP will apply existing methods used by the California Department of Boating and Waterways' (DBW) *Egeria densa* and Water Hyacinth Control Programs, such as applying herbicides as specific as possible to these species, conducting mechanical removal, and/or using other methods of removal as dictated by site-specific conditions and intended outcome/goal. Application of herbicides or other means to control SAV/FAV will be timed to eliminate or minimize potential negative effects of SAV/FAV removal on covered species.

Nonnative vegetation control costs can vary greatly in the Delta, depending on location, plant density, time of year, method of eradication, and need for environmental monitoring. In recent years, environmental monitoring and regulatory compliance costs have comprised approximately 40 percent of total eradication costs, adding substantially to costs of eradication per acre (DBW 2006). Between 2003 and 2005, DBW's aquatic vegetation removal program costs averaged about $2,500 per acre (2010 dollars). Budgetary estimates contained in the 2006 addendum to DBW's *Egeria densa* EIR suggest per acre costs as high as $4,500 per acre (DBW 2006). However, this higher cost was based on high regulatory compliance costs. Because regulatory costs for BDCP vegetation control are not expected to be this high, the cost estimate for this conservation measure is based on the average cost of $2,500 per acre (2010 dollars) reported by DBW for the period 2003 to 2005.

The amount of acreage that will require treatment annually is expected to vary. The low cost estimate assumes, on average, 5 percent of tidal habitat acreage would be treated each year.[31] The high cost estimate assumes, on average, 10 percent of tidal habitat acreage would be treated each year. Average annual treatment costs are summarized in Table 8-34.[32]

Table 8-34. BDCP Aquatic Vegetation Removal Cost

Aquatic Vegetation Removal Cost	***Low Estimate*** *(in millions)*	***High Estimate*** *(in millions)*
Average Acres Treated	1,679/Yr	3,358/Yr
Average Annual Cost	$4.3/Yr	$8.6/Yr
Subtotal Aquatic Vegetation Removal Cost	**$4.3/Yr**	**$8.6/Yr**
Contingency at 20%	*$0.9/Yr*	$1.7/Yr
Aquatic Vegetation Removal, including Contingency	**$5.2/Yr**	**$10.3/Yr**

[31] Treated acreage is calculated as a percentage of the total tidal marsh footprint, including upland acreage. Therefore, the amount of treated tidal and subtidal acreage, as a percentage of total restored tidal and subtidal acreage, would be much higher than the percentages listed above.

[32] Note that annual removal costs will increase over the permit period with the addition of more tidal marsh habitat. Table 8-34 shows the average annual cost over the 50-year permit period.

8.3.14 CM14: Stockton Deep Water Ship Channel Dissolved Oxygen Levels

This conservation measure, which will occur within the Stockton Deep Water Ship Channel, is designed to maintain dissolved oxygen concentrations at levels that will not adversely affect covered fish species during periods when these fish are present in the channel. The BDCP Implementation Office will operate and maintain an oxygen aeration facility in the channel to increase dissolved oxygen concentrations between Turner Cut and Stockton to meet total maximum daily load (TMDL) objectives established by the Central Valley Regional Water Quality Control Board (above 6.0 mg/L from September 1 through November 30 and above 5.0 mg/L [milligrams per liter] at all times). The existing aeration facility will be modified as necessary and, if necessary, additional aerators and associated infrastructure will be added to optimize oxygen delivery to the river, contingent upon results of an ongoing demonstration project conducted by DWR. Operating costs at DWR's existing demonstration facility vary depending on the flows through the ship channel. During dry years, the facility may operate for up to 100 days per year, while in wet years no operations may be required. Depending on flow conditions, annual operating costs range from $10,000 to $300,000 per year. For the purpose of cost estimation, an average annual operating cost of $150,000 has been assumed. Given expected flows through the ship channel, this provides a conservative estimate of likely operating cost (McLaughlin, pers. comm.).[33]

The existing aeration facility was build in 2007 and cost $3.5 million. It is expected to have a 15 year useful life (McLaughlin, pers. comm.).

Low and high estimated costs over the term of the BDCP are shown in Table 8-35 and Table 8-36.[34]

Table 8-35. SDWSC Dissolved Oxygen Diffuser Capital Cost

Diffuser Capital Costs	**Low Estimate** *(in millions)*	**High Estimate** *(in millions)*
Facility Capital Replacement [1]	$9.6	$11.8
Subtotal Diffuser Facility Capital Cost	**$9.6**	**$11.8**
Contingency at 20%	*$1.9*	$2.4
Diffuser Facility Capital Costs, including Contingency	**$11.5**	**$14.2**

[1]Assumes diffuser facility replacement between the 11th and 15th, 26th and 30th, and41st and 50th years of the permit period.

[33] The operating cost estimate prepared by DWR assumed the facility would operate on average 50 days per year. However, recent changes to the City of Stockton's Regional Wastewater Treatment Facility have resulted in improved water quality in the ship channel. If ship channel water quality improves further as a result of San Joaquin River restoration or Delta improvements, average operating days may dip below the level assumed for the cost analysis.

[34] Low and high estimates are +/- 10 percent of the diffuser cost estimate.

Table 8-36. SDWSC Dissolved Oxygen Diffuser Operation Cost

Diffuser Operation Costs	*Low Estimate (in millions)*	*High Estimate (in millions)*
Avg. Annual Diffuser Operation Cost	$0.14/Yr	$0.17/Yr
Subtotal Diffuser Operation Cost	**$0.14/Yr**	**$0.17/Yr**
Contingency at 20%	*$0.03/Yr*	$0.03/Yr
Diffuser Operation Costs, including Contingency	**$0.17/Yr**	**$0.20/Yr**

8.3.15 CM15: Predator Control

This conservation measure addresses the local effects of nonnative predators on covered fish species by supporting focused predator control in high predator density locations. The BDCP will conduct focused predator control using a variety of methods in locations in the Delta that are known to have high densities of predators (“predator hot spots”). Locations of hot spots in which focused predator control will occur and assumptions used to estimate predator control costs for these sites are listed in Table 8-37.

Table 8-37. Focused Predator Control Locations in Delta

Delta Nonnative Predator Hot Spot	*Assumptions for Cost Estimate*
1. Old structures in or hanging over Delta waterways, such as pier pilings or other artificial structures, that are no longer functional or have been abandoned but affect flow fields and provide shade	Up to 20 structures removed per year
2. Vessels that were abandoned throughout the Delta	Up to 10 vessels removed per year
3. New intake structures of the North Delta Diversions	Daily predator harvest using large purse seine nets at 5 locations from October through May.
4. The deep hole just downstream of the Head of Old River in the San Joaquin River	Daily predator harvest using large purse seine nets at 1 location from October through May.
5. Specific locations in Georgiana Slough, as identified by fishery agencies	Daily predator harvest using large purse seine nets at 3 locations from October through May.
6. Specific locations in Sutter and Steamboat sloughs, as identified by fishery agencies	Daily predator harvest using large purse seine nets at 4 locations from October through May.
7. Release sites of salvaged fish from CVP/SWP facilities	Weekly predator harvest using large purse seine nets at 4 locations from October through May.

8.3.15.1 Structure Removal Cost Assumptions

An average cost of $7,800 per structure was assumed. Average structure removal costs are based on costs to remove 30 feet of docking with piles spaced at 10 foot intervals. Dock demolition and disposal was assumed to cost $100 per foot. Pile removal was assumed to cost $800 per pile. Dock and pile removal costs are based on cost information provided by the Contra Costa County Sheriff Department (Powell, pers. comm.) It was assumed that up to 20 structures per year will be removed.

8.3.15.2 Vessel Removal Cost Assumptions

Vessel removal costs are based on the average cost per vessel for removal of 408 vessels in 2002-03 and 2003-04 by the Department of Boating and Waterways (DBW 2005). The average cost of removal was approximately $3,050 per vessel (in 2010 dollars). It was assumed that up to 10 vessels would be removed per year.

8.3.15.3 Focused Predator Control Cost Assumptions

Predator control using large purse seine nets was assumed to occur daily at 13 locations and weekly at 4 locations in the Delta (Table 8-37) between October and May. A predator control event was assumed to require three boat passes over a hot spot, requiring on average 1.5 hours, plus 0.5 hours for travel between sites. It was estimated that 3.4 full-time-equivalent boat crews would be required to operate 241 days per year.

Boat crews were assumed to consist of two mates and a California Department of Fish and Game (DFG) fish habitat specialist. Labor rates were based on FY 2008-09 salary scales for reference positions within the DFG, as reported by the California Department of Finance (CDFA 2009). Labor rates were increased by a factor of 1.35 to account for benefits. A cost contingency of 20 percent was added to calculated labor costs.

Boats used for predator control were assumed to cost $40,000 and have a 10-year useful life.[35] An annual operating cost, covering fuel, maintenance, repairs, and other incidental costs of $48,200 per boat was estimated.[36] A cost contingency of 20 percent was added to calculated boat purchase and operating costs.

Average annual costs for nonnative predatory control are summarized in Table 8-38.[37]

Table 8-38. Focused Nonnative Predator Control Cost

Nonnative Predator Control Cost Items	***Low Estimate*** *(in millions)*	***High Estimate*** *(in millions)*
Hot Spot Predator Removal	$0.55/Yr	$0.68/Yr
Abandoned Vessel Removal	$0.03/Yr	$0.03/Yr
Abandoned Structure Removal	$0.14/Yr	$0.17/Yr
Subtotal Nonnative Predator Control Cost	**$0.72/Yr**	**$0.88/Yr**
Contingency at 20%	*$0.14/Yr*	$0.18/Yr
Nonnative Predator Control Cost, including Contingency	**$0.86/Yr**	**$1.06/Yr**

[35] Boat cost assumption based on a sample of prices for new 20-25 foot center console fishing boats.

[36] Operating costs are based on sample of hourly vessel operating costs for DFG 20-25 foot boats used for IEP surveys. Costs include fuel, maintenance, repairs, and haul out. Operating costs calculated with DFG Vessel Op Costs spreadsheet model (VesselOpCosts2009.xls).

[37] Low and high estimates are +/- 10 percent of the estimated costs for nonnative predator control.

8.3.16 CM16: Non-Physical Fish Barriers

This conservation measure provides funding for the installation and operation of non-physical barriers at the heads of various Delta channels to redirect outmigrating juvenile salmonids. Potential locations for non-physical barriers are described in Chapter 3, *Conservation Strategy*, and include the Head of Old River, the Delta Cross Channel, Georgiana Slough, Turner Cut, Columbia Cut, the Delta Mendota Canal intake, and the Clifton Court Forebay (CFF).

A pilot project was carried out at the Head of Old River, using 14 sections of bubble generators, each 8 meters long. This project used leased equipment and consultant operators. For the spring season of 2009, equipment and operating costs totaled $1.3 million dollars (Holderman, pers. comm.). DWR expects the experience gained through this pilot program will allow a 10 percent reduction in future operating costs. Operating costs were reduced by 10 percent, resulting in an estimated annual cost of $1.2 million per location, to which a 20 percent contingency was added. Non-physical barriers are expected to be operated at seven Delta locations during outmigration periods. Low and high estimated costs to construct and operate the seven barriers over the term of the BDCP are summarized in Table 8-39.[38]

Table 8-39. Estimated Non-Physical Barriers Program Cost (Millions of 2010 dollars)

Non-Physical Fish Barrier Cost	***Low Estimate*** *(in millions)*	***High Estimate*** *(in millions)*
No. of Barrier Locations	7	7
Equipment Lease and Operation	$7.5/Yr	$9.1/Yr
Subtotal Non-Physical Barrier Cost	**$7.5/Yr**	**$9.1/Yr**
Contingency at 20%	*$1.5/Yr*	$1.8/Yr
Non-Physical Barrier Cost, including Contingency	**$9.0/Yr**	**$10.9/Yr**

8.3.17 CM17: Hatchery and Genetic Management Plans

This conservation measure provides for the accelerated development and implementation of Hatchery and Genetic Management Plans (HGMPs) for state Chinook salmon and steelhead hatcheries located in California's Central Valley. Several coordinating actions with DFG and National Marine Fisheries Services (NMFS) associated with this conservation measure will be undertaken by the BDCP Implementation Office. The costs associated with these efforts will primarily be staff-related and were included in the estimated costs for BDCP Program Administration presented later in this chapter.

In addition to these coordinating actions, the BDCP Implementation Office will provide funding for: (1) the development of the HGMPs, (2) a new DFG HGMP staff position, and (3) additional staff at Central Valley hatcheries needed for HGMP implementation and updating. The costs estimated for each action are as follows.

[38] Low and high estimates are +/- 10 percent of the estimated costs for non-physical barriers.

8.3.17.1 HGMP Development and Updating

The cost analysis assumed 12 HGMPs would be updated every five years.[39] Recent genetic management plans developed by DWR for the Feather River Hatchery have cost $125,000 on average, with approximately 90 percent of this being consultant time, and 10 percent DWR staff time (Kindopp pers. comm.). The estimated cost for all 12 plans is estimated to be $1.5 million every five years.

8.3.17.2 DFG HGMP Coordinator Staff Position

An HGMP Coordinator will be hired to coordinate the development, updating, and implementation of the HGMPS among the state hatcheries. It was assumed the salary for this position would be equivalent to that for a Supervising Biologist with DFG's Fisheries Division. DFG estimated overhead and operating costs for the position at $20,000 per year (Shaffer pers. comm.). Total estimated cost to fund the position, including employee benefits and overhead, is $128,000 per year.

8.3.17.3 Central Valley Hatcheries Staff Positions and Operations

It was assumed that each hatchery would need to hire a biologist to oversee the implementation of the individual management plans. DFG estimated the cost of the position at $92,000 per year, including benefits (Shaffer pers. comm.). It was assumed four biologists would be needed for the state hatcheries and two for the federal hatcheries. DFG estimated overhead and operating costs for each position at $20,000 per year (Shaffer pers. comm.). Each hatchery was assumed to undertake genetic testing of ten salmonids stocks every three years. The cost analysis assumed each test would require 50 samples at a cost of $200 per sample. It was also assumed each hatchery would need to seasonally hire technicians to collect and record population data during salmon runs at a cost of $40,000 per year (Lee pers. comm.).

Average annual costs over the permit period are summarized in Table 8-40.[40]

Table 8-40. Estimated HGMP Development and Implementation Support Cost

HGMP Development & Implementation	***Low Estimate*** *(in millions)*	***High Estimate*** *(in millions)*
HGMP Development & Updates	$0.3/Yr	$0.3/Yr
DFG HGMP Coordinator	$0.1/Yr	$0.1/Yr
Hatcheries Staff & Operations	$0.7/Yr	$0.8/Yr
Subtotal HGMP Cost	**$1.1/Yr**	**$1.2/Yr**
Contingency at 20%	*$0.2/Yr*	$0.3/Yr
HGMP Cost, including Contingency	**$1.3/Yr**	**$1.6/Yr**

[39] Appendix J, *Implementation Costs Supporting Materials* provides the list of Central Valley hatcheries for which it is assumed HGMPs will be developed.

[40] Low and high estimates are +/- 10 percent of the estimated costs for HGMP development.

8.3.18 CM18: Illegal Harvest

This conservation measure provides for the funding of actions designed to reduce incidence of illegal harvest of covered fish species. Over the course of the BDCP, funding will be provided to support 17 field wardens and five supervisory staff that will be assigned to the Delta-Bay Enhanced Enforcement Program (DBEEP). Funding will be used to cover the following expenses: (1) salaries, wages, and benefits, (2) operating expenses, (3) minor equipment, (4) major equipment, and (5) overhead. Cost estimates for each category of expense are based on information provided by DFG.

8.3.18.1 Salaries, Wages, and Benefits

Estimated annual staffing costs are based on the DFG positions and salaries shown in Table 8-41, and the employee benefit assumptions described in Section 8.2.

Table 8-41. DFG Game Warden and Support Staff Wage and Salary Assumptions

Position	*Annual FTE Salary**	*FTE Positions*	*Resources Agency Reference Position*
Fish & Game Warden	$61,000	17	Fish and Game Warden, DFG Law Enforcement Div.
Patrol Lieutenant - Supervisor	$75,000	1.0	Fish and Game Patrol Lieutenant – Supervisor, DFG Law Enforcement Div.
Associate Governmental Program Analyst	$62,000	1.0	Associate Governmental Program Analyst, DFG Law Enforcement Div.
Staff Services Analyst-General	$50,000	2.0	Staff Services Analyst-General, DFG Law Enforcement Div.
Secretary	$39,000	1.0	Secretary, DFG Law Enforcement Div.

*Salary estimates based on proposed salaries for 2008-09 for corresponding positions within the Resources Agency, as reported by the California Department of Finance (www.dof.ca.gov/budget/historical/2008-09/salaries_and_wages/index.htm).
* FTE = full-time equivalent
Annual salary amounts shown in this table were multiplied by 1.35 to account for paid leave, health, retirement and other benefits.

8.3.18.2 Operating Expenses

Operating expenses have been estimated by DFG to be approximately $1.3 million annually. Operating costs include allowances for facilities, vehicles, travel, training, general office expenses, and employee overtime (Naslund pers. comm.).

8.3.18.3 Minor and Major Equipment

Costs for minor equipment were estimated by DFG to be approximately $410,000. Minor equipment is expected to be replaced every five years. Costs for major equipment were estimated by DFG to be approximately $892,000. Major equipment is expected to be replaced every ten years. Boat costs were estimated by DFG to cost $1.15 million. Boats are expected to be replaced every 15 years.

8.3.18.4 Overhead

An overhead multiplier of 0.23 was applied to labor, operating, and equipment costs to account for associated overhead costs DFG expects to incur to support the additional staff and equipment assigned to the DBEEP program.

Average annual costs to reduce illegal harvest are summarized in Table 8-42.[41]

Table 8-42. Estimated Illegal Harvest Reduction Costs by Cost Period

Illegal Harvest Reduction	***Low Estimate*** *(in millions)*	***High Estimate*** *(in millions)*
Salaries & Benefits	$1.6/Yr	$2.0/Yr
Operating Expenses, including equipment	$1.5/Yr	$1.8/Yr
Overhead	$0.7/Yr	$0.9/Yr
Subtotal Illegal Harvest Reduction Cost	**$3.8/Yr**	**$4.7/Yr**
Contingency at 20%	*$0.8/Yr*	$0.9/Yr
HGMP Cost, including Contingency	**$4.6/Yr**	**$5.6/Yr**

8.3.19 CM19: Conservation Hatcheries

This conservation measure provides for the support of existing and establishment of new conservation propagation programs for delta and longfin smelt. The conservation measure includes the following: (1) the development of a USFWS delta and longfin smelt conservation hatchery to house a delta smelt refugial population and provide a source of delta and longfin smelt for supplementation or reintroduction, if deemed necessary by fishery agencies, and (2) the expansion of the refugial population of delta smelt and establishment of a refugial population of longfin smelt at the University of California, Davis Fish Conservation and Culture Laboratory to serve as a population safeguard in case of a catastrophic event in the wild.

8.3.19.1 USFWS Delta and Longfin Smelt Conservation Hatchery

The proposed USFWS hatchery is described in Chapter 3, *Conservation Strategy*. Estimated construction costs for the facility, as developed by USFWS, are $19.4 million (Clarke pers. comm.). Annual operating costs, also developed by USFWS, are $1.5 - $2.0 million (Clarke pers. comm.). It was assumed the facility will be constructed by the end of the fifth year of the BDCP and that an annual operating cost of $1.75 million will be incurred starting in the sixth year of the BDCP.

8.3.19.2 Expansion of Delta and Longfin Smelt Refugial Population

The current fish facility at the University of California, Davis will be expanded to support delta and longfin smelt refugial populations in the near term. U.C. Davis has estimated facility expansion will cost $5 million. It is also estimated that annual operating costs will be $2 million. Operating costs are expected to decrease to approximately $800,000 in the eighth year, once the

[41] Low and high cost estimates are +/- 10 percent of the estimated costs for staff, equipment, and overhead.

USFWS hatchery is in full operation (Lindberg pers. comm.). It is further assumed that expansion will be completed within the first two years of plan implementation and that annual operating costs will accrue starting the third year of plan implementation.

Construction and operation costs for conservation hatcheries are shown in Table 8-43 and Table 8-44, respectively.[42]

Table 8-43. Smelt Propagation Facilities Construction Costs

Smelt Propagation Facilities Costs	***Low Estimate*** *(in millions)*	***High Estimate*** *(in millions)*
FWS Smelt Hatchery Construction	$17.8	$21.8
UC Davis Smelt Refugium Expansion	$4.6	$5.6
Subtotal Smelt Facilities Construction Costs	**$22.4**	**$27.4**
Contingency at 20%	*$4.5*	$5.5
Smelt Facilities Construction Costs, including Contingency	**$26.9**	**$32.9**

Table 8-44. Smelt Propagation Facilities Operation Costs

Smelt Facilities Operation Costs *1/*	***Low Estimate*** *(in millions)*	***High Estimate*** *(in millions)*
FWS Smelt Hatchery Construction	$1.8/Yr	$2.2/Yr
UC Davis Smelt Refugium Expansion	$0.9/Yr	$1.1/Yr
Subtotal Smelt Facilities Operation Costs	**$2.7/Yr**	**$3.3/Yr**
Contingency at 20%	*$0.5/Yr*	$0.7/Yr
Smelt Facilities Operation Costs, including Contingency	**$3.2/Yr**	**$4.0Yr**

1/ Average annual over 50-year permit period.

8.4 PLAN ADMINISTRATION COST ESTIMATE

***[Note to Reviewers:** The composition of the BDCP Implementation Office is still under development and the staff and related costs presented in this section are likely to change as the BDCP Implementation Office is better defined. The assumption that the BDCP Implementation Office is an independent entity is adopted only for the purpose of cost estimation. The specific structure of the BDCP Implementation Office and its relationship to existing state and federal agencies will be determined and described in Chapter 7 of the Plan.]*

The costs associated with the administration of the BDCP reflect all of the expenditures that will be reasonably necessary for the BDCP Implementation Office to effectively oversee the implementation of the BDCP throughout the term of the Plan. Program administration costs include expenditures related to employees, facilities, equipment, vehicles, and associated overhead necessary to support the BDCP Implementation Office. Associated overhead costs include employee benefits, insurance, legal and financial assistance, and travel. For the purpose of the cost analysis, the BDCP Implementation Office is assumed to be an independent entity

[42] Low and high estimates are +/- 10 percent the estimated costs for conservation hatchery construction and operating cost.

located in Sacramento, California. This assumption provides a conservative basis from which to estimate program administration costs. Administrative costs that may be incurred by entities other than the BDCP Implementation Office (e.g., supporting entities – see Chapter 7, *Implementation Structure*) are not included in the program administration cost estimate.

8.4.1.1 Staff and Related Costs

The BDCP Implementation Office employee costs are based on a staffing plan developed for BDCP and the salary and benefit assumptions described in Section 8.2 (see Appendix J, *Implementation Costs Supporting Materials* for details). Staffing costs include allowances for benefits, travel, and training. Staffing levels assumed for the cost estimate vary over the permit period, from a low 41 full-time equivalent (FTE) positions in the first five years of Plan implementation to a maximum of 57 FTE positions by the 21st year of Plan implementation.

8.4.1.2 Office Space and Related Costs

Office space and related costs include the office rental costs, utilities, general office equipment, employee-assigned office equipment, geographic information system (GIS) hardware and software, and public outreach materials. Cost assumptions for each of these items are as follows:

Office Space and Utilities: An office space requirement of 250 square feet per FTE was assumed. Unfurnished office space was estimated to cost $2.50 per square foot per month, including utilities.[43]

General Office Equipment: General office equipment includes copy machines, telephone systems, printers, fax machines, and specialized equipment such as digital cameras, trunked radio systems, and publications and subscriptions. It also includes common area office furniture. Annual costs were estimated by amortizing the purchase cost of each type of equipment or furniture over its useful life.[44] Some items were assumed to include annual service contract costs (see Appendix J, *Implementation Costs Supporting Materials* for details).

Employee-Assigned Office Equipment: Employee-assigned office equipment includes cubicle office furniture, computers, cell phones, and office supplies. Annual costs were estimated by multiplying the number of FTE staff positions by the amortized cost of equipment. Some items were assumed to include annual service contract costs. See Appendix J, *Implementation Costs Supporting Materials* for specific employee-assigned equipment cost assumptions.

GIS Hardware and Software: This category includes a dedicated GIS/database server, tablet personal computer, plotter, global positioning system (GPS) unit, GIS software, and related computer software. Annual costs are based on the estimated purchase cost for each item amortized over its useful life. Some items were assumed to include annual service contract

[43] The rental rate assumption is approximately 125 percent of current office rental rates if downtown Sacramento. The 25 percent premium is added to account for the currently depressed commercial real estate market in Sacramento.

[44] This is equivalent to assuming general office equipment and furniture is leased by the BDCP Implementation Office.

costs. See Appendix J, *Implementation Costs Supporting Materials* for specific GIS equipment cost assumptions.

Public Outreach Costs: This category includes an annual allowance for printed material, public meetings and focus groups, including costs for design, layout, printing, postage, web services, and facilities rental. Annual public outreach costs were assumed to vary over the term of the BDCP. See Appendix J, *Implementation Costs Supporting Materials* for specific public outreach cost assumptions.

8.4.1.3 Vehicle and Related Costs

Vehicle costs include the costs for owned and rented vehicles and as well as allowances for fuel, maintenance, and insurance. Owned vehicle annual costs were based on the vehicle's estimated purchase cost amortized over its useful life plus an annual allowance for fuel, maintenance, and insurance. Annual costs for rented vehicles were based on a daily rental rate multiplied by the number of rental days per year per 1,000 acres of habitat under management. See Appendix J, *Implementation Costs Supporting Materials* for the specific vehicle quantity and cost assumptions.

8.4.1.4 Legal, Accounting, and Insurance Costs

Insurance requirements for the BDCP Implementation Office were assumed to include directors and officers insurance, general liability insurance, and professional liability insurance. Liability insurance was assumed to total $30,000 per year, or $150,000 every five years.[45] The BDCP Implementation Office was assumed to require outside legal and accounting assistance throughout the term of the BDCP.[46] Outside legal costs were calculated by multiplying an hourly rate by annual hours of assistance. The amount of outside legal assistance needed by the Implementing Office was assumed to vary over the term of the BDCP. Accounting assistance costs were based on an annual lump sum allowance for auditing and other financial services. See Appendix J, *Implementation Costs Supporting Materials* for specific legal and accounting assistance cost assumptions.

8.4.1.5 Summary of Program Administration Costs

Annual average program administration costs are summarized in Table 8-45. The allocation of program administration costs to specific program functions is shown in Table 8-46.[47]

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[45]Vehicle and employee health/disability/workers compensation insurance costs are calculated separately from liability insurance costs. Vehicle insurance costs are included in the vehicle cost estimate, while employee insurance costs are captured by the benefits multiplier applied to wage and salary costs.

[46] These services would be in addition to legal counsel and budget analyst positions within the Implementing Office. See Appendix J, *Implementation Costs Supporting Materials for details.*

[47] Implementation of conservation measures addressing other stressors will be paid for by the contributors to that stressor or by public dollars. However, the SWP and CVP will provide funding for a program that is projected to be about $1 million per year to pay for staff in the BDCP Implementation Office to advocate and pursue research to continue evaluation of other stressors and engage the regulatory agencies to take actions based upon improved scientific understanding to reduce the affects of these stressors on the health of at risk fish species in the Delta.

Table 8-45. Estimated BDCP Implementation Office Costs

Implementation Office Costs 1/	***Low Estimate*** *(in millions)*	***High Estimate*** *(in millions)*
Salary & Benefits	$3.9/Yr	$4.8/Yr
Office, Furniture, Computers	$0.5/Yr	$0.6/Yr
Vehicles	$0.2/Yr	$0.3/Yr
Legal, Accounting, Insurance	$0.5/Yr	$0.6/Yr
Total Implementation Office Costs	**$5.2/Yr**	**$6.4/Yr**

1/ Average annual over 50-year permit period.

Table 8-46. Functional Allocation of BDCP Implementation Office Costs

Implementation Office Cost Allocation	***Low Estimate*** *(in millions)*	***High Estimate*** *(in millions)*
Program Administration	$1.9/Yr	$2.3/Yr
Restoration	$1.8/Yr	$2.2/Yr
Other Stressors Program	$0.9/Yr	$1.1/Yr
Monitoring & Research	$0.7/Yr	$0.8/Yr
Total Implementing Office Cost (Mil/Year)	**$5.2/Yr**	**$6.4/Yr**

8.5 Monitoring/Research and Avoidance and Minimization Measures Cost Estimate

*[**Note to Reviewers:** Monitoring/research and avoidance and minimization measure cost estimates are under development and not included in this draft of Chapter 8. These costs have been roughly estimated to range between $60 and $90 million/year, inclusive of on-going IEP expenditures of roughly $30 million/year.]*

8.6 Adaptive Management Program Cost Estimate

Costs for adaptive management are included in the contingencies of each conservation measure's cost estimate, and therefore are not estimated separately.

8.7 Changed Circumstances Cost Estimate

The changed circumstances provisions of the BDCP are intended to address reasonably foreseeable events that may impede or prevent the BDCP from achieving its biological goals and objectives within the Plan Area. Section 6.3.2, *Changed Circumstances*, of the BDCP identifies a broad range of potential changed circumstances. As noted in Section 6.3.2, responses to changed circumstances will largely be developed and implemented as part of the adaptive management program. In some cases the expected costs associated with responses to changed circumstances are accounted for directly or implicitly through contingencies in the estimated costs of conservation measures. However, responses to certain changed circumstances are expected to result in additional implementation costs, if such responses become necessary. This section describes these costs and how they were estimated.

For purposes of cost estimation, the changed circumstances described in Section 6.3.2 of the BDCP were divided into three categories:

1. Changed circumstances for which responses beyond those contemplated by the adaptive management program would likely be impracticable and ineffective;

2. Changed circumstances for which response costs are accounted for directly or implicitly in the estimated costs of conservation measures, including adaptive management; and

3. Changed circumstances for which responses are expected to result in additional implementation costs.

Changed circumstances for which responses beyond those contemplated by the adaptive management program would likely be impracticable and ineffective. This category includes changed circumstance related to climate, water temperature, ocean conditions, and long-term temperature and precipitation patterns. Responses to significant changes in any of these circumstances, beyond the basic responses dictated by the adaptive management program, are not expected to be practicable or effective, and, as such, are not provided for under the BDCP.

Changed circumstances for which response costs are accounted for directly or implicitly in the estimated costs of conservation measures. This category includes changed circumstances related to water operations infrastructure, conflicts with state or federal environmental regulation, new species listings, invasive species, and toxic or hazardous spills.

- *Water Operations Infrastructure*: A changed circumstance in water operations infrastructure is defined as a malfunction or breakdown of water operations conveyance facilities which precludes or substantially inhibits the ability to manage water operations within the water operations parameters in effect at the time of the infrastructure failure. The planned response to this changed circumstance is to work with DWR and/or Reclamation to make repairs to the affected facilities and restore operations to normal as quickly as possible. The expected costs of minor and major repair and replacement of water operations infrastructure are accounted for directly in the operating cost estimate for Conservation Measure 1, *Water Facilities and Operation*. Costs for minor repairs and maintenance are included in annual costs for O&M, while costs for repairs to and/or replacement of major components of water operations infrastructure are included in the annual reliability and replacement fund, which over the 50-year permit period, provides for roughly $2 billion for these purposes.

- *Conflicts with state or federal environmental regulation*: Responses to conflicts with State or federal environmental regulation include modifying conservation measures to ensure compliance and/or implementing alternative conservation measures that provide equivalent ecological benefits. The cost contingencies, which range from 20 to 50 percent, included in the conservation measure cost estimates are deemed sufficient to accommodate changes in design or implementation required to ensure compliance with applicable state and federal environmental regulations. If compliance necessitates implementation of alternative conservation measures, it is expected that costs would be comparable to the costs of the measures being replaced.

- *New species listing*: In the event that a fish or wildlife agency lists a species not covered by the BDCP, the BDCP Implementation Office will evaluate potential impacts of covered activities on the species and conduct an assessment of suitable habitat in areas of potential effect. It will also implement measures to avoid impacts to the newly listed specified until such time as the BDCP has been amended to include the newly listed species as a covered species. Any incremental costs of these activities are expected to fall within the cost contingencies applied to the conservation measure cost estimates including adaptive management. It is anticipated that the natural communities protected and restored in the Plan Area under the BDCP will include suitable habitat for most if not all newly listed species having a presence in the Plan Area and therefore no additional land acquisition costs would be incurred.
- *Introduction of new invasive species*: Responses to new invasive species will be determined through the adaptive management process and may include measures to reduce or control the adverse effect of new nonnative species and/or implementation of alternative conservation measures that provide equivalent levels of benefit to applicable covered species. The cost contingencies, which range from 20 to 50 percent, included in the conservation measure cost estimates are deemed sufficient to accommodate changes in design or implementation required to control adverse effects of new nonnative species. If presence of new nonnative species necessitates implementation of alternative conservation measures, it is expected that costs would be comparable to the costs of the measures being replaced.
- *Toxic of hazardous spills*: Cost liability is assumed to rest with the party responsible for the spill event. Thus spill events that are not attributable to BDCP actions would not result in additional BDCP cost. Construction activity is considered to be the most likely source of a spill event caused by a BDCP action. In such situations, construction contingencies and bonding/insurance requirements of contractors are expected to cover any costs of spill remediation.

Changed circumstances for which responses are expected to result in additional implementation costs. This category includes changed circumstances related to failure of BDCP constructed levees and damage to BDCP protected lands caused by non-prescribed fire.

- *Failure of BDCP constructed levees*: Both tidal habitat restoration and floodplain development involve modification of existing and/or construction of new levees. Notwithstanding the integrity of constructed levees, the BDCP Implementation Office may encounter circumstances in which these levees subsequently fail. In such an event, the BDCP Implementation Office may be responsible for undertaking actions to restore the functions of habitat degraded or lost as a result of failure. For cost estimating purposes, the response is assumed to include a contribution to repair of the damaged levee and restoration or replacement of damaged habitat. Because of differences in geographic location, land use, and levee design, expected costs of levee failure were estimated separately for levees connected to tidal habitat restoration and floodplain development.[48]

Levees constructed for tidal habitat restoration: A probabilistic model of levee failure was used to estimate the likelihood of a levee failure in each permit year. Failure due to both flood and seismic events was considered. Risk of failure due to flood events was estimated by converting a 1:100 year level of flood protection into an expected rate of failure per mile of constructed levee. Seismic failure rates per mile were assumed to be similar to those for existing levees within the relevant ROA, as estimated by the Delta Risk Management Strategy Phase 1 report.[49] The flood and seismic failure rates per mile were added together to get the composite rate of failure per mile. The composite rate was then multiplied by the number of miles of BDCP constructed levees in each permit year to get the probability of a levee failure for each permit year. A low and high estimate of levee repair cost was used to calculate the expected cost of levee repair in each permit year. The high estimate assumes repair costs for tidal habitat levees would be similar to the average cost of repair for a significant levee failure, as reported by Suddeth, Mount, and Lund (2010).[50] The low estimate set repair costs at half the average cost, on the assumption that it may not be necessary to repair every breach or reclaim all flooded land in tidal habitat zones. It was also assumed that a failed tidal habitat levee would, on average, require reconstruction of 10 percent of the affected tidal habitat at a cost of $6,000 per acre.[51] Expected costs over the 50-year permit period are summarized in Table 8-46 and work out to approximately 10 to 15 percent of the tidal habitat construction cost for Conservation Measure 4, *Tidal Habitat Restoration*.

Levees constructed for floodplain development: A probabilistic model of levee failure similar to the one developed for tidal habitat was used to estimate the probability of floodplain levee failure in each permit year. The average cost of repair for a significant levee failure, as reported by Suddeth, Mount, and Lund (2010). Additionally, it was assumed that damages to land and assets protected by a breached floodplain levee would equal 10 percent of the flooded island's or tract's land and asset value. The two costs were multiplied by the probability of failure for each permit year to estimate the expected cost of floodplain levee failure of the 50-year permit period. This cost was then allocated between the BDCP and state/federal flood agencies according to the cost share percentages used to calculate the low and high cost estimates for Conservation Measure 5 (CM 5), *Seasonally Inundated Floodplain Restoration*.

Damage to BDCP protected lands caused by non-prescribed fire: Most natural communities in the Plan Area, including valley/foothill riparian, wetlands, and agriculture, are typically not prone to fire. The non-aquatic lands within the Plan Area are primarily characterized by intensively managed agriculture, which generally does not provide the conditions for

[48] The detailed calculations are presented in Appendix J, *Implementation Costs Supporting Materials*.

[49] Seismic levee failure probabilities for Delta islands and tracts within each ROA were taken from Table 13-3 of the Final Delta Risk Management Strategy Phase 1 Report. These island failure probabilities were converted to seismic failure rates per mile of levee using data on island levee miles reported in Table 13-1 of the Final Delta Risk Management Strategy Phase 1 Report. The average of these probabilities was used to estimate the seismic risk per mile of BDCP constructed levees in each ROA.

[50] They estimate the average cost of repair, which includes costs of mobilization, breach stabilization, breach closure, and island pump-out, averages $25 million, based on data compiled by the Delta Risk Management Strategy, DWR, and interviews with various Delta engineers.

[51] The per acre cost is derived from the tidal habitat construction cost estimate developed for conservation measure 4 and includes the habitat restoration costs other than land acquisition, levee construction, and major grading.

uncontrolled or extensive fire events. Non-prescribed fire on restored riparian acreage is more likely to go unchecked and may result in significant impairment of habitat function. If it is determined through monitoring that burned riparian vegetation is not recovering at a sufficient rate through natural processes, active reestablishment may be required. These costs are not expected to exceed 5 percent of the initial cost of riparian habitat establishment estimated for Conservation Measure 7, *Riparian Habitat Restoration*.

Average annual incremental costs for changed circumstances are summarized in Table 8-47.

Table 8-47. Incremental Costs of Changed Circumstances

Changed Circumstances Costs [1]	***Low Estimate*** *(in millions)*	***High Estimate*** *(in millions)*
Failure of Constructed Levees for Tidal Habitat	$2.0/Yr	$3.3/Yr
Failure of Constructed Levees for Floodplain Habitat	$0.8/Yr	$1.2/Yr
Restoration of Habitat damaged by Fire	$0.1/Yr	$0.1/Yr
Incremental Costs of Changed Circumstances	**$2.9/Yr**	**$4.6/Yr**

[1]Average annual over 50-year permit period.

8.8 Mitigation Measures Cost Estimate

*[**Note to Reviewers:** This section will present costs for mitigation measures, which are still underdevelopment. Per Steering Committee request, it will present NEPA/CEQA mitigation costs for non-biological resources to the extent that such costs are developed through the EIR/EIS process.]*

8.9 Summary of Program Costs

BDCP capital outlays over the 50-year permit period are summarized in Table 8-48 for the low and high cost estimates. Capital outlays are shown in five-year increments. Approximately 90 percent of capital outlays are expected to occur within the first 15 years of Plan implementation. Approximately 80 percent of capital outlays are for water conveyance and 20 percent are for habitat conservation measures. Figure 8-1 depicts capital outlays graphically over the 50-year permit period for the midpoint of the low and high cost estimates.

BDCP operating outlays over the 50-year permit period are summarized in Table 8-49 for the low and high cost estimates. Operating outlays are shown in five-year increments. Operating outlays for habitat and other stressor conservation measures are spread fairly evenly over the 50-year permit period. Operating outlays for water conveyance step up significantly starting in the eleventh year of Plan implementation, as the conveyance facility becomes fully operational, and again in the 21^{st} year when contributions to the capital replacement fund are assumed to begin. Approximately 57 percent of operating outlays are for water conveyance, 7 percent are for habitat conservation measures, 27 percent are for other stressor measures, and 9 percent are for program oversight. *[**Note to Reviewers**: share of operating costs for other stressor measures and program oversight will increase once costs for CM 12 and monitoring, research, and avoidance & minimization measures are included in the cost estimate.]* Figure 8-2 depicts operating outlays graphically over the 50-year permit period for the midpoint of the low and high cost estimates.

Table 8-48. BDCP Capital Outlays in Five-Year Increments

Low Estimate *(millions)*	***Plan Year***									
	1-5	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**31-35**	**36-40**	**41-45**	**46-50**
Water Conveyance [1]										
Subtotal	$5,170	$7,521	$0	$0	$0	$0	$0	$0	$0	$0
Habitat Restoration										
Subtotal	$567	$522	$448	$317	$319	$319	$306	$306	$2	$2
Other Stressors										
Subtotal	$0	$0	$4	$0	$0	$4	$0	$0	$4	$0
Total Capital Outlays	**$5,737**	**$8,042**	**$452**	**$317**	**$319**	**$323**	**$306**	**$306**	**$6**	**$2**

High Estimate *(millions)*	***Plan Year***									
	1-5	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**31-35**	**36-40**	**41-45**	**46-50**
Water Conveyance [1]										
Subtotal	$5,170	$7,521	$0	$0	$0	$0	$0	$0	$0	$0
Habitat Restoration										
Subtotal	$765	$695	$610	$391	$394	$394	$377	$377	$3	$3
Other Stressors										
Subtotal	$0	$0	$5	$0	$0	$5	$0	$0	$5	$0
Total Capital Outlays	**$5,935**	**$8,216**	**$614**	**$391**	**$394**	**$398**	**$377**	**$377**	**$7**	**$3**

[1]CM1: Midpoint estimate

Table 8-49. BDCP Operating Outlays in Five-Year Increments

Low Estimate *(millions)*	**Plan Year**									
	1-5	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**31-35**	**36-40**	**41-45**	**46-50**
Water Conveyance [1]										
Subtotal	$10	$10	$192	$192	$422	$422	$422	$422	$422	$422
Habitat Restoration										
Subtotal	$10	$22	$28	$32	$36	$39	$42	$45	$46	$46
Other Stressors										
Subtotal	$116	$106	$110	$115	$119	$123	$128	$132	$132	$132
Program Oversight [2]										
Subtotal	$25	$32	$37	$39	$39	$45	$47	$48	$46	$46
Total Operating Outlays	**$161**	**$170**	**$367**	**$378**	**$615**	**$629**	**$638**	**$646**	**$646**	**$646**

High Estimate *(millions)*	**Plan Year**									
	1-5	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**31-35**	**36-40**	**41-45**	**46-50**
Water Conveyance [1]										
Subtotal	$10	$10	$192	$192	$422	$422	$422	$422	$422	$422
Habitat Restoration										
Subtotal	$13	$27	$35	$40	$45	$49	$53	$57	$59	$59
Other Stressors										
Subtotal	$144	$137	$146	$157	$165	$174	$183	$191	$191	$191
Program Oversight [2]										
Subtotal	$31	$42	$49	$52	$52	$61	$65	$66	$65	$65
Total Operating Outlays	**$197**	**$216**	**$422**	**$441**	**$684**	**$706**	**$723**	**$736**	**$737**	**$736**

[1]Midpoint estimate

[2]Monitoring, Research, and Avoidance & Minimization Measures cost under development and not included in subtotal and grand total.

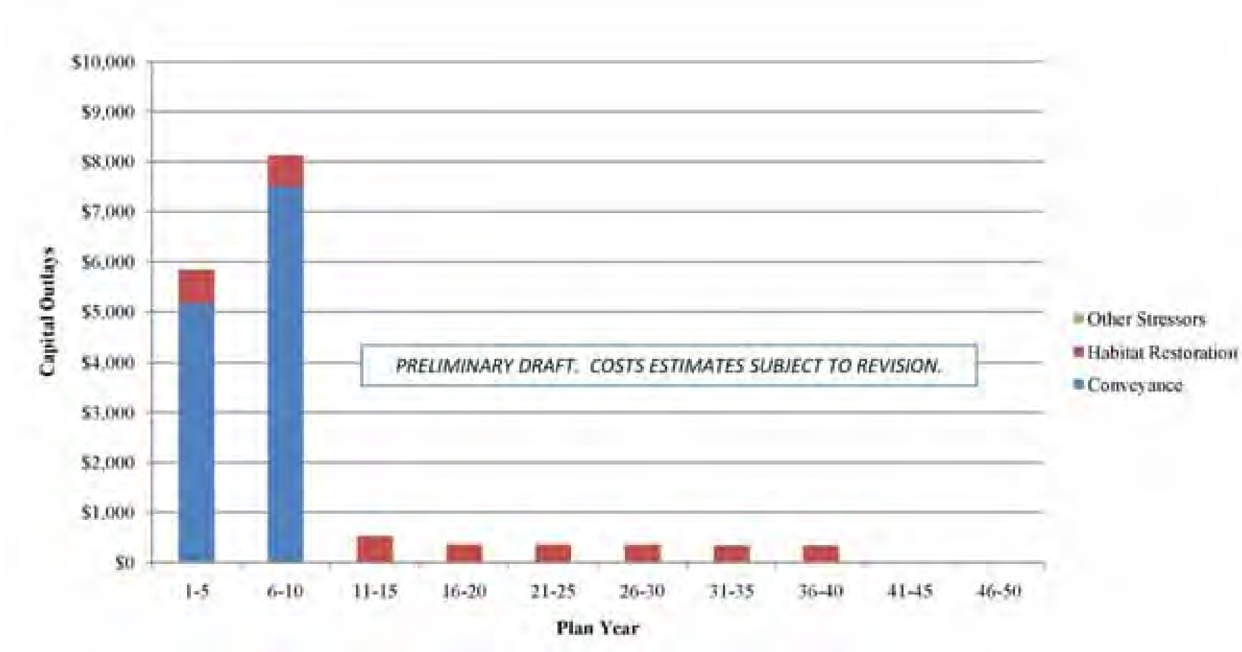

Figure 8-1. BDCP Capital Outlays in Five-Year Increments – Midpoint Cost Estimate (Millions of 2010 Dollars)

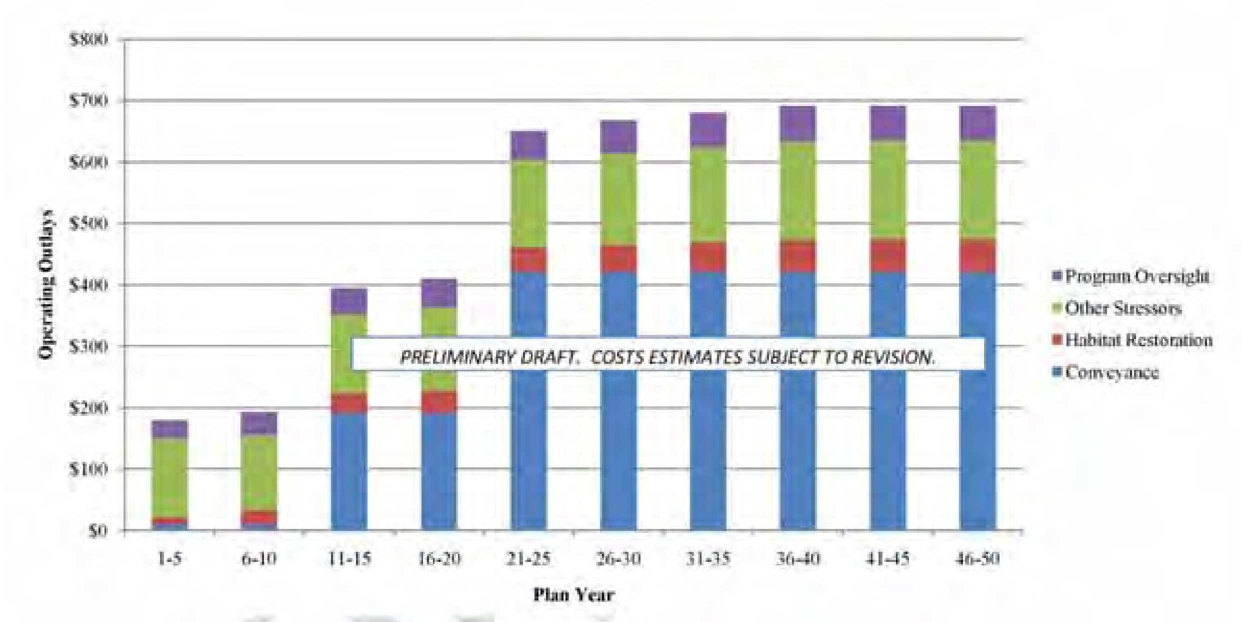

Figure 8-2. BDCP Operating Outlays in Five-Year Increments – Midpoint Cost Estimate (Millions of 2010 Dollars)

Note: Subtotal for Program Oversight does not include costs for Monitoring, Research, and Avoidance & Minimization Measures

8.10 NET BDCP COSTS

[Note to Reviewers: *This section will compare total to net costs of BDCP implementation. Total costs are the sum of costs for all plan components expected to be incurred over the 50-year planning period. Net costs recognize that some of these costs might be incurred even if the Plan were not put into operation. This will be the last step in the cost analysis and cannot be completed until the analyses of total costs for all conservation measures and related activities are completed.]*

8.11 FUNDING SOURCES AND ASSURANCES

[Note to Reviewers: *Funding Sources and Assurances are not included with this draft. This section will be completed following completion of the cost analysis and the development of the funding plan. It should be emphasized that the PREs have not committed to pay for any BDCP costs beyond the conveyance component, and substantial public and other sources of funding are expected to contribute to the cost of implementing the elements of the Plan.]*

CHAPTER 9. ALTERNATIVES TO TAKE

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CHAPTER 9. ALTERNATIVES TO TAKE

[**Note to Reviewers:** *This is a first partial draft of Chapter 9 provided to the Steering Committee for review. As of November 18, 2010, it consists of regulatory standard and evaluation criteria. The evaluation of Alternatives to Take will appear in the next version of this chapter. The Effects Analysis of the BDCP proposed project (Chapter 5) will inform both the development and evaluation of these Alternatives to Take. As such, this section of the chapter will be completed once sufficient information is available from the Effects Analysis to ensure consistency among the BDCP chapters. A brief introduction to this Section 9.3 is provided.*]

9.1 INTRODUCTION

During the development of the BDCP, the Steering Committee identified and considered a broad range of alternate approaches to achieving the planning goals and conservation objectives for the Plan. Among the approaches considered were those that would potentially result in less incidental take of species, including species listed as threatened and endangered under the federal Endangered Species Act (ESA), than would be expected to occur under the proposed actions of the BDCP. This chapter describes the alternatives considered during the development of the BDCP that potentially could further reduce levels of take of federally-listed species covered by the Plan and sets out the reasons such alternates were not incorporated in the proposed project.

9.1.1 Regulatory Standard and Evaluation Criteria

The ESA requires that section 10 permit applicants specify in habitat conservation plans what alternative actions to the taking of federally-listed threatened and endangered species were considered and the reasons why those alternatives are not proposed to be used.[1] The USFWS/NMFS HCP Handbook (USFWS/NMFS 1996) provides guidance to applicants regarding the approach that should be followed with regard to the analysis of alternatives. Specifically, the Handbook identifies two types of alternatives that are typically considered in HCPs: 1) alternatives that would result in take levels below those anticipated for the proposed project, and 2) alternatives that would cause no incidental take, thereby eliminating the need for an incidental take permit. Since the evaluation of alternatives to take is a requirement solely of the ESA, and no similar analysis is required under the NCCPA, the following evaluation is focused on take associated with federally-listed species.[2]

[1] 50 CFR 17.22(b)(1)(iii)(C)

[2] The following description and analysis of Alternatives to Take have been developed solely for the purpose of meeting the requirements of Section 10 of the ESA. As part of the NEPA/CEQA processes, a separate set of project alternatives will be identified and evaluated. The analysis of Alternatives to Take serves a specific regulatory purpose, which is separate and apart from the analysis of project alternatives under NEPA and CEQA. The EIS/EIR for the BDCP will identify a reasonable range of alternatives to the project proposed by the BDCP and evaluate a broad array of potential environmental effects of these alternatives in relation to the likely impacts of the proposed project.

The alternatives to take set out in this chapter were evaluated at two levels: first, various alternative approaches to key components of the BDCP Conservation Strategy and to the activities covered by the Plan were identified and evaluated individually for their potential to reduce take. Second, these approaches to the key components and activities were assembled in different combinations to create full alternatives to take that could be compared to the proposed Conservation Strategy.[3] The alternative approaches to each component, as well as the full alternatives to take, were evaluated under the following three criteria:

1. Level of incidental take expected to result and conservation benefits likely to accrue to listed covered species;
2. Consistency with the BDCP overall goals and objectives of ecosystem restoration and water supply reliability; and
3. Practicability in light of cost, logistics and technology.

The evaluation sets out the reasons that each of the component variations and alternatives to take were not adopted in the BDCP Conservation Strategy.

[3] The activities that are proposed for regulatory coverage under the BDCP ("Covered Activities") are generally reflected in the BDCP Conservation Strategy. Consequently, the alternative approaches to the BDCP Conservation Strategy incorporate alternative approaches to the Covered Activities that could potentially reduce take of listed covered species.

CHAPTER 10. INTEGRATION OF INDEPENDENT SCIENCE IN BDCP DEVELOPMENT

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CHAPTER 10. INTEGRATION OF INDEPENDENT SCIENCE IN BDCP DEVELOPMENT

[***Note to Reviewers****: Draft text of Chapter 10, Integration of Independent Science in BDCP Development, was provided to the Steering Committee on October 7, 2010. This text is draft and subject to change as the BDCP planning process, including the independent science process, continues. The BDCP Steering Committee members have submitted comments to the October 7, 2010 draft of this chapter, which may or may not have been incorporated into this November 18, 2010 draft. While the text of this chapter is subject to change and revision as the BDCP planning process progresses, the chapter has been drafted and formatted to appear as it may in a completed draft HCP/NCCP. Although the chapter includes declarative statements (e.g., the Implementation Office will…), it is nonetheless a "working draft" that will undergo further modification based on input from the BDCP Steering Committee, state and federal agencies, and the public*.]

10.1 BACKGROUND AND REGULATORY REQUIREMENTS

The BDCP is built upon and reflects the extensive body of scientific investigation, study, and analysis of the Delta compiled over several decades,[1] including the results and findings of numerous studies initiated under the CALFED Bay-Delta Science Program and Ecosystem Restoration Program, the long-term monitoring programs conducted by the Interagency Ecological Program (IEP), research and monitoring conducted by state and federal resource agencies, and research contributions of academic investigators.

In addition, the BDCP Steering Committee considered several other recent reports on the Delta, including reports of the Governor's Delta Vision Blue Ribbon Task Force (January and October 2008), recent reports from the Public Policy Institute of California (Public Policy Institute of California 2007, 2008), and Delta flow criteria recommended by the State Water Resources Control Board and California Environmental Protection Agency (SWRCB and CalEPA 2010) Many elements of the BDCP conservation strategy parallel the recommendations of these other reports.

In the Five-Point Policy for HCPs, USFWS and NMFS encourage the use of independent science to help inform the development of HCPs.[2] The NCCPA requires the planning process to include opportunity for independent scientific input to assist with the development of the plan. This independent scientific input would:

A. Recommend scientifically-sound conservation strategies for species and natural communities proposed to be covered by the plan.

[1] See *The State of Bay-Delta Science* (2008).
[2] 65 Fed. Reg. 35242 (June 1, 2000).

B. Recommend a set of reserve design principles that addresses the needs of species, landscapes, ecosystems, and ecological processes in the planning area proposed to be addressed by the plan.

C. Recommend management principles and conservation goals that can be used in developing a framework for the monitoring and adaptive management component of the plan.

D. Identify data gaps and uncertainties so that risk factors can be evaluated.[3]

Recognizing the need for and value of independent science input, the Steering Committee took a number of steps to engage independent scientists at several stages of the BDCP planning process. Engagement of independent scientists was managed through a neutral facilitation team established specifically for this purpose, as described in more detail below. Advice and recommendations from independent scientists were captured in Independent Science Advisor reports prepared by the advisors and provided to the Steering Committee. All advice provided by independent scientists was given serious consideration by the Steering Committee in the development of the BDCP. The following sections provide more details on the independent science advisory process, recommendations provided, and how these recommendations were incorporated into the BDCP. Examples of recommendations that were not incorporated into the BDCP and rationale for those decisions are provided in this chapter.

10.2 INDEPENDENT SCIENCE ADVISORY PROCESS

To ensure that the BDCP would be based on the best scientific and commercial data available, the Steering Committee sought input and advice from independent scientists on key elements of the Plan. Early in the planning process, the Steering Committee retained the services of an independent Science Facilitation team, consisting of staff from the Conservation Biology Institute and The Essex Partnership, to facilitate independent science panels consistent with the Five Point Policy and the Guidance for the NCCP Independent Science Advisory Process established in 2002 by the California Department of Fish and Game (DFG).[4] The BDCP Steering Committee also established a "Science Liaisons" group consisting of members of the Steering Committee to work with the Science Facilitators to ensure an appropriate level of independent scientific input into the development of the BDCP. The Science Liaisons and the Science Facilitators worked together to identify potential areas of scientific expertise needed to support plan development and to identify issues and questions for the science advisors to address. Basic planning guidelines to select and engage independent scientists were developed (see Appendix G, *Independent Science Advisors Reports*). These planning guidelines were further refined in 2008 when the Science Liaisons and the Science Facilitators developed a process designed to accommodate different levels or tiers of review based on the scope of the input sought. This tiered approach is outlined in Appendix G, *Independent Science Advisors Reports*.

[3] Fish & Game Code § 2810(b)(5).

[4] DFG. 2002. *Guidance for the NCCP Independent Science Advisory Process* at http://www.dfg.ca.gov/habcon/nccp/publications.html

Consistent with the requirements of the NCCPA and the policy directives of the Five-Point Policy,[5] the BDCP Steering Committee directed the facilitators to convene independent scientists at several key stages of the BDCP planning process, enlisting well-recognized experts in ecological and biological sciences to produce recommendations on a range of relevant topics, including approaches to conservation planning for aquatic and terrestrial species in the Delta and developing adaptive management and monitoring programs.[6] Five different groups of independent science advisors were convened during the development of the BDCP.

Each of the independent science efforts are summarized in Section 10.3, *Independent Science Review Teams*, including a brief summary of major findings and information regarding how recommendations were incorporated into the overall planning process. Reports prepared by independent science advisors to the BDCP are provided in Appendix G, *Independent Science Advisors Reports.*

The Steering Committee also engaged a group of over 50 scientists in 2009 to review each of the draft conservation measures in development at that time using a scientific evaluation process developed for the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP). The process for this DRERIP Evaluation is described in Section 10.4 *DRERIP Evaluation Process* and the results of the evaluation are provided in Appendix F, *DRERIP Evaluation Results*.

10.3 INDEPENDENT SCIENCE REVIEWS

10.3.1 Initial BDCP Independent Science Advisors

The first group of Independent Science Advisors gathered in September 2007 to provide guidance on the approach to planning for the conservation of aquatic species and ecosystem processes in the Delta. Specifically, the group advised the Steering Committee on the following elements of the BDCP:

- The application of conservation planning principles within the Plan Area;
- Geographic and temporal scope of the BDCP;
- Addressing facets of Delta ecosystem dynamics;
- Analytical methods used in BDCP formulation, methods of analysis; and
- Adaptive management and monitoring considerations.

Relative to conservation planning, the Advisors offered the following principles:

A. Changes in the estuarine ecosystem may be irreversible.

[5] 65 Fed. Reg. 35242.

B. Future states of the Delta ecosystem depend on both foreseeable changes (e.g., climate change and associated sea-level rise) and unforeseen or rare events (e.g., the consequences of new species invasions).

C. The Delta is part of a larger river-estuarine system that is affected by both rivers and tides. The Delta is also influenced by long-distance connections, extending from the headwaters of the Sacramento and San Joaquin rivers into the Pacific Ocean.

D. The Delta is characterized by substantial spatial and temporal variability, including disturbances and extreme events that are fundamental characteristics of ecosystem dynamics. The Delta cannot be managed as a homogeneous system.

E. Species that use the Delta have evolved life history strategies in response to variable environmental processes. Species have limited ability to adapt to rapid changes caused by human activities.

F. Achieving desired ecosystem outcomes will require more than manipulation of Delta flow patterns alone.

G. Habitat should be defined from the perspective of a given species and is not synonymous with vegetation type, land (water) cover type, or land (water) use type.

H. Changes in water quality have important direct and indirect effects throughout the estuarine ecosystem.

I. Land use is a key determinant of the spatial distribution and temporal dynamics of flow and contaminants which, in turn, can affect habitat quality.

J. Changes in one part of the Delta may have far-reaching effects in space and time.

K. Prevention of undesirable ecological responses is more effective than attempting to reverse undesirable responses after they have occurred.

L. Adaptive management is essential to successful conservation.

M. Conservation measures to benefit one species may have negative effects on other species.

N. Data sources, analyses, and models should be documented and transparent so they can be understood and repeated.

O. Ecosystem responses, especially to changes in system configuration, can be predicted using a combination of statistical and process models. Statistical models document status, trends, and relationships between responses and environmental variables, whereas process-based models are useful in understanding system responses and for forecasting responses to new conditions.

P. There are many sources of uncertainty in understanding a complex system and predicting its responses to interventions and change.

A number of the above principles were used to develop and refine the overall BDCP Conservation Strategy as well as individual conservation measures and the evaluation of those measures. For example, Principles D and E lead to the development of specific BDCP ecosystem goals and objectives that recognize the importance of environmental gradients and the need to provide for a highly variable system. Principles F, and J, lead to efforts to focus on regional strategies that acknowledge particular characteristics and tidal regimes as well as a focus on developing conservation measures that promote broader geographical range diversity for key species. Similarly, Principles N and O were embraced and lead to the development of specific modeling tools designed to predict the outcomes of given actions and combinations of actions as evaluated in the Effects Analysis (Chapter 5, *Effects Analysis*).

In addition to general conservation principles, the first group of Independent Science Advisors also provided a number of more specific recommendations regarding the plan scope, ecosystem dynamics, analytical methods, and adaptive management and monitoring. With regard to the scope of the plan, additional advice was sought regarding geographic scope and additional species were added to the covered species list, as recommended by the Advisors.

Sensitivity analyses were also conducted, as recommended by the Advisors to examine the effect on conservation outcomes of anticipated changes in environmental gradients expected to arise from sea-level rise, subsidence, climate-change induced alteration in the timing of runoff, human activities, and other processes over the time frame of Plan implementation. With regard to ecosystem dynamics, the BDCP was specifically designed to consider relationships between environmental conditions and the covered species in a life cycle context, and to anticipate how changes in environmental conditions, including those associated with covered activities and climate change, may propagate through populations of covered species, as suggested by the Advisors. For example, bypass flow requirements associated with the proposed new north Delta Diversions were carefully designed to minimize or avoid adverse effects on outmigrating juvenile Chinook salmon. Similarly, proposed tidal habitat restoration areas were selected and designed to include a sufficient spatial extent of appropriate elevations to provide for environmental gradients and accommodate sea-level rise.

With regard to analytical methods, the Advisors recommended several specific approaches to hydrodynamic modeling, including the use of models that accurately reproduce tidal flows in the system for analysis of Delta transport and dispersion, and the use of data that span as broad a range of hydrologic and operational conditions as possible. Several detailed two and three-dimensional models were used to analyze the effects of potential conservation actions, particularly with regard to issues of transport, dispersion, residence time, and sea level rise.

With regard to adaptive management and monitoring, the Advisors recommended that the Steering Committee convene a group of science advisors to work with the planning team to develop an appropriate adaptive management and monitoring strategy to support implementation of the BDCP. The Steering Committee convened such a group in 2009, as described in section 10.3.3 below.

A few of the recommendations were not implemented because they were not deemed practicable at this time or other alternate tools were available to address the underlying issue intended by the recommendation. For example, recommendations related to the development of new planning tools (e.g., hydrodynamic, ecosystem, and species models) were not deemed practicable because they could not be developed to a usable form within the timeframe Plan development. Development of these planning tools, however, could be conducted during Plan implementation to inform development and implementation of specific actions in fulfillment of the conservation measures. The BDCP adaptive management program (Section 3.7, Adaptive Management Program) calls for the development and use of such models.

10.3.2 Independent Science Advisors for Non-Aquatic Resources

A second group of Science Advisors convened in September 2008 to consider approaches to planning for the conservation of non-aquatic resources in the Plan Area. The group provided recommendations to the Steering Committee on various issues, including:

- Non-aquatic species to be considered for regulatory coverage under the BDCP;
- Terrestrial natural communities that should be addressed under the BDCP;
- Landscape-level approaches to conservation planning for non-aquatic resources;
- Additional sources of information to be developed to support the non-aquatic resource elements of the BDCP; and
- Conservation strategies that may be considered to address terrestrial and non-tidal wetland communities and dependent wildlife and plant species.

The Advisors offered specific advice on the species selection process, including consideration of listing status, occurrence within the planning area, potential to be affected by Plan actions, and sufficiency of information. The advisors also offered suggestions regarding potential covered species additions and deletions, as well as suggestions regarding potential planning species. The Advisors also offered specific suggestions regarding proposed conservation measures and design considerations regarding the refinement of the conservation strategy for non-aquatic resources. General principles suggested in considering the selection, design, and implementation of conservation measures included:

- Plan conservation measures hierarchically, working from ecosystem to community to species-level considerations. Do not plan conservation measures for specific covered species or communities in isolation, without considering their relationships with other species and communities in the broader ecosystem.
- Design reserve or management areas to achieve mosaics of community types within areas large enough to support the most area-dependent covered (or planning) species and desired ecological services, and to accommodate future shifts due to climate change (e.g., sea-level rise, changing runoff patterns, shifting climate "envelopes").

- Strive for representation of all community types in habitat mosaics well distributed across the Delta, but considering site-specific conditions. Where possible, maintain or create "soft edges" or natural transitions along environmental gradients, as opposed to abrupt transitions or "hard edges" between community types.
- Bigger is better for habitat conservation and restoration sites, but do not ignore small areas that support rare communities or species. For example, small areas of seasonal wetlands, inland dunes, or alkali flats support disproportionate numbers of imperiled species.
- Seek to preserve and enhance natural heterogeneity in elevation, water depth, flooding frequency, nutrient conditions, vegetation types, and adjacency of different habitat types within and among the conserved, restored, or maintained habitat mosaics.
- Enhance and preserve habitat connectivity where possible to maximize potential for natural range shifts, population expansions, escape from disturbance events (fires, floods), and maintenance of ecological processes, and to avoid isolating small populations of those species having limited dispersal abilities.
- Strive to create self-sustaining systems, but recognize that some communities and species may need active or perpetual management. For example, some invasive, nonnative species may require prolonged control efforts to sustain covered species or communities that they adversely affect.

Suggestions regarding covered species and design principles were used to refine the covered species list for the Plan and in refining the proposed conservation measures. The species recommended for coverage by the Advisors were evaluated and added to the BDCP covered species list if they were likely to become listed over the term of the BDCP. Recommended additions to the covered species list that were not included because they did not meet the selection criteria are expected, however, to benefit from implementation of the ecosystem-level and natural community-level conservation measures in the Plan. As specifically suggested by the Advisors, BDCP goals and objectives, as well as the BDCP conservation measures are structured to work from ecosystem to community to species-level considerations. Very few of the conservation measures are oriented toward a specific covered species, and only when proposed landscape or community level actions are not sufficient to address a specific species need. Similarly, all proposed habitat restoration actions in the Plan are designed to preserve and enhance natural heterogeneity in elevation, water depth, flooding frequency, nutrient conditions, vegetation types, and adjacency of different habitat types, as recommended by the Advisors.

10.3.3 Independent Science Advisors on Adaptive Management

[***Note to Reviewers***: *This section describes the scientific advisory process used in development of the BDCP adaptive management plan. As indicated in the note to reviewers at the beginning of the chapter, it is written as though this process is complete. Certain components of the* *adaptive management plan have been drafted, but the adaptive management plan is still in development.*]

The third group of Science Advisors met in December 2008 and provided input on approaches to the development of an adaptive management plan and decision making process for the BDCP, informed by data and information generated by monitoring and research efforts. This group built upon guidance on adaptive management that was provided in the first of the independent science workshops, offering more specific advice based on progress that had since been made in the development of the BDCP.

The Advisors offered eight principles for adaptive management as follows:

1. The scope and degree of reversibility of each proposed action (i.e., conservation measure) determines the form of adaptive management that can be applied (e.g.,"active" or experimental adaptive management versus "passive" adaptive management).
2. The knowledge base about the ecosystem is key to decisions about what to do and what to monitor, and includes all relevant information, not just that derived from monitoring and analysis within the context of BDCP.
3. Program goals should relate directly to the problems being addressed and provide the intent behind the conservation measures; objectives should correspond to measurable, predicted outcomes.
4. Models should be used to formalize the knowledge base, develop expectations of future conditions and conservation outcomes that can be tested by monitoring and analysis, assess the likelihood of various outcomes, and identify tradeoffs among conservation measures.
5. Monitoring should be targeted at specific mechanisms thought to underlie the conservation measures, and must be integrated with an explicitly funded program for assessing the resulting data.
6. Prioritization and sequencing of conservation measures should be assessed at multiple steps in the adaptive management cycle.
7. Specifically targeted institutional arrangements are required to establish effective feedback mechanisms to inform decisions about whether to retain, modify, or replace conservation measures.
8. A dedicated, highly skilled agent (person, team, office) is essential to assimilate knowledge from monitoring and technical studies and make recommendations to senior decision makers regarding programmatic changes.

A number of the principles above have been incorporated into the proposed BDCP Adaptive Management Program, including plans for an explicitly funded monitoring and assessment program, a research program, and clear institutional arrangements to establish feedback mechanisms to support decision making.

10.3.4 Independent Science Input on Logic Chain Approach

[***Note to Reviewers****: The logic chain development and review is currently in process. The results of this process will be used to inform various components of the BDCP as appropriate, including identification and development of biological goals and objectives for covered species and metrics for use in the monitoring and adaptive management programs.*]

The Delta Science Program provided assistance in assembling a fourth group of independent science advisors in February-March 2010 and a fifth group in July-August 2010 to evaluate and provide recommendations on the logic chain planning structure. The logic chain has been proposed as a framework to link recovery goals for covered fish species with BDCP goals, objectives, conservation measures, monitoring, and adaptive management. Two science reports on the Logic Chain were prepared.

In the first report, dated March 19, 2010 (Appendix G, *Independent Science Advisors Reports*), the group of science advisors initially assessed the value of the logic chain as a tool, its internal consistency, and next steps for input of information into the logic chain. The group stated that the logic chain was a useful tool for clearly articulating and linking goals, objectives, actions, and outcomes, but recommended an alternate approach to:

- Clarify the links in the chain and reduce areas of ambiguity;
- Distinguish between order-of-magnitude approximations of goals and objectives that are acceptable in early planning and the more detailed descriptions developed later;
- Frame projected outcomes as testable hypotheses linked to specific conservation measures;
- Use metrics to evaluate the success of outcomes that clearly link to biological functions and consider the judicious use of surrogate metrics;
- Consider constraints to implementation of conservation measures;
- Consider the potential impacts of system dynamics, variation, and change over time; and
- Provide more detail to the adaptive management framework.

As next steps, the group recommended developing logic chains for a few species initially; leaving recovery goal development to responsible regulatory agencies; focusing on development of the BDCP biological goals and objectives; and convening a workshop to develop monitoring metrics. In response to this recommendation, the Steering Committee convened a Logic Chain Group that developed example logic chains for two fish species. These two examples, and the lessons learned from their development formed the basis for a second independent logic chain review.

In the second report, dated August 23, 2010 (Appendix G, *Independent Science Advisors Reports*), the group assessed the two populated logic chains to evaluate internal logic, measurability, and linkages, and consistency in approach. The group also recommended alternative strategies and metrics for goals and objectives and alternative ways to frame goals and objectives to be more practicable and provided advice on constructing an integrated monitoring program linked to the logic chains. Recommendations of this science group included:

- Simplify the logic chain structure to reduce the number of objective statements and to focus on BDCP objectives;
- Identify stressors that are outside of BDCP management;
- Focus BDCP objectives on measures of individual and population-level performance, such as habitat-specific estimates of growth and survivorship, quantitative estimates of abundance, and quantitative measures of movement and/or distribution;
- Take care in populating the compliance and performance monitoring actions and consider three monitoring levels separately, the global goal, the "covered activity" level, and compliance; and
- Link implementation of conservation measures, through monitoring and evaluation, to the adaptive management program.

In Response to the recommendations from the second logic chain review, the Steering Committee directed staff to complete logic chains for all of the BDCP covered fish species in accordance with the guidance provided by the review panel. Draft logic chains were completed in October 2010 and a technical workshop was organized, as recommended by the review panel, to review and refine the drafts.

10.3.5 DRERIP Evaluation Process

The BDCP Steering Committee undertook a rigorous process to incorporate new and updated information and to evaluate a wide variety of issues and approaches as it formulated a cohesive, comprehensive BDCP conservation strategy. This effort included an evaluation conducted early in 2009 by multiple teams of experts of draft BDCP conservation measures in development at that time, using the CALFED Bay-Delta Ecosystem Restoration Program's (ERP) Delta Region Ecosystem Restoration Implementation Plan (DRERIP) Scientific Evaluation Process.

In October 2008, the Steering Committee developed early drafts of BDCP conservation measures related to water operations, habitat restoration, and other stressors. The DRERIP evaluation process was used to evaluate these draft conservation measures. The DRERIP process was specifically developed to aid in planning and decision making regarding potential ecosystem restoration projects in the Delta. The process entails engaging teams of experts to work through a structured, step-by-step examination of the scientific efficacy of proposed restoration actions by analyzing both potential positive and negative outcomes which might result from a given action.

To conduct the DRERIP evaluations, the Steering Committee engaged 52 technical experts assembled into five teams to address related groupings of conservation measures. The DRERIP Technical Team meetings were limited to specific technical experts trained in the DRERIP evaluation process. The teams conducted DRERIP evaluations, from January-April 2009, on 32 draft conservation measures that could be evaluated using the process. The evaluations were conducted using a series of peer-reviewed DRERIP ecosystem and species conceptual models developed specifically for the Delta and additional relevant sources of information (e.g., published literature, recently collected data). The conceptual models describe the current scientific understanding regarding how the Delta ecosystem works and were designed to serve as a foundation for the evaluation process.

A description of the BDCP DRERIP evaluations and evaluation results is presented in Appendix F, *DRERIP Evaluation Results*. Results include an assessment of the likely magnitude of the ecological outcomes and the certainty of those outcomes that could be associated with implementing each evaluated conservation measure. However, because the DRERIP process was designed to evaluate restoration actions independently, it does not provide for a direct assessment of the combined magnitude and certainty of positive and negative ecological outcomes that would be associated with the contemporaneous implementation of multiple conservation measures under BDCP. To address this need, the Steering Committee established the Synthesis Team comprised of Steering Committee member representatives and technical experts that participated in the DRERIP evaluations to conduct an assessment of the likely synergistic ecological effects of concurrent implementation of multiple conservation measures based on the evaluation results for individual conservation measures. The Synthesis Team conducted their evaluation during March-April 2009 and provided recommendations to the Steering Committee for refining conservation measures, sequencing implementation of conservation measures, and adjusting DRERIP results for individual conservation measures based on their synergistic effects with implementation of other conservation measures.

DRERIP evaluation results were also used to inform development of the effectiveness monitoring for conservation measures (see Section 3.6, *Monitoring and Research Program*). DRERIP evaluation results include assessments and sources of uncertainty surrounding the magnitude of ecological outcomes that could be expected with the implementation of each conservation measure. Based on these assessments, effectiveness monitoring was developed to collect the information necessary to address these sources of uncertainty and to inform the need for future adjustments to conservation measures to improve their performance over time through the BDCP adaptive management decision making process (Section 3.7, *Adaptive Management Program*).

CHAPTER 11 LIST OF PREPARERS

[***Note to Reviewers:*** *The list of preparers provided in this first draft of Chapter 11 is partial and will require input from the various organizations and individuals involved in developing the BDCP to identify all appropriate names and affiliations to be included in this chapter.]*

This Chapter provides names of organizations and individuals involved in the development of the BDCP.

11.1 BDCP Steering Committee Members and Alternates

[*Note to Reviewers*: *This section identifies past and present members and alternates on the Steering Committee as of November 18, 2010. Any changes to Steering Committee membership will be reflected in future versions of this chapter. The listing of the names of Steering Committee member entities and individual members and alternates in this chapter only indicates their participation in the BDCP develop process and is not intended to imply any agreement with the materials in this working draft of the BDCP]*

11.1.1 California Natural Resources Agency

Karen Scarborough, committee chair

11.1.2 California Department of Water Resources (Authorized Entity)

Mark Cowin, member

Lester Snow, past member

Jerry Johns, alternate

11.1.3 U.S. Bureau of Reclamation (Authorized Entity)

Don Glaser, member

John Davis, past member

Federico Barajas, alternate

Frank Michny, past alternate

Ann Lubas-Williams, past alternate

Susan Fry, past alternate

11.1.4 Kern County Water Agency (Potential Regulated Entity [PRE])

Brent Walthall, member

Larry Rodriguez, alternate

Tom Clark, past alternate

11.1.5 Metropolitan Water District of Southern California (PRE)

Roger Patterson, member

Randall Neudeck, alternate

11.1.6 San Luis & Delta-Mendota Water Authority (PRE)

Dan Nelson, member

Ara Azhderian, alternate

11.1.7 Santa Clara Valley Water District (PRE)

Jim Fiedler, member

Walt Wadlow, past member

Greg Zlotnick, past member

Cindy Kao, alternate

Tracy Ligon, past alternate

11.1.8 Westlands Water District (PRE)

Tom Birmingham, member

Jason Peltier, alternate

11.1.9 Zone 7 Water Agency (PRE)

Jill Duerig, member

Dale Myers, past member

Karla Nemeth, past member

Kurt Arends, alternate

Karla Nemeth, past alternate

Dale Myers, past alternate

11.1.10 Mirant Delta, LLC (Authorized Entity)

John Chillemi, member

Peter Landreth, alternate

Ron Kino, past alternate

11.1.11 State Water Resources Control Board (*ex officio*)

Les Grober, member

Tom Howard, past member

11.1.12 U.S. Army Corps of Engineers (*ex officio*)

Paul Robershotte, member

11.1.13 American Rivers

Richard Roos-Collins, member

John Cain, alternate

Steve Rothert, past alternate

11.1.14 Defenders of Wildlife

Kim Delfino, member

11.1.15 Environmental Defense Fund

Ann Hayden, member

Michael Bean, past member

Spreck Rosekrans, alternate

Ann Hayden, past alternate

11.1.16 Natural Heritage Institute

Greg Thomas, member

Carson Cox, alternate

John Cain, past alternate

Gerald Meral, past alternate

11.1.17 The Nature Conservancy

Campbell Ingram, member

Anthony Saracino, past member

Campbell Ingram, past alternate

11.1.18 The Bay Institute

Gary Bobker, member

11.1.19 California Farm Bureau Federation

Kenny Watkins, member

11.1.20 Contra Costa Water District

Greg Gartrell, member

11.1.21 Friant Water Authority

Ron Jacobsma, member

Steve Ottemoeller, alternate

11.1.22 North Delta Water Agency

Melinda Terry, member

11.1.23 California Department of Fish and Game (*ex officio*)

John McCamman, member

Don Koch, past member

Carl Wilcox, alternate

John McCamman, past alternate

11.1.24 U.S. Fish and Wildlife Service (*ex officio*)

Ren Lohoefener, member

Steve Thompson, past member

Dan Castleberry, alternate

John Engbring, past alternate

11.1.25 National Marine Fisheries Service (*ex officio*)

Michael Tucker, member

Russ Strach, past member

Maria Rea, past member

Ted Myers, past alternate

Michael Tucker, past alternate

11.1.26 Delta Stewardship Council (*ex officio*)

Joe Grindstaff, member

Keith Coolidge, alternate

11.1.27 California Bay Delta Authority (past *ex officio* member agency)

Joe Grindstaff, past member

Leo Winternitz, past alternate

11.2 MANAGEMENT TEAM

Karen Scarborough (Chair) – California Natural Resources Agency

Jerry Johns – Department of Water Resources

Laura King Moon – State Water Contractors

Karla Nemeth – California Natural Resources Agency

Ron Milligan – Federal Partners (USFWS, NMFS, Reclamation)

Chuck Gardner – Delta Habitat Conservation and Conveyance Program

Susan Ramos – California Department of Water Resources

Marc Ebbin – Ebbin Moser + Skaggs

Paul Cylinder – SAIC

Chadi Groom – SAIC

11.3 SCIENCE APPLICATIONS INTERNATIONAL CORPORATION (SAIC) CONSULTANT TEAM

11.3.1 SAIC

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11.4 STATE AND FEDERAL AGENCY SUPPORTING STAFF

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11.4.3 Fish and Wildlife Service

11.4.4 National Marine Fishery Service

11.4.5 Bureau of Reclamation

11.5 STATE AND FEDERAL WATER CONTRACTORS SUPPORTING STAFF

[List of names to come]

11.6 DHCCP SUPPORTING STAFF

[List of names to come]

11.7 NON-GOVERNMENT ORGANIZATIONS SUPPORTING STAFF

[List of names to come]

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CHAPTER 12. REFERENCES

CHAPTER 1. INTRODUCTION

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CHAPTER 3. CONSERVATION STRATEGY

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Appendix A

Covered Species Accounts

APPENDIX A1. CENTRAL VALLEY STEELHEAD (*ONCORHYNCHUS MYKISS*)

A1.1 LEGAL STATUS

The Central Valley steelhead Evolutionarily Significant Unit (ESU) was listed as a threatened species under the Federal Endangered Species Act (ESA) on March 19, 1998, and includes all naturally spawned populations of steelhead in the Sacramento and San Joaquin rivers and their tributaries, including the Bay-Delta (63 FR 13347). Steelhead from San Francisco and San Pablo Bays and their tributaries are excluded from this listing but are included in the Central California Coast DPS, which is also listed as threatened under the ESA. On June 14, 2004, the National Marine Fisheries Service (NMFS) proposed that all West Coast steelhead be reclassified from ESUs to Distinct Population Segments (DPS) and proposed to retain Central Valley steelhead as threatened (69 FR 33102). On January 5, 2006, after reviewing the best available scientific and commercial information, NMFS issued its final decision to retain the status of Central Valley steelhead as a threatened DPS (71 FR 834). This decision included the Coleman National Fish Hatchery and Feather River Hatchery steelhead populations. These populations were previously included in the ESU but were not deemed essential for conservation and thus not part of the listed steelhead population.

Central Valley steelhead are not listed under the California Endangered Species Act but are designated as a California Species of Special Concern.

A1.2 SPECIES DISTRIBUTION AND STATUS

Information on the status and geographic distribution of Central Valley steelhead is extremely limited (The Nature Conservancy et al. 2008). Adult steelhead typically migrate upstream and spawn during the winter months when river flows are high and water clarity is low. Unlike Chinook salmon, adult steelhead do not necessarily die after spawning and can return to coastal waters. Juvenile steelhead cannot be differentiated from resident rainbow trout based on visual characteristics. In addition, steelhead frequently inhabit streams and rivers that are difficult to access and survey. As a result of these and other factors, information on the trends in steelhead abundance within the Central Valley has primarily been limited to observations at fish ladders and weirs (e.g., Red Bluff Diversion Dam [RBDD] when the gates were closed, Woodbridge Irrigation District dam and fish ladders on the Mokelumne River, etc.) and returns to Central Valley fish hatcheries. Juvenile steelhead are collected incidentally in various fishery surveys (e.g., Mossdale and Chipps Island trawls). However, as a result of their relatively large size and good swimming performance, juvenile steelhead are able to avoid capture in most fishery surveys. Therefore, information on the distribution, abundance, habitat use, and behavior of steelhead within the Plan Area is very limited.

A1.2.1 Range and Status

Central Valley steelhead were widely distributed historically throughout the Sacramento and San Joaquin rivers (see Figure A-1a) (Busby et al. 1996, McEwan 2001). Steelhead inhabited waterways from the upper Sacramento and Pit River river systems (now inaccessable due to Shasta and Keswick Dams) south to the Kings River and possibly the Kern River systems, and in both east- and west-side Sacramento River tributaries (Yoshiyama et al. 1996). Lindley et al. (2006) estimated that there were historically at least 81 independent Central Valley steelhead populations distributed primarily throughout the eastern tributaries of the Sacramento and San Joaquin rivers.

The geographic distribution of spawning and juvenile rearing habitat for Central Valley steelhead has been greatly reduced by the construction of dams (McEwan and Jackson 1996, McEwan 2001). Presently, impassable dams block access to 80 percent of historically available habitat, and all spawning habitat for approximately 38 percent of historic populations (Lindley et al. 2006). Existing wild steelhead stocks in the Central Valley inhabit the upper Sacramento River and its tributaries, including Antelope, Deer, and Mill creeks and the Yuba River. Populations may exist in Big Chico and Butte creeks, and a few wild steelhead are produced in the American and Feather rivers (McEwan and Jackson 1996).

Historical Central Valley steelhead run sizes are difficult to estimate given the paucity of data, but may have approached one to two million adults annually (McEwan 2001). By the early 1960s, steelhead run size had declined to approximately 40,000 adults (McEwan 2001). Over the past 30 years, naturally-spawned steelhead populations in the upper Sacramento River have declined substantially (see Figure A-1b). Until recently, Central Valley steelhead were thought to be extirpated from the San Joaquin River system. However, recent monitoring has detected small self-sustaining populations of steelhead in the Stanislaus, Mokelumne, and Calaveras rivers, and other streams previously thought to be devoid of steelhead (McEwan 2001). Incidental catches and observations of steelhead juveniles also have occurred on the Tuolumne and Merced rivers during fall-run Chinook salmon monitoring activities, indicating that steelhead are widespread throughout accessible streams and rivers in the Central Valley (Good et al. 2005). Some of these fish, however, may have been resident rainbow trout, which are the same species but are not anadromous.

A1.2.2 Distribution and Status in the Plan Area

The entire population of the Central Valley steelhead DPS must pass through the Plan Area as adults migrating upstream to spawning areas and juveniles emigrating downstream to rearing areas and the ocean. Furthermore, juvenile steelhead likely use the Delta as well as Suisun Marsh and the Yolo Bypass for rearing. Adult Central Valley steelhead migrating into the San Joaquin River and its tributaries use the central, southern, and eastern edge of the Delta, whereas adults entering the Sacramento River system to spawn use the northern, western, and central Delta as a migration pathway

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Figure A-1a. Central Valley Steelhead Inland Range in California

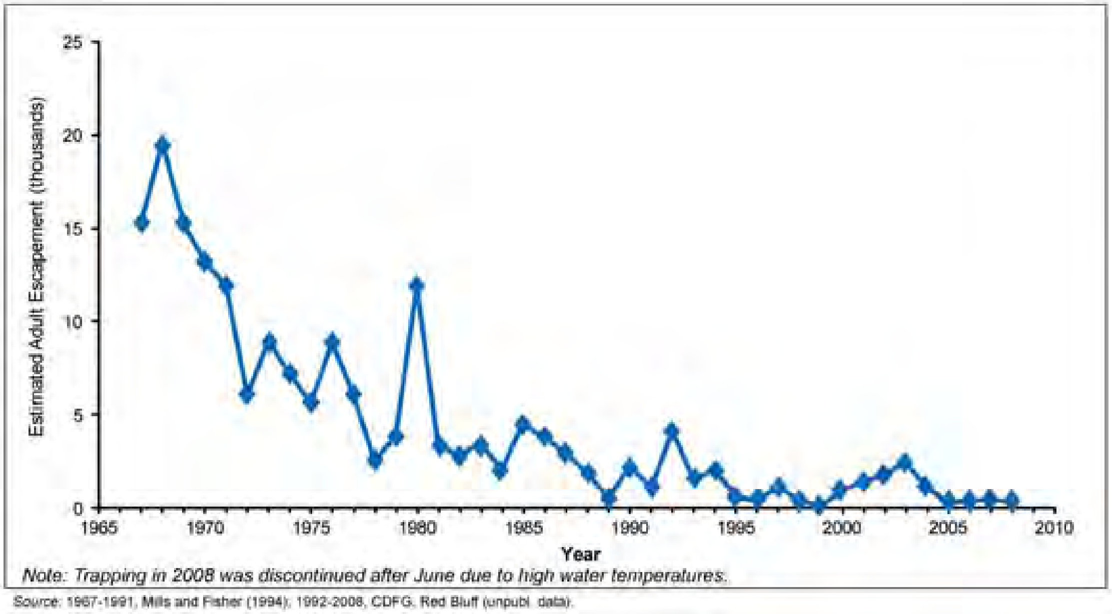

Figure A-1b. Estimated Historical Spawner Escapement of Wild Central Valley Steelhead in the Upper Sacramento River Upstream of the Red Bluff Diversion Dam (1967-2008)

A1.3 HABITAT REQUIREMENTS AND SPECIAL CONSIDERATIONS

Critical habitat for the Central Valley steelhead DPS was designated by NMFS on September 2, 2005 (70 FR 52488) with an effective date of January 2, 2006 and includes 2,308 miles of stream habitat in the Central Valley and an additional 254 square miles of estuarine habitat in the San Francisco-San Pablo-Suisun Bay complex (see Figure A-1c). Critical habitat for Central Valley steelhead includes stream reaches such as those of the Sacramento, Feather, and Yuba rivers; Deer, Mill, Battle, and Antelope creeks in the Sacramento River basin; the San Joaquin River and its tributaries; and the Delta. Critical habitat includes stream channels in the designated stream reaches and the lateral extent as defined by the ordinary high-water line. In areas where the ordinary high-water line has not been defined, the lateral extent of critical habitat is defined by the bankful elevation (defined as the level at which water begins to leave the channel and move into the floodplain; it is reached at a discharge that generally has a recurrence interval of 1 to 2 years on the annual flood series) (70 FR 52488). Critical habitat for Central Valley steelhead is defined as specific areas that contain the Primary Constituent Elements (PCEs) and physical habitat elements or biological features essential to the conservation of a species for which its designated or proposed critical habitat is based on" (USFWS 2004). The following are the habitat types used as PCEs for Central Valley steelhead.

DRAFT

Figure A-1c. Central Valley Steelhead Critical Inland Habitat in California

A1.3.1 Spawning Habitat

Freshwater spawning sites are those with water quantity and quality conditions and substrate supporting spawning, egg incubation, and larval development. Spawning habitat for Central Valley steelhead primarily occurs in mid to upper elevation reaches or immediately downstream of dams located throughout the Central Valley, which contain suitable environmental conditions (e.g., seasonal water temperatures, substrate, dissolved oxygen, etc.) for spawning and egg incubation. Spawning habitat has a high conservation value as its function directly affects the spawning success and reproductive potential of steelhead.

A1.3.2 Freshwater Rearing Habitat

Freshwater steelhead rearing sites are those with suitable instream flows, water quantity (e.g., water temperatures) and floodplain connectivity to form and maintain physical habitat conditions that support juvenile growth and mobility, provide forage species and include cover such as shade, submerged and overhanging large wood, log jams, beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Spawning areas and migratory corridors may also function as rearing habitat for juveniles, which feed and grow before and during their outmigration. Rearing habitat quality is strongly affected by habitat complexity, food supply, and the presence of predators. Some of these more complex and productive habitats with floodplain connectivity are still present in the Central Valley (e.g., the lower Cosumnes River, Sacramento River reaches with set-back levees [i.e., primarily located upstream of the City of Colusa]). The channeled, leveed, and riprapped river reaches and sloughs common in the lower Sacramento and San Joaquin rivers and throughout the Delta, however, typically have low habitat complexity, low abundance of food organisms, and offer little protection from predation by fish and birds. Freshwater rearing habitat has a high conservation value because juvenile steelhead are dependent on the function of this habitat for successful survival and recruitment to the adult population.

A1.3.3 Freshwater Migration Corridors

Optimal freshwater steelhead migration corridors (including river channels, channels through the Delta, and the Bay-Delta estuary) support mobility, survival, and food supply for juveniles and adults. Migration corridors should be free from obstructions (passage barriers and impediments to migration), provide favorable water quantity (instream flows) and quality conditions (seasonal water temperatures), and contain natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Migratory corridors are typically downstream of the spawning area and include the lower Sacramento and San Joaquin rivers, the Delta, and the San Francisco Bay complex extending to coastal marine waters. These corridors allow the upstream passage of adults and the downstream emigration of juvenile steelhead. Migratory corridor conditions are strongly affected by the presence of passage barriers, which can include dams, unscreened or poorly screened diversions, and degraded water quality. For freshwater migration corridors to function properly, they must provide adequate passage, provide suitable migration cues, reduce false attraction, avoid areas where vulnerability to predation is increased, and avoid impediments and delays in both upstream and downstream migration. For this reason, freshwater migration corridors are considered to have a high conservation value.

A1.3.4 Estuarine Areas

Estuarine migration and juvenile rearing habitats should be free of obstructions (i.e., dams and other barriers) and provide suitable water quality, water quantity, and salinity conditions to support juvenile and adult physiological transitions between fresh and salt water. Natural cover, such as submerged and overhanging large wood, aquatic vegetation, and side channels, provide juvenile and adult foraging. Estuarine areas contain a high conservation value as they function to support juvenile steelhead growth, smolting, avoidance of predators, and provide a transition to the ocean environment.

A1.3.5 Ocean Habitats

Although ocean habitats have not been designated as critical habitat for Central Valley steelhead, biologically productive coastal waters are an important habitat component. Juvenile steelhead rear within coastal marine waters for a period of approximately one to three years before returning to the Central Valley rivers as adults to spawn. During their marine residence, steelhead forage on krill and other marine organisms. Offshore marine areas with water quality conditions and food, including squid, crustaceans, and fish (fish become a larger component in the steelhead diet later in life [Moyle 2002]), to support growth and maturation are important habitat elements. These features are essential for conservation because, without them, juveniles cannot forage and grow to adulthood.

Results of oceanographic studies have shown the variation in ocean productivity off the West Coast within and among years. Changes in ocean currents and upwelling have been identified as significant factors affecting nutrient availability, phytoplankton and zooplankton production in near-shore surface waters. Although the effects of ocean conditions on steelhead growth and survival have not been investigated, recent observations since 2007 have shown a significant decline in the abundance of adult Chinook salmon and coho salmon returning to California rivers and streams. This decline has been hypothesized to be the result of declines in ocean productivity and associated high mortality rates during the period when these fish were rearing in near-shore coastal waters (MacFarlane et al. 2008). The importance of changes in ocean conditions on growth, survival, and population abundance of Central Valley steelhead, although potentially similar to that of Chinook salmon, is largely unknown.

A1.4 LIFE HISTORY

Steelhead can be divided into two life history types based on their state of sexual maturity at the time of river entry and the duration of their spawning migration: stream-maturing and ocean-maturing. Stream-maturing steelhead enter freshwater in a sexually immature condition and require several months to mature prior to spawning, whereas ocean-maturing steelhead enter freshwater with well-developed gonads and spawn shortly after river entry. These two life history types are more commonly referred to by their season of freshwater entry (i.e., summer [stream-maturing] and winter [ocean-maturing] steelhead). Only winter steelhead currently are present in Central Valley rivers and streams (McEwan and Jackson 1996). There are, however, indications that summer steelhead were present in the Sacramento River system prior to the commencement of large-scale dam construction in the 1940s (Interagency Ecological Program (IEP) Steelhead Project Work Team 1999, McEwan 2001). At present, summer steelhead are found only in North Coast drainages, mostly in tributaries of the Eel, Klamath, and Trinity river systems (McEwan and Jackson 1996).

There is high polymorphism among steelhead/rainbow trout populations with respect to a continuum from anadromy to permanent freshwater residency (Behnke 1992 as cited in McEwan 2001). Furthermore, there is plasticity in an individual from a specific life history form to assume a different life history strategy if conditions necessitate it (McEwan 2001). For example, if environmental conditions, such as water temperature and flow, allow for year-round residence in freshwater, an individual may choose not to emigrate to the ocean. This polymorphic life history structure provides the flexibility for steelhead to remain persistent within highly variable conditions, particularly near the edges of their range (McEwan 2001).

Central Valley steelhead generally leave the ocean and migrate upstream from August through April (Busby et al. 1996), and spawn from December through April. Peak spawning typically occurs from January though March in small streams and tributaries where cool, well-oxygenated water is available year-round (see Table A-1a; Hallock et al. 1961, McEwan and Jackson 1996). Timing of upstream migration is correlated with higher flow events such as freshets and associated lower water temperatures and increased turbidity. Before the occurrence of large-scale changes to the hydrology of the Delta system, the peak period of adult immigration appears to have been during fall months with a smaller component of immigrants in the winter (as reviewed in McEwan 2001). Unlike Pacific salmon, steelhead are iteroparous, or capable of spawning more than once before death (Busby et al. 1996). It is, however, rare for steelhead to spawn more than twice before dying; most individuals that do spawn more than twice are females (Busby et al. 1996). Iteroparity is more common among southern steelhead populations than northern populations (Busby et al. 1996). Although one-time spawners are the great majority, Shapolov and Taft (1954) reported that repeat spawners are relatively numerous (17.2 percent) in California streams.

After reaching a suitable spawning area, the female steelhead selects a site with good intergravel flow, digs a redd, and deposits eggs while an attendant male fertilizes them. Eggs in the redd are covered with gravel dislodged just upstream by similar redd building actions. The length of time it takes for eggs to hatch varies in response to water temperature. Hatching of steelhead eggs in hatcheries takes about 30 days at 51 °F (10.6 °C). Fry generally emerge from the gravel four to six weeks after hatching, but factors such as redd depth, gravel size, siltation, and water temperature can speed or retard the time to emergence (Shapovalov and Taft 1954, as cited in

Table A-1a. Temporal occurrence of (a) adult and (b) juvenile Central Valley steelhead in the Central Valley. Darker shades indicate months of greatest relative abundance.

(a) Adult

Location	*Jan*		*Feb*		*Mar*		*Apr*		*May*		*Jun*		*Jul*		*Aug*		*Sep*		*Oct*		*Nov*		*Dec*	
[1,3]Sacramento (Sac) River (R.)	Low	Low	Low	Low	Low	Low						Low	Low	Low	Low	Medium	Medium	High	High	Medium	Low	Low	Low	Low
[2,3]Sac R. at Red Bluff	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Medium	Medium	High	Medium	Low	Low	Low	Low
[4]Mill, Deer creeks			High	Medium	Medium	Low	Low	Low	Low	Low	Low									High	High	Medium	Medium	Medium
[5]Sac R. at Fremont Weir	Low	Low	Low	Low											Medium	Medium	High	High	Medium	Medium	Low	Low	Low	Low
[6]San Joaquin River	Medium	Medium	Medium	Medium	Medium	Medium							Low	Low	Low	Low	Medium	Medium	Medium	Medium	Medium	Medium	High	High

(b) Juvenile

Location	*Jan*		*Feb*		*Mar*		*Apr*		*May*		*Jun*		*Jul*		*Aug*		*Sep*		*Oct*		*Nov*		*Dec*	
[1,2]Sac R.	Low	Low	Low	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Low	Low	Low	Low	Low	Low	Medium	Medium	Medium	Medium	Low	Low
[2,7]Sac R. at Knights Landing (KL)	Low	Low	Low	Low	High	High	Low	Low	Low															Low
[8]Sac R. at KL	Medium	Medium	Medium	Medium	High	High	High	High	Medium	Medium											Low	Low	Low	Low
[9]Chipps Island (wild)	Low	Low	Low	Low	High	High	High	High	Medium	Medium	Medium	Medium	Low	Low					Low	Low	Low	Low	Low	Low
[7]Mossdale							High	High	High	High														
[10]Woodbridge Dam	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium										
[11]Stanislaus R. at Caswell	Low	Low	Medium	Medium	High	High	Medium	Medium	Medium	Medium	Low	Low												
[12]Sac R. at Hood	Low	Low	High	High	High	High	High	High	High	High											Low	Low	Low	Low
Relative Abundance:	High	= High							Medium	= Medium							Low	= Low						

Sources: [1]Hallock et al. 1961; [2]McEwan 2001; [3]USFWS unpublished data; [4]DFG 1995; [5]Hallock et al. 1957 [6]Based on limited unpublished data from DFG Steelhead Report Card; [7]DFG unpublished data; [8]Snider and Titus 2000; [9]Nobriga and Cadrett 2003; [10]Jones & Stokes Associates, Inc., 2002; [11]S.P. Cramer and Associates, Inc. 2000 and 2001; [12]Schaffter 1980

McEwan and Jackson 1996). Newly emerged fry move to shallow, protected areas with lower water velocities associated with the stream margin, and soon establish feeding locations within the juvenile rearing habitat (Shapovalov and Taft 1954, as cited in McEwan and Jackson 1996).

Steelhead rearing during the summer takes place primarily in higher velocity areas in pools, although young-of-the-year also are abundant in glides and riffles. Productive steelhead habitat is characterized by habitat complexity, primarily in the form of large and small woody debris. Cover is an important habitat component for juvenile steelhead both as velocity refugia and as a means of avoiding predation (Meehan and Bjornn 1991, as cited in McEwan and Jackson 1996).

Juvenile steelhead emigrate episodically from natal streams during fall, winter, and spring high flows. Emigrating Central Valley steelhead use the lower reaches of the Sacramento and San Joaquin rivers and the Delta for rearing and as a migration corridor to the ocean. Juvenile Central Valley steelhead feed mostly on drifting aquatic organisms and terrestrial insects and will also take active bottom invertebrates (Moyle 2002).

Some juvenile steelhead may use tidal marsh areas, non-tidal freshwater marshes, and other shallow water areas in the Delta and estuary as rearing areas for short periods prior to their emigration to the ocean. Hallock et al. (1961) found that juvenile steelhead in the Sacramento River basin migrate downstream during most months of the year, but the peak emigration period occurred in the spring, with a much smaller peak in the fall. Nobriga and Cadrett (2003) verified these temporal findings based on analysis of captures in USFWS salmon monitoring conducted near Chipps Island. Diversity and richness of habitat and food sources in the estuary allow juveniles to attain a larger size before entry into the ocean, thereby increasing their chances for survival in the marine environment.

Central Valley steelhead spend from several months to 3 years (with a maximum of 6 years) in the Pacific Ocean before returning to freshwater. The age composition of the steelhead population in the Pacific Ocean is dominated by 1-year (61.9 percent) and 2-year (31.4 percent) fish (Burgner et al. 1992). Ocean migration and distribution of Central Valley steelhead stocks is unknown.

Steelhead experience most of their marine phase mortality soon after they enter the Pacific Ocean (Pearcy 1992). Ocean mortality is poorly understood, however, because few studies have been conducted to evaluate the importance of various factors including predation mortality, changes in ocean currents, water temperatures, and coastal upwelling, on steelhead survival. Possible causes of ocean mortality include predation, competition, starvation, osmotic stress, unauthorized high seas driftnet fisheries, disease, advective losses and other poor environmental conditions (Wooster 1983, Cooper and Johnson 1992, Pearcy 1992). Competition between steelhead and other species for limited food resources in the Pacific Ocean may be a contributing factor to declines in steelhead populations, particularly during years of low productivity (Cooper and Johnson 1992).

Ocean and climate conditions such as sea surface temperatures, air temperatures, strength of upwelling, El Niño events, salinity, ocean currents, wind speed, and primary and secondary productivity affect all facets of the physical, biological, and chemical processes in the marine environment. Some of the conditions associated with El Niño events include warmer water temperatures, weak upwelling, low primary productivity (which leads to decreased zooplankton biomass), decreased southward transport of subarctic water, and increased sea levels (Pearcy 1992). For juvenile steelhead, warmer water and weak upwelling are possibly the most important of the ocean conditions associated with El Niño. Because of the weakened upwelling during an El Niño year, juvenile California steelhead must migrate more actively offshore through possibly stressful warm waters with numerous inshore predators. Strong upwelling is probably beneficial because of the greater transport of smolts offshore, beyond major concentrations of inshore predators (Pearcy 1992). Investigations are currently underway to examine decadal oscillations in coastal marine environmental conditions and the associated biological changes that may affect the survival, growth, and recruitment of steelhead to the adult population.

A1.5 Threats and Stressors

The following have been identified as important threats and stressors to Central Valley steelhead (without priority).

Reduced staging and spawning habitat. Adult steelhead historically migrated upstream into higher gradient reaches of rivers and tributaries where water temperatures were cooler, turbidity was lower, and gravel substrate size was suitable for spawning and egg incubation (McEwan 2001). Steelhead are known to migrate upstream into higher gradient and elevation reaches of the rivers and streams than fall-run Chinook salmon, which predominantly spawn at lower elevations within the valley floor. The majority of historical adult staging/holding and spawning habitat for Central Valley steelhead is no longer accessible to upstream migrating steelhead or has been eliminated or degraded by man-made structures (e.g., dams and weirs) associated with water storage and conveyance, diversions, flood control, municipal, industrial, agricultural, and hydropower purposes (see Figure A-1a) (McEwan and Jackson 1996, McEwan 2001, USBR 2004, Lindley et al. 2006, NMFS 2007). Due to construction of these impediments and barriers to upstream passage, steelhead are currently limited in their geographic distribution within the Central Valley to lower elevation habitats.

Steelhead in the Central Valley migrate upstream into the mainstem Sacramento River and major tributaries (e.g., American, Feather rivers; Clear, Battle creeks and others), and are also known to occur within tributaries to the San Joaquin River (e.g., Mokelumne, Cosumnes, Stanislaus, Merced, Tuolumne rivers), where they spawn and rear. Steelhead do not currently spawn in the mainstem San Joaquin River. The majority of current steelhead spawning habitat exists upstream of the RBDD on the Sacramento River and its tributaries. Although the overall effect of operations of the RBDD on the Central Valley steelhead populations is not well understood, concerns have been expressed regarding the effect of gate operations on upstream and downstream migration by steelhead. Additional concerns include the potential for increased vulnerability of juvenile steelhead to predation by Sacramento pikeminnow, striped bass, and other predators that pass through the RBDD gates or fish ladder.

Reduced flows from dams and upstream water diversions can lower attraction cues for adult spawners, causing straying and delays in spawning or the inability to spawn (California Department of Water Resources [DWR] 2005). Adult steelhead migration delays can reduce fecundity and egg viability and increase susceptibility to disease and harvest.

Reduced rearing and out-migration habitat. Juvenile steelhead prefer to utilize natural stream banks, floodplains, marshes, and shallow water habitats for rearing during out-migration. Modification of natural flow regimes from upstream reservoir operations has resulted in dampening of the hydrograph in most Central Valley rivers, reducing the extent and duration of inundation of floodplains and other flow-dependent habitat used by migrating juvenile steelhead (DWR 2005, 70 FR 52488). Changes in river hydrology that have impacted floodplain inundation may have impacted areas thought to provide significant growth benefits to rearing fish (Sommer et al. 2001). Reductions in flow rates have also resulted in increased water temperature and residence time, and reductions in dissolved oxygen levels in localized areas of the Delta (e.g., Stockton Deep Water Ship Channel) which impact the quality of rearing and migration habitat. Reduced dissolved oxygen levels in the lower San Joaquin River during late summer and early fall have been identified as a barrier and/or impediment to migration for some salmonids (Regional Water Resources Control Board 2003), including Central Valley steelhead (Jassby and Van Nieuwenhuyse 2005). .Much of the Delta has been leveed, channelized, and fortified with riprap for flood protection, reducing and degrading the quality and availability of natural habitat for use by steelhead during migration (McEwan 2001). Furthermore, impacts to the quality, quantity, and availability of suitable habitat is likely to reduce fitness and increase susceptibility to entrainment, disease, exposure to contaminants, and predation.

Predation by non-native species. In general, the effect of non-native predation on the Central Valley steelhead distinct population segment (DPS) is unknown. However, non-native predation is likely an important threat to Central Valley steelhead in areas with high densities of non-native fish (e.g., small and large mouth bass, striped bass, and catfish) are thought to prey on out-migrating juvenile steelhead. Predation risk may covary with increased temperatures. Metabolic rates of non-native, predatory fish increase with increasing water temperatures based on bioenergetic studies (Loboschefsky et al. 2009, Miranda et al. 2010). Upstream gravel pits and flooded ponds such as those that occur on the San Joaquin River and its tributaries, attract non-native predators because of their depth and lack of cover for juvenile steelhead (DWR 2005). Non-native aquatic vegetation, such as Brazilian waterweed and water hyacinth, provide suitable habitat for non-native predators (Brown and Michniuk 2007). The low spatial complexity of channelized waterways (e.g., riprap-lined levee that provide virtually no cover protection from predators) and general low habitat diversity elsewhere in the Delta reduces refuge cover and protection of steelhead from predators (Raleigh et al. 1984, Missildine et al. 2001, 70 FR 52488). A major concern is the potential invasion of the Delta by the highly predatory northern pike. The pike, recently present in Lake Davis on the Feather River, is currently the target of a major eradication effort (California Department of Fish and Game [DFG] 2007a). If eradication fails and pike were to escape downstream to the Delta, they would likely be present in areas frequently inhabited by Central Valley steelhead.

Predation by native species such as the Sacramento pikeminnow in the Sacramento River at locations such as the RBDD has also been identified as a potentially significant source of mortality on juvenile steelhead.

Harvest. Steelhead have been, and continue to be, an important recreational fishery within inland rivers throughout the Central Valley. Although there are no commercial fisheries for steelhead, inland steelhead fisheries include tribal and recreational fisheries. In the Central Valley, recreational fishing for steelhead of hatchery origin is popular, but harvest is restricted to only visibly marked fish of hatchery origin (adipose fin clipped). Unmarked steelhead (adipose fin intact) must be released, reducing the take of naturally spawned wild fish. The impacts of illegal harvest occurring in the Delta and tributary rivers is thought to be relatively minor for Chinook salmon and steelhead. The effects of recreational fishing and the unknown level of illegal harvest on the abundance and population dynamics of wild Central Valley steelhead have not been quantified.

Reduced genetic diversity/integrity. Artificial propagation programs for steelhead in Central Valley hatcheries present multiple threats to the wild steelhead population, including mortality of natural steelhead in fisheries targeting hatchery origin steelhead, competition for prey and habitat, predation by hatchery origin fish on younger natural fish, disease transmission, and impediments to fish passage imposed by hatchery facilities. It is now recognized that Central Valley hatcheries are a significant and persistent threat to wild Chinook salmon and steelhead populations and fisheries (NMFS 2009a). One major concern with hatchery operations is the genetic introgression by hatchery origin fish that spawn naturally and interbreed with local natural populations (USFWS 2001, USBR 2004, Goodman 2005). Such introgression introduces maladaptive genetic changes to the wild steelhead stocks (McEwan and Jackson 1996, Myers et al. 2004). Impacts to fitness in Chinook salmon have been detected due to hatchery operations (Araki et al. 2007). Taking eggs and sperm from a large pool of individuals is one method for ameliorating genetic introgression, but artificial selection for traits that assure individual success in a hatchery setting (e.g., rapid growth and tolerance to crowding) are unavoidable (USBR 2004).

Entrainment. Juvenile steelhead migrating downstream through the Delta are vulnerable to entrainment and salvage at the SWP and CVP export facilities, primarily between March and May (see Table A-1a). There are also multiple factors that can influence the vulnerability of juvenile steelhead to entrainment by State Water Project (SWP) and Central Valley Project (CVP) export facilities, including the geographic distribution of steelhead within the Delta and hydrodynamic factors such as reverse flows in Old and Middle rivers, which are a function of export operations relative to San Joaquin River inflows, and southward flows of Sacramento River water towards pumps through an open Delta Cross Channel and Georgiana Slough. SWC and CVP exports have been shown to affect the tidal hydrodynamics (e.g., water current velocities and direction). The magnitude of these hydrodynamic effects varies in response to a variety of factors including tidal stage and magnitude of ebb and flood tides, the rate of SWP and CVP exports, operation of the Clifton Court Forebay (CCF) radial gate opening, and inflow from upstream tributaries. Steelhead respond behaviorally to hydraulic cues (e.g., water currents) during both upstream adult and downstream juvenile migration through the Delta. Changes in these hydraulic cues as a result of SWP and/or CVP export operations during the period when steelhead are migrating through Delta channels may contribute to attraction to false migration pathways, delays in migration, or increased movement of migrating steelhead toward the export facilities where there is an increase in the risk fish will be entrained into the salvage facilities. DWR and U.S. Bureau of Reclamation (USBR) (1999) found significant relationships between total monthly exports in January through May and monthly steelhead salvage at SWP and CVP facilities, suggesting the risk of steelhead entrainment is related, in part, to export rates. During the past several years, additional investigations have been designed using radio or acoustically-tagged juvenile and adult (post spawning adults) steelhead to monitor their migration behavior through the Delta channels and to assess the effects of changes in hydraulic cues and SWP and CVP export operations on migration (Holbrook et al. 2009, Perry et al. 2010, San Joaquin River Group Authority 2010). These studies are ongoing. Studies have also been recently conducted to assess the potential losses of juvenile steelhead, primarily as a result of predation by adult striped bass, during passage through CCF (Clark et al. 2008). Results of these studies have estimated that pre-screen losses of juvenile steelhead within CCFare greater than 80 percent.

In addition to SWP and CVP export facilities, there are over 2,200 small water diversions within the Delta, of which the majority are unscreened (Herren and Kawasaki 2001). The risk of entrainment is a function of the size of juvenile fish and the slot opening of the screen mesh (Tomljanovich et al. 1978, Schneeberger and Jude 1981, Zeitoun et al. 1981, Weisberg et al. 1987, C. Hanson unpubl. data). Although entrainment/salvage of steelhead at the SWP and CVP export facilities is well documented, it is unclear how many juvenile steelhead are entrained at other unscreened Delta diversions. Because steelhead are moderately large (greater than 200 mm fork length) and relatively strong swimmers when out-migrating, the effects of small in-Delta agricultural water diversions are thought to be lower than those of other Central Valley salmonids. In addition, many of the juvenile steelhead migrate downstream through the Delta during the late winter or early spring before many of the agricultural irrigation diversions are operating. Power plants within the Plan Area have the ability to impinge juvenile steelhead on the existing intake screens. However, use of cooling water is currently low with the retirement of older units. Furthermore, newer units are equipped with a closed cycle cooling system that virtually eliminates the risk of impingement of juvenile steelhead.

Exposure to toxins. Toxic chemicals are widespread throughout the Delta and may occur on a more localized scale in response to episodic events (e.g., stormwater runoff, point source discharges, etc.). These toxic substances include mercury, selenium, copper, pyrethroids, and endocrine disruptors with the potential to impact fish health and condition, and negatively impact steelhead distribution and abundance directly or indirectly. Some loads of toxics, such as selenium, are much higher in the San Joaquin River than the Sacramento River because they are naturally occurring in the alluvial soils and have been leached by irrigation water and concentrated by evapotranspiration (Nichols et al. 1986). This may indicate that the potential effects of chronic exposure could be greater for steelhead of San Joaquin River origin. Additionally, agricultural return flows that may contain toxic chemicals are widely distributed throughout the Sacramento and San Joaquin rivers and the Delta, although dilution flows from the rivers may reduce chemical concentrations to sublethal levels. Sublethal concentrations of toxics may interact with other stressors on salmonids, such as increasing their vulnerability to predation or disease (Werner 2007). For example, Clifford et al. (2005) found in a laboratory setting that juvenile fall-run Chinook salmon exposed to sublethal levels of a common pyrethroid, esfenvalerate, were more susceptible to infectious hematopoietic necrosis virus than those not exposed to esfenvalerate. Although not tested on steelhead, a similar response is likely, however juvenile steelhead generally migrate through the Delta in a comparatively shorter time period to Chinook salmon. The short duration may decrease juvenile steelhead exposure and susceptibility to toxic substances in the Delta. Adult migrating steelhead may be less affected by toxins in the Delta because they are not feeding, and thus not bioaccumulating toxic exposure, and they are moving rapidly through the system.

Iron Mountain Mine, located adjacent to the upper Sacramento River, has been a source of trace elements that are known to adversely affect aquatic organisms (Upper Sacramento River Fisheries and Riparian Habitat Advisory Council 1989). Storage limitations and limited availability of dilution flows have caused downstream copper and zinc levels to exceed salmonid tolerances and resulted in documented fish kills in the 1960s and 1970s (USBR 2004). The U.S. Environmental Protection Agency's Iron Mountain Mine remediation program has removed toxic metals in acidic mine drainage from the Spring Creek watershed with a state-of-the-art lime neutralization plant. Contaminant loading into the Sacramento River from Iron Mountain Mine has shown measurable reductions since the early 1990s.

Increased water temperature. Water temperature is among the physical factors that affect quality of habitat for salmonid adult holding, spawning and egg incubation, juvenile rearing, and migration. Adverse sublethal and lethal effects can result from exposure to elevated water temperatures at sensitive lifestages, such as during incubation or rearing. Water temperature criteria for various lifestages of salmonids in the Central Valley have been developed by NMFS (2009). The tolerance of steelhead water temperatures depends on life stage, acclimation history, food availability, duration of exposure, health of the individual, and other factors such as predator avoidance (Myrick and Cech 2004, USBR 2004). Higher water temperatures can lead to physiological stress, reduced growth rate, reduced spawning success, and increased mortality of steelhead (Myrick and Cech 2001). Temperature can also indirectly influence disease incidence and predation (Waples et al. 2008). Exposure to seasonally elevated water temperatures may occur as a result of reductions in flow as a result of upstream reservoir operations, reductions in riparian vegetation, channel shading, local climate and solar radiation. The installation of the Shasta Temperature Control Device in 1998, in combination with reservoir management to maintain the cold water pool, has reduced many of the temperature issues on the Sacramento River. During dry years, however, the release of cold water from Shasta Dam is still limited. As the river flows further downstream, particularly during the warm spring, summer, and early fall months, water temperatures continue to increase until they reach thermal equilibrium with atmospheric conditions. As a result of the longitudinal gradient of seasonal water temperatures, the coldest water and, therefore, the best areas for steelhead spawning and rearing are typically located immediately downstream of the dam.

Increased temperature can also arise from a reduction in shade over rivers by tree removal (Watanabe et al. 2005). Because river water is typically in thermal equilibrium with atmospheric conditions by the time it enters the Delta (C. Hanson, unpubl. data), this issue is caused primarily from actions upstream of the Delta. As a result of the relatively wide channels that occur within the Delta, the effects of additional riparian vegetation on reducing water temperatures.

A1.6 RELEVANT CONSERVATION EFFORTS

Because steelhead biology is similar to that of Chinook salmon, few conservation actions are specific to steelhead. Efforts by DFG to restore Central Valley steelhead are described in the "Steelhead Restoration and Management Plan for California" (McEwan and Jackson 1996). Measures to protect steelhead throughout the State of California have been in place since 1998 and a wide range of measures have been implemented including 100 percent marking of all hatchery steelhead, zero bag limits for unmarked steelhead, gear restrictions, closures, and size limits designed to protect rearing juveniles and smolts. The Central Valley Steelhead Project

Work Team, an interagency technical working group led by DFG, drafted a proposal to develop a comprehensive steelhead monitoring plan that was selected by the CALFED Ecosystem Restoration Program (ERP) Implementing Agency Managers for directed action funding. Long-term funding for implementation of the monitoring plan still needs to be secured.

Biological opinions for SWP and CVP operations (e.g., NMFS 2009b) and other federal projects involving irrigation and water diversion and fish passage, for example, have improved or minimized adverse impacts on steelhead in the Central Valley. In 1992, an amendment to the authority of the CVP through the Central Valley Project Improvement Act (CVPIA) was enacted to give protection of fish and wildlife equal priority with other Central Valley Project objectives. From this Act arose several programs that have benefited listed salmonids. The USFWS's Anadromous Fish Restoration Program (AFRP) is engaged in monitoring, education, and restoration projects designed to contribute toward doubling the natural populations of select anadromous fish species residing in the Central Valley. Restoration projects funded through the AFRP include fish passage, fish screening, riparian easement and land acquisition, development of watershed planning groups, instream and riparian habitat improvement, and gravel replenishment. The AFRP combines federal funding with State and private funds to prioritize and construct fish screens on major water diversions mainly in the upper Sacramento River. The goal of the Water Acquisition Program is to acquire water supplies to meet the habitat restoration and enhancement goals of the CVPIA, and to improve the ability of the U.S. Department of the Interior to meet regulatory water quality requirements. Water has been used to improve fish habitat for Central Valley steelhead by maintaining or increasing instream flows on Butte and Mill creeks and the San Joaquin River at critical times. Additionally, salmonid entrainment at the SWP and CVP export facilities is decreased through reducing seasonal diversion rates during periods when protected fish species are vulnerable to export related losses.

Two programs included under CALFED, the Ecosystem Restoration Program (ERP) and the Environmental Water Account, were created to improve conditions for fish, including steelhead, in the Central Valley. Restoration actions implemented by the ERP include the installation of fish screens, modification of barriers to improve fish passage, habitat acquisition, and instream habitat restoration. The majority of these actions address key factors affecting listed salmonids and emphasis has been placed in tributary drainages with high potential for Central Valley steelhead and spring-run Chinook salmon production. Additional ongoing actions include efforts to enhance fishery monitoring and directly support salmonid production through hatchery releases. The Environmental Water Account has been under scrutiny recently as to its success in meeting its original goal.

A major CALFED ERP action currently underway is the Battle Creek Salmon and Steelhead Restoration Project. The project will restore 77 km (48 miles) of habitat in Battle Creek to support steelhead and Chinook salmon spawning and juvenile rearing at a cost of over $90 million. The project includes removal of five small hydropower diversion dams, construction of new fish screens and ladders on another three dams, and construction of several hydropower facility modifications to ensure the continued hydropower operations. It is thought that this restoration effort is the largest cold water restoration project to date in North America.

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) was formed to guide the implementation of CALFED Ecosystem Restoration Plan elements within the Delta (DFG 2007b). The DRERIP team has created a suite of ecosystem and species conceptual models, including steelhead, that document existing scientific knowledge of Delta ecosystems. The DRERIP Team has used these conceptual models to assess the suitability of actions proposed in the Ecosystem Restoration Plan for implementation. DRERIP conceptual models were used in the analysis of proposed BDCP conservation measures.

Oroville Dam Federal Energy Regulatory Commission (FERC) relicensing efforts on the Feather River have considered instream flows and temperature management for steelhead spawning and juvenile rearing downstream of the dam.

Multiple fish passage projects have been recently implemented for steelhead and other salmonids in the Sacramento and San Joaquin Watersheds. Multiple large diversions on the Sacramento River (e.g., Glenn-Colusa Irrigation District, RD108, RD1004, Sutter Mutual, and Wilkins Slough) have been equipped with positive barrier fish screens to reduce entrainment of steelhead and other salmonids. The Woodbridge Irrigation District Dam on the Mokelumne River was designed to improve upstream and downstream passage of steelhead and other salmonids by installing fish screens and fish ladders at the dam.

Mitigation under the Delta Fish Agreement has increased the number of wardens enforcing harvest regulations for steelhead and other fish in the Bay-Delta and upstream tributaries by creating the Delta Bay Enhanced Enforcement Program (DBEEP). Initiated in 1994, DBEEP currently consists of nine wardens and a supervisor.

Many smaller tributaries to the Sacramento and San Joaquin rivers have local watershed conservancies with master plans to contribute to conservation and recovery of steelhead and other salmonids.

A1.7 Recovery Goals

The Public Draft Recovery Plan for Central Valley salmonids, including steelhead, was released by NMFS on October 19, 2009. Although not final, the overarching goal in the public draft is the removal of, among other listed salmonids, the Central Valley steelhead DPS from the Federal List of Endangered and Threatened Wildlife (NMFS 2009a). Several objectives and related criteria represent the components of the recovery goal, including the establishment of at least two viable populations within each historical diversity group, as well as other measurable biological criteria.

A1.8 REFERENCES

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APPENDIX A2. SACRAMENTO RIVER WINTER-RUN CHINOOK SALMON (*ONCORHYNCHUS TSHAWYTSCHA*)

A2.1 LEGAL STATUS

The Sacramento River winter-run Chinook salmon Evolutionarily Significant Unit (ESU) was originally listed as a threatened species in August 1989, under emergency provisions of the Federal Endangered Species Act (ESA), and was formally listed as threatened in November 1990 (55 FR 46515). The ESU consists of only one population confined to the upper Sacramento River in California's Central Valley. The ESU was reclassified as endangered under the federal ESA on January 4, 1994 (59 FR 440), due to increased variability of run sizes, expected weak returns as a result of two small year classes in 1991 and 1993, and a 99 percent decline between 1966 and 1991. The Sacramento River winter-run Chinook salmon ESU includes all naturally spawned winter-run Chinook salmon in the Sacramento River and its tributaries as well as two artificial propagation programs: winter-run Chinook salmon produced from the Livingston Stone National Fish Hatchery and released as juveniles into the Sacramento River and winter-run Chinook salmon held in a captive broodstock program maintained at Livingston Stone National Fish Hatchery (70 FR 37160, June 28, 2005) (see Figure A-2a).

The National Marine Fisheries Service (NMFS) reaffirmed the listing of Sacramento River winter-run Chinook salmon as endangered on June 28, 2005 (70 FR 37160) and included the Livingston Stone National Fish Hatchery population within the listed population.

Winter-run Chinook salmon was listed as endangered under the California Endangered Species Act on September 22, 1989.

A2.2 SPECIES DISTRIBUTION AND STATUS

A2.2.1 Range and Status

The distribution of winter-run Chinook salmon spawning and rearing was limited historically to the upper Sacramento River and tributaries, where cool spring-fed streams supported successful adult holding, spawning, egg incubation, and juvenile rearing (Slater 1963, Yoshiyama et al. 1998). The headwaters of the McCloud, Pit, and Little Sacramento Rivers, Hat and Battle creeks , provided clean, loose gravel, cold, well-oxygenated water, and year-round flow in riffle habitats for spawning and incubation (see Figure A-2a). These areas also provided the cold, productive waters necessary for egg and fry survival, and juvenile rearing over summer. Construction of Shasta Dam in 1943 and Keswick Dam in 1950 blocked access to all of these upstream waters except Battle Creek, which is blocked by a weir at the Coleman National Fish Hatchery and other small hydroelectric facilities (Moyle et al. 1989, NMFS 1997).

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Figure A-2a. Sacramento River Winter-Run Chinook Salmon Inland Range in California

Primary spawning and rearing habitats for winter-run Chinook salmon are now confined to the cold water areas between Keswick Dam and Red Bluff Diversion Dam (RBDD)(see Figure A-2a). The lower reaches of the Sacramento River, Delta, and San Francisco Bay serve as migration corridors for the upstream migration of adult and downstream migration of juvenile winter-run Chinook salmon.

Estimates of the Sacramento River winter-run Chinook salmon population (including both male and female salmon) reached nearly 100,000 fish in the 1960s before declining to under 200 fish in the 1990s (Good et al. 2005). Abundance of returning adult spawners generally increased between the mid-1990s and 2006 (see Figure A-2b). However, recent population estimates of winter-run Chinook salmon spawning upstream of the RBDD have dropped off since the 2006 peak (DFG 2010).

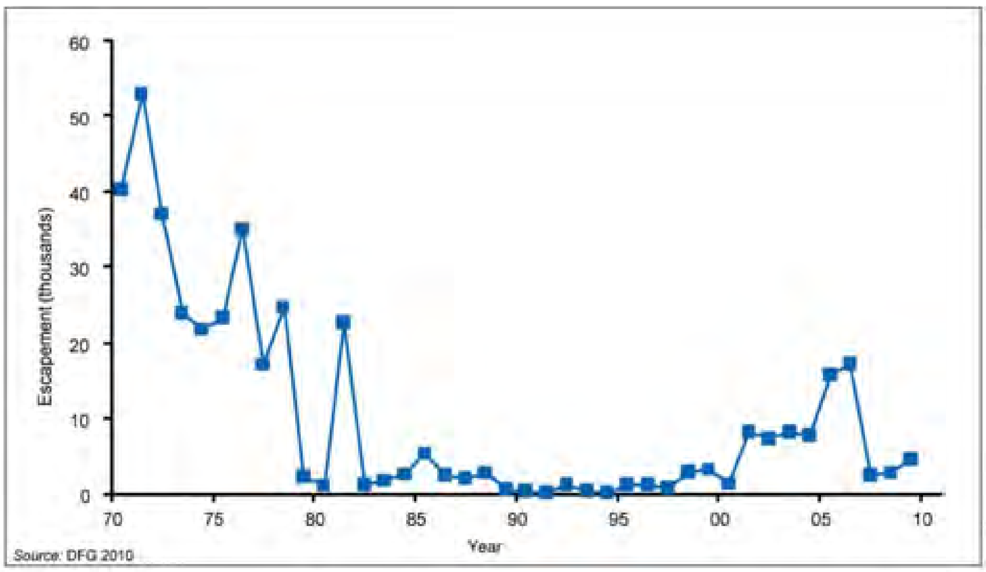

Figure A-2b. Estimate Historical Spawner Escapement of Sacramento River Winter-Run Chinook Salmon (1970-2009)

Two methods are currently used to estimate the juvenile production of Sacramento River winter-run Chinook salmon: the juvenile production index method (using rotary screw traps) and the juvenile production estimate method (using carcass surveys). Average juvenile population of Sacramento River winter-run Chinook salmon inhabiting the upper Sacramento River at the RBDD is 4,230,378 juveniles per year using the juvenile production index method between 1995 and 2007 (excluding 2000 and 2001 when rotary screw trapping was not conducted) (Poytress and Carillo 2010). Using the juvenile production estimate method, average production is estimated to be 5,034,921 juveniles exiting the upper Sacramento River at the RBDD in all years between 1996 and 2007 (Poytress and Carillo 2010).

Although the abundance of the Sacramento River winter-run Chinook salmon population has on average been growing since the 1990s (despite recent declines since 2007), there is only one population and it depends heavily on cold-water releases from Shasta Dam (Good et al. 2005).

Lindley et al. (2007) considers the Sacramento River winter-run Chinook salmon population at a moderate risk of extinction primarily due to the risks associated with only one existing population. The viability of an ESU that is represented by a single population is vulnerable to changes in the environment through a lack of spatial geographic diversity and genetic diversity that result from having only one population. A single catastrophic event with effects persisting for four or more years could extirpate the entire Sacramento River winter-run Chinook salmon ESU, which puts the population at a high risk of extinction over the long-term (Lindley et al. 2007). Such potential catastrophes include volcanic eruption of Mt. Lassen; prolonged drought, which depletes the cold water pool in Lake Shasta or some related failure to manage cold water storage; a spill of toxic materials with effects that persist for four years; regional declines in upwelling and productivity of near-shore coastal marine waters resulting in reduced food supplies for juvenile and sub-adult salmon, reduced growth, and/or increased mortality; or a disease outbreak. Another vulnerability to an ESU that is represented by a single population is the limitation in life history and genetic diversity that would otherwise increase the ability of individuals in the population to withstand environmental variation.

Although NMFS recently proposed that this ESU be downgraded from endangered to threatened status, NMFS decided in its Final Listing Determination (June 28, 2005, 70 FR 37160) to continue to list the Sacramento River winter-run Chinook salmon ESU as endangered because the population remains below the draft recovery goals established for the run (NMFS 1997) and the naturally-spawned component of the ESU is dependent on one extant population in the Sacramento River.

A2.2.2 Distribution and Status in the Plan Area

The entire population of the Sacramento River winter-run Chinook salmon must pass through the Plan Area as migrating adults and emigrating juveniles. Because winter-run Chinook salmon use only the Sacramento River system for spawning, it has been hypothesized that adults are attracted to, and migrate upstream primarily along, the western edge of the Delta through the Sacramento River corridor. Because juvenile winter-run salmon have been collected at various locations within the Delta (including the State Water Project [SWP] and the Central Valley Project [CVP] south Delta export facilities), it has been hypothesized that juveniles likely use a wider range of the Delta for migration and rearing than adults. Studies using acoustically tagged juvenile and adult Chinook salmon are ongoing to further investigate the migration routes, migration rates, reach-specific mortality rates, and the effects of hydrologic conditions (including the effects of SWP and CVP export operations) on salmon migration through the Delta (Lindley et al. 2008, MacFarlane et al. 2008a, Michel et al. 2008, Perry et al. 2008). Juvenile winter-run Chinook salmon likely inhabit Suisun Marsh for rearing and may inhabit the Yolo Bypass when flooded, although use of these two areas is not well understood.

Results of fishery monitoring using a combination of adult counts at the RBDD fish ladder and carcass surveys have been used to estimate annual adult escapement of winter-run Chinook salmon on the mainstem Sacramento River. The estimated annual adult escapement over the period from 1970 through 2010 is shown in Figure A-2b. During the late 1960s and throughout the 1970s, winter-run Chinook salmon abundance declined significantly from a high of approximately 120,000 adults to several thousand adults. Population abundance remained low through the mid-1990s, with adult abundance in some years less than 500 fish. Beginning in the mid-1990s and continuing to date, adult escapement has shown a trend of increasing abundance, approaching 20,000 fish in 2006. A variety of factors have been identified that are thought to have contributed to the recent increasing trend in adult abundance. These factors, include but are not limited to, improved water temperatures and temperature management in the Shasta Reservoir and the mainstem river downstream of Keswick Dam, improvements in the operations of the RBDD (keeping holding gates open for a longer period), favorable hydrological and ocean rearing conditions, habitat enhancements, reductions in loading of toxic chemicals, improved fish screens on major water diversions, and changes in ocean commercial and recreational angling to reduce harvest mortality.

Adult winter-run Chinook salmon escapement to the Sacramento River declined substantially in 2007, with an estimated 2,542 adults retuning to spawn (see Figure A-2b). As discussed below, it has been hypothesized that the substantial decline in adult winter-run Chinook salmon escapement was the result of reduced productivity of near-shore coastal waters and reduced prey availability resulting in poor juvenile salmon growth and high mortality during the juvenile ocean rearing phase (MacFarlane et al. 2008b). A similar substantial decline in abundance of retuning fall-run Chinook salmon (and other salmon populations in California) was observed in 2007. Adult escapement remained low during 2008 and 2009. In response to the low numbers of adult Chinook salmon returning to the Central Valley, commercial and recreational fishing for salmon has been curtailed since 2007.

A2.3 Habitat Requirements and Special Considerations

Critical habitat for the winter-run Chinook ESU was designated under the ESA on June 16, 1993 (58 FR 33212). Designated critical habitat includes: the Sacramento River from Keswick Dam (RM 302) to Chipps Island (RM 0) at the westward margin of the Sacramento-San Joaquin Delta, all waters from Chipps Island westward to Carquinez Bridge, including Honker, Grizzly, and Suisun bays, and Carquinez Strait, all waters of San Pablo Bay westward of San Pablo Bay westward of the Carquinez Bridge, and all waters of San Francisco Bay (north of the San Francisco/Oakland Bay Bridge) from San Pablo Bay to the Golden Gate Bridge (59 FR 440, January 4, 1994) (see Figure A-2c). In the Sacramento River, critical habitat includes the river water column, river bottom, and adjacent riparian zone used by fry and juveniles for rearing. In the areas westward of Chipps Island, critical habitat includes the estuarine water column and essential foraging habitat and food resources used by Sacramento River winter-run Chinook salmon as part of their juvenile emigration or adult spawning migration.

Figure A-2c. Sacramento River Winter-Run Chinook Salmon Inland Designated Critical Habitat in California

Habitat of Sacramento River winter-run Chinook salmon is also protected under the Magnuson-Stevens Fishery Conservation and Management Act as Essential Fish Habitat (EFH). Those waters and substrate necessary to support Sacramento River winter-run Chinook salmon spawning, breeding, feeding, or growth are included as EFH (see Figure A-2d). Critical Habitat and EFH are managed differently from a regulatory standpoint, but are biologically equivalent with regard to conservation.

The PCEs considered essential for the conservation of Sacramento River winter-run Chinook salmon are: (1) freshwater spawning sites, (2) freshwater rearing sites, (3) freshwater migration corridors, (4) estuarine areas, (5) nearshore marine areas, and (6) offshore marine areas.

A2.3.1 Spawning Habitat

Spawning habitat for Sacramento River winter-run Chinook salmon is restricted to the Sacramento River primarily between RBDD and Keswick Dam.

Spawning sites for Sacramento River winter-run Chinook salmon include those stream reaches with water movement, velocity, depth, temperature, and substrate composition that support spawning, egg incubation, and larval development. Water velocity and substrate conditions are more critical to the viability of spawning habitat than depth. Incubating eggs and embryos buried in gravel require sufficient water flow through the gravel to supply oxygen and removal of metabolic wastes (Resources Agency et al. 1998). Spawning occurs in gravel substrate in relatively fast-moving, moderately shallow riffles or along banks with relatively high water velocities. The gravel must be clean and loose, yet stable for the duration of egg incubation and the larval development.

Substrate composition has other key implications to spawning success. The embryos and alevins (newly hatched fish with the yolk sac still attached) require adequate water movement through the substrate; however, this movement can be inhibited by the accumulation of fines and sand. Generally, the redd should contain less than 5 percent fines (Resources Agency et al. 1998).

Water velocity in Chinook salmon spawning areas typically ranges from 1.0 to 3.5 feet per second and optimum velocity is 1.5 feet per second (Resources Agency et al. 1998). Spawning occurs at depths between 1 to 5 feet with a maximum depth observed of 20 feet. A depth of less than 6 inches can be restrictive to Chinook salmon movement.

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Figure A-2d. Sacramento River Winter-Run Chinook Salmon Inland Essential Fish Habitat in California

A2.3.2 Freshwater Rearing Habitat

Freshwater salmon rearing sites are those with sufficient water quantity and floodplain connectivity to form and maintain physical habitat conditions that support juvenile growth and mobility; suitable water quality; availability of suitable forage species that support juvenile salmon growth and development; and cover such as shade, submerged and overhanging large wood, log jams, beaver dams, aquatic vegetation, large rocks and boulders, side channels, andundercut banks. Both spawning areas and migratory corridors also function as rearing habitat for juveniles, which feed and grow before and during their outmigration. Non-natal, intermittent tributaries also may be used for juvenile rearing. Rearing habitat quality is strongly affected by habitat diversity and complexity, food supply, and fish and avian predators. Some of these more complex and productive habitats with floodplains are still found in the system (e.g., the lower Cosumnes River, Sacramento River reaches with set-back levees [i.e., primarily located upstream of the City of Colusa]). The channeled, leveed, and rip-rapped river reaches and sloughs common along the Sacramento River and throughout the Delta, however, typically have low habitat complexity, low abundance of food organisms, and offer little protection from predation by fish and birds. Freshwater rearing habitat has a high conservation value as the juvenile life stage of salmonids is dependent on the function of this habitat for successful survival and recruitment into the adult population.

A2.3.3 Freshwater Migration Corridors

Freshwater migration corridors for winter-run Chinook salmon, including river channels, channels through the Delta, and the Bay-Delta estuary, support mobility, survival, and food supplies for juveniles and adults. Migration corridors should be free from obstructions (passage barriers and impediments to migration), provide favorable water quantity (instream flows) and quality conditions (seasonal water temperatures), and contain natural cover such as submerged and overhanging large wood, native aquatic vegetation, large woody debris, rocks and boulders, side channels, and undercut banks. Migratory corridors for winter-run Chinook salmon are located downstream of the spawning areas and include the lower Sacramento River, the Delta, and the San Francisco Bay complex extending to coastal marine waters. These corridors allow the upstream passage of adults and the downstream emigration of juvenile salmon. Migratory corridor conditions are strongly affected by the presence of passage barriers, which can include dams, unscreened or poorly screened diversions, and degraded water quality. For freshwater migration corridors to function properly, they must provide adequate passage, provide suitable migration cues, limit false attraction, provide low vulnerability to predation, and not contain impediments and delays in both upstream and downstream migration.

Results of mark-recapture studies conducted using juvenile Chinook salmon (typically hatchery-reared late fall-run Chinook salmon that are considered to be representative of juvenile winter-run salmon) released into the Sacramento River have shown high mortality during passage downstream through the rivers and Delta (Brandes and McLain 2001, Newman and Rice 2002, Hanson 2008). Mortality is typically greater in years when spring flows are reduced and water temperatures are increased. Results of survival studies have shown that closing the Delta Cross Channel gates to reduce the movement of juvenile salmon into the Delta, contributes to improved survival of emigrating juvenile Chinook salmon (Brandes and McLain 2001, Manly 2004, Low and White undated). Observations at the SWP and CVP fish salvage facilities have shown that very few of the marked salmon (typically less than 1 percent [Hanson 2008]) are entrained and salvaged at the export facilities. Results of estimating incidental take of juvenile winter-run Chinook salmon at the SWP and CVP fish salvage facilities based on comparison of the juvenile production estimates for winter-run emigrating from the upper Sacramento River rearing areas (e.g., estimated based on results of spawning carcass surveys and environmental conditions and/or fishery monitoring at RBDD) show a similar low magnitude to direct losses of juvenile winter-run Chinook salmon at the fish salvage facilities. Although the factors contributing to the high juvenile mortality have not been quantified, results of acoustic tagging experiments and anecdotal observations suggest that exposure to adverse water quality conditions leading to mortality (e.g., elevated water temperatures, potentially toxic chemicals) and vulnerability to predation mortality are two of the factors contributing to the high juvenile mortality observed in the Sacramento River and Delta.

A2.3.4 Estuarine Areas

Estuarine migration and juvenile rearing habitats should be free of obstructions (i.e., dams and other barriers) and provide suitable water quality, water quantity (river and tidal flows), and salinity conditions to support juvenile and adult physiological transitions between fresh and salt water. Natural cover, such as submerged and overhanging large wood, native aquatic vegetation, and side channels, provide juvenile foraging habitat and cover from predators. Tidal wetlands and seasonally inundated floodplains have also been identified as high value foraging and rearing habitats for juvenile salmon migrating downstream through the estuary. Estuarine areas contain a high conservation value because they function to support juvenile Chinook salmon growth, smolting, avoidance of predators, and provide a transition to the ocean environment.

A2.3.5 Ocean Habitats

Although ocean habitats are not part of the critical habitat listings for Sacramento River winter-run Chinook salmon, biologically productive coastal waters are an important habitat component for the species. Juvenile Chinook salmon inhabit near-shore coastal marine waters for a period of typically two to four years before adults return to Central Valley rivers to spawn. During their marine residence, Chinook salmon forage on krill, squid, and other marine invertebrates as well as a variety of fish such as northern anchovy and Pacific herring. These features are essential for conservation because, without them, juveniles cannot forage and grow to adulthood.

The variation in ocean productivity off the West Coast can be high both within and among years. Changes in ocean currents and upwelling have been identified as significant factors affecting nutrient availability, phytoplankton, and zooplankton production and the availability of other forage species in near-shore surface waters. Ocean conditions during a salmon’s ocean residency period can be important, as indicated by the effect of the 1983 El Niño on the size and fecundity of Central Valley fall-run Chinook salmon (Wells et al. 2006). Although the effects of ocean conditions on Chinook salmon growth and survival have not been investigated extensively, recent observations since in 2007 have shown a significant decline in the abundance of adult Chinook salmon and coho salmon returning to California rivers and streams (fall-run adult returns to the Sacramento and San Joaquin rivers were the lowest on record) (Pacific Fishery Management Council 2008) that has been hypothesized to be the result of declines in ocean productivity and associated high mortality rates during the period when these fish were rearing in near-shore coastal waters (MacFarlane et al. 2008b). The importance of changes in ocean conditions on growth, survival, and population abundance of Central Valley Chinook salmon is currently undergoing further investigation.

A2.4 LIFE HISTORY

Chinook salmon exhibit two generalized freshwater life history types (Healey 1991). Stream-type adults enter freshwater months before spawning and juveniles reside in freshwater for a year or more following emergence, whereas ocean-type adults spawn soon after entering freshwater and juveniles migrate to the ocean as fry or parr within their first year. Winter-run Chinook salmon are somewhat anomalous in that they have characteristics of both stream- and ocean-type races (Healey 1991). Adults enter freshwater in winter or early spring, and delay spawning until spring or early summer (stream-type). However, juvenile winter-run Chinook salmon migrate to sea after only 4 to 7 months of river life (ocean-type). Adequate instream flows and cool water temperatures are more critical for the survival of Chinook salmon exhibiting a stream-type life history due to over-summering by adults and/or juveniles.

Sacramento River winter-run Chinook salmon adults enter the Sacramento River basin between December and July; the peak occurring in March (see Table A-2a) (Yoshiyama et al. 1998, Moyle 2002). Spawning occurs from mid-April to mid-August, peaking in May and June, in the Sacramento River reach between Keswick Dam and RBDD (Vogel and Marine 1991). The majority of Sacramento River winter-run Chinook salmon spawners are three years old. Adult winter-run Chinook salmon tend to enter freshwater as sexually immature fish, migrate far upriver, and delay spawning for weeks or months. Pre-spawning activity requires an area of 200 to 650 square feet. The female digs a nest, called a redd, with an average size of 165 square feet, in which she buries her eggs after they are fertilized by the male (Resources Agency et al. 1998).

Table A-2a. Temporal occurrence of (a) Adult and (b) Juvenile Sacramento River Winter-Run Chinook salmon in the Sacramento River and Delta. Darker shades indicate months of greatest relative abundance.

a) Adult

Location	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Sac. River basin[1]	Medium	Medium	High	Medium	Medium	Medium	Medium					Medium
Sac. River[2]	Medium	Medium	Medium	Medium	Medium	Medium					Medium	Medium

b) Juvenile

Location	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Sac. River @ Red Bluff[3]	Low						Low / Medium	Medium	Medium	Medium	Medium	Medium
Sac. River @ Red Bluff[2]	Medium	Medium					Low	High	High	High	Medium	Medium
Sac. River @ Knights L.[4]	Medium	Medium	Medium	Low				Low	Low	Low	High	High
Lower Sac. River (seine)[5]	High	High	Medium	Low / –					Low	Low	Medium	High
West Sac. River (trawl)[5]	Medium	High	High	High	Low / –						Low	Medium
Chipps Island (trawl)[5]	Medium	Medium / High	High	High	Low							Low
Relative Abundance:	[dark] = High				[medium] = Medium				[light] = Low			

Sources: [1]Yoshiyama *et al.* 1998; Moyle 2002; [2]Myers *et al.* 1998; [3]Martin *et al.* 2001; [4]Snider and Titus 2000; [5]USFWS 2006

Sacramento River winter-run Chinook salmon fry begin to emerge from the gravel in late June to early July and continue through October (Fisher 1994), with emergence generally occurring at night. Fry then seek lower velocity nearshore habitats with riparian vegetation and associated substrates important for providing aquatic and terrestrial invertebrates, predator avoidance, and slower velocities for resting (NMFS 1996). Emigrating juvenile Sacramento River winter-run Chinook salmon pass the RBDD beginning as early as mid-July, typically peaking in September, and can continue through March in dry years (Vogel and Marine 1991, NMFS 1997). From 1995 to 1999, all Sacramento River winter-run Chinook salmon outmigrating as fry passed the RBDD by October, and all outmigrating pre-smolts and smolts passed the RBDD by March (Martin et al. 2001).

Juvenile Sacramento River winter-run Chinook salmon occur in the Delta primarily from November through early May based on data collected from trawls in the Sacramento River at West Sacramento (RM 55; USFWS 2006). The timing of migration varies somewhat due to changes in river flows, dam operations, seasonal water temperatures, and hydrologic conditions (water year type). Winter-run Chinook salmon juveniles remain in the Delta until they reach a fork length of approximately 118 mm and are between five and 10 months of age. It has been hypothesized that changes in habitat conditions within the Delta over the past century have resulted in a reduction in extended juvenile salmon rearing when compared to periods when habitat for juvenile salmon rearing was more suitable. Emigration to the ocean begins as early as November and continues through May (Fisher 1994, Myers et al. 1998). The importance of the Delta in the life history of Sacramento River winter-run Chinook salmon is not well understood.

Data from the Pacific States Marine Fisheries Commission Regional Mark Information System database indicate that Sacramento River winter-run Chinook salmon adults are not as broadly distributed along the Pacific Coast as other Central Valley Chinook salmon runs and concentrate in the region between San Francisco and Monterey. This localized distribution may indicate a unique life history strategy related to the fact that Sacramento River winter-run Chinook salmon also mature at a relatively young age (Myers et al. 1998). Sacramento River winter-run Chinook salmon remain in the ocean environment for two to four years.

A2.5 Threats and Stressors

The following have been identified as important threats and stressors to winter-run Chinook salmon (without priority).

Reduced staging and spawning habitat. Access to much of the historical upstream spawning habitat for winter-run Chinook salmon (see Figure A-2a) has been eliminated or degraded by man-made structures (e.g., dams and weirs) associated with water storage and conveyance, flood control, and diversions and exports for municipal, industrial, agricultural, and hydropower purposes (Yoshiyama et al. 1998). The construction and operation of Shasta Dam reduced the winter-run Chinook salmon ESU from four independent populations to just one. The remaining available habitat for natural spawners is currently maintained with cool water releases from Shasta and Keswick dams, thereby significantly limiting spatial distribution of this ESU within the reach of the mainstem Sacramento River immediately downstream of the dam.

Upstream diversions and dams have decreased downstream flows and altered seasonal hydrologic patterns, which have been identified as factors resulting in delayed upstream migration by adults and increased mortality of out-migrating juveniles (Yoshiyama et al. 1998, DWR 2005). Dams and reservoir impoundments and associated reductions in peak flows have blocked gravel recruitment and reduced flushing of sediments from existing gravel beds, reducing and degrading natal spawning grounds. Furthermore, reduced flows can lower attraction cues for adult spawners, causing straying and delays in spawning (DWR 2005). Adult salmon migration delays can reduce fecundity and increase susceptibility to disease and harvest (McCullough 1999).

The RBDD, located on the Sacramento River, has been identified as a barrier and impediment to adult winter-run Chinook salmon upstream migration. Although the RBDD is equipped with fish ladders, migration delays occur when the dam gates are closed. Mortality as a result of increased predation by Sacramento pikeminnow on juvenile salmon passing downstream through the fish ladder has also been identified as a factor affecting abundance of salmon produced on the Sacramento River (Hallock 1991). The construction and operation of the RBDD has been identified as one of the primary factors contributing to the decline in winter-run Chinook salmon abundance that lead to listing of the species under the ESA.

Reduced rearing and out-migration habitat. Juvenile winter-run Chinook salmon prefer natural stream banks, floodplains, marshes, and shallow water habitats to utilize as rearing habitat during out-migration. Channel margins throughout the Delta have been leveed, channelized, and fortified with riprap for flood protection and island reclamation, reducing and degrading the quality of natural habitat available for juvenile Chinook salmon rearing (Brandes and McLain 2001). Man-made barriers further reduce and degrade rearing and migration habitat and delay juvenile out-migration. Juvenile out-migration delays can reduce fitness and increase susceptibility to diversion screen impingement, entrainment, disease, and predation. Modification of natural flow regimes from upstream reservoir operations has resulted in dampening and altering the seasonal timing of the hydrograph, reducing the extent and duration of seasonal floodplain inundation and other flow-dependent habitat used by migrating juvenile Chinook salmon (70 FR 52488, Sommer et al. 2001, DWR 2005). Recovery of floodplain habitat in the Central Valley has been found to contribute to increased production in fall-run Chinook salmon (Sommer et al. 2001), but little is known about the potential benefits of recovered floodplains during the migration period for winter-run. Reductions in flow rates have resulted in increased seasonal water temperature. The potential adverse effects of dam operations and reductions in seasonal river flows, such as delays in juvenile emigration and exposure to a higher proportion of agricultural return flows, have all been identified as factors that could affect the survival and success of winter-run Chinook salmon inhabiting the Sacramento River in the future.

Predation by non-native species. Predation on juvenile salmon by non-native fish has been identified as an important threat to winter-run Chinook salmon in areas with high densities of non-native fish (e.g., small and large mouth bass, striped bass, and catfish) that prey on out-migrating juveniles (Lindley and Mohr 2003). Water temperatures are generally lower during out-migration of winter-run compared to other salmonids, and may ameliorate predation pressures that can increase with increasing water temperature. In addition, non-native aquatic vegetation, such as Egeria and water hyacinth, provide suitable habitat for non-native predators (Nobriga et al. 2005, Brown and Michniuk 2007). Predation risk may covary with increased temperatures. Metabolic rates of non-native, predatory fish increase with increasing water temperatures based on bioenergetic studies (Loboschefsky et al. 2009, Miranda et al. 2010). The low spatial complexity and reduced habitat diversity (e.g., lack of cover) of channelized waterways within the Sacramento River and Delta reduces refuge space of salmon from predators (Raleigh et al. 1984, Missildine et al. 2001, 70 FR 52488). A major concern is the potential invasion of the Delta by the highly predatory northern pike. The pike, recently present in Lake Davis on the Feather River, was the target of a major eradication effort (DFG 2007a). If eradication fails and pike escape downstream to the Delta, they would likely be present in areas inhabited by juvenile winter-run Chinook salmon.

Increased predation mortality by native fish species, such as Sacramento pikeminnow at the RBDD, has also been identified as a factor affecting the survival of juvenile salmon within the Sacramento River and Delta.

Harvest. Commercial and recreational harvest of winter-run Chinook salmon in the ocean and inland fisheries has been a subject of management actions by the California Fish and Game Commission and the Pacific Fishery Management Council. The primary concerns focus on the effects of harvest on wild Chinook salmon produced in the Central Valley, as well as the incidental harvest of winter-run Chinook salmon as part of the fall-run and late fall-run salmon fisheries. Naturally reproducing winter-run Chinook salmon are less able to withstand high harvest rates when compared to hatchery-based stocks because of differences in survival rates for incubating eggs and rearing and emigrating juvenile salmon produced in streams and rivers (relatively low survival rates) compared to Central Valley salmon hatcheries (relatively high survival rates) (Knudsen et al. 1999). As a result of recent changes in fishing regulations and restrictions on harvest, commercial and recreational fishing does not appear to have a significant impact on winter-run Chinook salmon populations, but continued assessment is warranted. Commercial fishing for salmon in West Coast ocean waters is managed by the Fishery Management Council and is constrained by time and area closures to meet the Sacramento River winter-run ESA consultation standard and restrictions requiring minimum size limits and use of circle hooks for anglers. Ocean harvest restrictions since 1995 have led to reduced ocean harvest of winter-run Chinook salmon (i.e., Central Valley Chinook salmon ocean harvest index, ranged from 0.55 to nearly 0.80 from 1970 to 1995, and was reduced to 0.27 in 2001). Major restrictions in the commercial fishing industry in California and Oregon during the past two years were enforced to protect Klamath River coho salmon stocks. Because the fishery is mixed, these restrictions have likely reduced harvest of winter-run Chinook salmon, as well. The DFG, NMFS, and Pacific Fishery Management Council continually monitor and assess the effects of harvest of winter-run Chinook salmon, such that regulations can be refined and modified as new information becomes available.

Because adult winter-run Chinook salmon hold in the mainstem Sacramento River until spawning during the summer months, they are particularly vulnerable to illegal (poaching) harvest. Various watershed groups have established public outreach and educational programs in an effort to reduce poaching. In addition, DFG wardens have increased enforcement against illegal harvest of winter-run Chinook salmon. The level and effect of illegal harvest on adult winter-run Chinook salmon abundance and population reproduction is unknown.

Reduced genetic diversity/integrity. Artificial propagation programs conducted for winter-run Chinook salmon conservation purposes (i.e., Livingston Stone National Fish Hatchery) were developed to increase the abundance and diversity of winter-run Chinook salmon and to protect the species from extinction in the event of a catastrophic failure of the wild population. It is unclear what the effects of the hatchery propagation program are on the productivity and spatial structure of the winter-run Chinook salmon ESU (i.e., genetic fitness and productivity). One of the primary concerns with hatchery operations is the genetic introgression by hatchery origin fish that spawn naturally and interbreed with local natural populations (USFWS 2001, USBR 2004, Goodman 2005). It is now recognized that Central Valley hatcheries are a significant and persistent threat to wild Chinook salmon and steelhead populations and fisheries (NMFS 2009a). Such introgression introduces maladaptive genetic changes to the wild winter-run stocks and may reduce overall fitness (Myers et al. 2004, Araki et al. 2007). Taking egg and sperm from a large number of individuals is one method to ameliorate genetic introgression, but artificial selection for traits that assure individual success in a hatchery setting (e.g., rapid growth and tolerance to crowding) are unavoidable (USBR 2004). Investigations are continuing to evaluate the genetic characteristics of winter-run Chinook salmon, improve genetic management of the artificial propagation program, evaluate the minimum viable population size that would maintain genetic integrity within the population, and explore methods for establishing additional independent winter-run Chinook salmon populations as part of recovery planning and conservation of the species.

Entrainment. The vulnerability of juvenile winter-run Chinook salmon to entrainment and salvage at SWP and CVP export facilities varies in response to multiple factors, including the seasonal and geographic distribution of juvenile salmon within the Delta, operation of Delta Cross Channel gates, hydrodynamic conditions occurring within the central and southern regions of the Delta (e.g., Old and Middle rivers), and export rates. The loss of fish to entrainment mortality has been identified as an impact to Chinook salmon populations (Kjelson and Brandes 1989). Juvenile winter-run Chinook salmon tend to be distributed within the central and southern Delta where they have an increased risk of entrainment/salvage between February and April (see Table A.X.1). The effect of changing hydrodynamics within Delta channels, such as reversed flows in Old and Middle rivers resulting from SWP and CVP export operations, has the potential to increase attraction of emigrating juveniles into false migration pathways, delay emigration through the Delta, and directly or indirectly increase vulnerability to entrainment at unscreened diversions. In addition, there is an increase the risk of predation and duration of exposure to seasonally elevated water temperatures and other water quality conditions. SWP and CVP exports have been shown to affect the tidal hydrodynamics (e.g., water current velocities and direction). The magnitude of these hydrodynamic effects vary in response to a variety of factors including tidal stage and magnitude of ebb and flood tides, the rate of SWP and CVP exports, operation of the Clifton Court Forebay (CCF) radial gate opening, and inflow from the upstream tributaries. Chinook salmon behaviorally respond to hydraulic cues (e.g., water currents) during both upstream adult and downstream juvenile migration through the Delta. Changes in these hydraulic cues as a result of SWP and/or CVP export operations during the period that salmon are migrating through Delta channels may contribute to use of false migration pathways, delays in migration, or increased movement of migrating salmon toward the export facilities leading to an increase in entrainment risk. During the past several years, additional investigations have been designed using radio or acoustically-tagged juvenile Chinook salmon to monitor migration behavior through the Delta channels and to assess the effects of changes in hydraulic cues and SWP and CVP export operations on migration (Holbrook et al. 2009, Perry et al. 2010, San Joaquin River Group Authority 2010). These studies are ongoing.

Incidental take of juvenile winter-run Chinook salmon at the SWP and CVP export fish salvage facilities is routinely monitored and reported as part of export operations. Salvage monitoring and the protocol for identifying juvenile winter-run Chinook salmon from other Central Valley Chinook salmon have been refined over the past decade. Run identification was originally determined based on the length of each fish and the date when it was collected. Subsequent genetic testing has been used to refine species identification. Methods for estimating juvenile winter-run Chinook salmon production each year (year class strength) have been developed that take into account the number of adults spawning in the river from carcass surveys, hatching success based on a consideration of water temperatures and other factors, and estimated juvenile survival. Authorized incidental take can then be adjusted each year (1-2 percent of juvenile production) to reflect the relative effect of take at a population level rather than based on a predetermined level that does not reflect year-to-year variation in juvenile production within the Sacramento River.

In addition to SWP and CVP exports, there are more than 2,200 small water diversions throughout the Delta, including unscreened diversions located on the tributary rivers (Herren and Kawasaki 2001). The risk of entrainment is a function of the size of juvenile fish and the slot opening of the screen mesh (Tomljanovich et al. 1978, Schneeberger and Jude 1981, Zeitoun et al. 1981, Weisberg et al. 1987, C. Hanson unpubl. data). Many juvenile winter-run Chinook salmon migrate downstream through the Delta during the late winter or early spring when many of the agricultural irrigation diversions are not operating or are only operating at low levels. Juvenile winter-run Chinook salmon also migrate primarily in the upper part of the water column, reducing their vulnerability to unscreened diversions located near the channel bottom. No quantitative estimates have been developed to assess the potential magnitude of entrainment losses for juveniles migrating through the rivers and Delta, or the effects of these losses on the overall population abundance of returning adult Chinook salmon. The effect of entrainment mortality on the population dynamics and overall adult abundance of winter-run Chinook salmon is not well understood.

Power plants within the Plan Area have the ability to impinge and entrain juvenile Chinook salmon on the existing cooling water system intake screens. However, use of cooling water is currently low with the retirement of older units. Furthermore, newer units are being equipped with a closed cycle cooling system that virtually eliminates the risk of impingement of juvenile salmon.

Besides direct mortality, salmon fitness may be affected by delays in out-migration of smolts caused by reduced or reverse flows. Delays in migration due to water management related to the SWP and CVP operations can make juvenile salmonids more susceptible to many of the threats and stressors discussed in this section, such as predation, entrainment, angling, exposure to poor water quality, and disease. The quantitative relationships among changes in Delta hydrodynamics, the behavioral and physiological response of juvenile salmon, and the increase or decrease in risk associated with other threats is unknown, but currently the subject of a number of investigations and analyses.

Exposure to toxins. Inputs of toxics into the Delta watershed include agricultural drainage and return flows, municipal wastewater treatment facilities, and other point and non-point discharges (Moyle 2002). These toxic substances include mercury, selenium, copper, pyrethroids, and endocrine disruptors with the potential to impact fish health and condition, and adversely impact salmon distribution and abundance. Toxic chemicals have the potential to be widespread throughout the Sacramento River and Delta, or may occur on a more localized scale in response to episodic events (e.g., stormwater runoff, point source discharges, etc.). Agricultural return flows are widely distributed throughout the Sacramento River and the Delta, although dilution flows from the rivers may reduce chemical concentrations to sublethal levels. Toxic algae (e.g., Microcystis) have also been identified as a potential factor adversely affecting salmon and other fish. Exposure to these toxic materials has the potential to directly and indirectly adversely impact salmon distribution and abundance. Concern regarding exposure to toxic substances for Chinook salmon includes both waterborne chronic and acute exposure, but also bioaccumulation and chronic dietary exposure. For example, selenium is a naturally occurring constituent in agricultural drainage water return flows from the San Joaquin River that is then dispersed downstream into the Delta (Nichols et al. 1986). Exposure to selenium in the diet of juvenile Chinook salmon has been shown to result in toxic effects (Saiki 1986, Saiki and Lowe 1987, Hamilton et al. 1986, 1990, Hamilton and Buhl 1990). Selenium exposure has been associated with agricultural and natural drainage within the San Joaquin River basin and refining operations adjacent to San Pablo and San Francisco bays. Other contaminants of concern for Chinook salmon include, but are not limited to, mercury, copper, oil and grease, pesticides, herbicides, ammonia, and localized areas of depressed dissolved oxygen (e.g., Stockton Deep Water Ship Channel, return flows from managed freshwater wetlands, etc.). As a result of the extensive agricultural development within the Central Valley, exposure to pesticides and herbicides has been identified as a significant concern for salmon and other fish species within the Plan Area (Bennett et al. 2001). In recent years, changes have been made in the composition of herbicides and pesticides used on agricultural crops in an effort to reduce potential toxicity to aquatic and terrestrial species. Modifications have also been made to water system operations and discharges related to agricultural wastewater discharges (e.g., agricultural drainage water system lock-up and holding prior to discharge) and municipal wastewater treatment and discharges. Concerns remain, however, regarding the toxicity of contaminants such as pyrethroids that adsorb to sediments and other chemicals (e.g., including selenium and mercury, as well as other contaminants) on salmon.

Mercury and other metals such as copper have also been identified as contaminants of concern for salmon and other fish as a result of direct toxicity and impacts such as those related to acid mine runoff from sites such as Iron Mountain Mine (EPA 2006). The potential problems include tissue bioaccumulation that may adversely impact the fish, but also represents a human health concern (Gassel et al. 2008). These materials originate from a variety of sources including mining operations, municipal wastewater treatment, agricultural drainage within the tributary rivers and Delta, non-point runoff, natural runoff and drainage within the Central Valley, agricultural spraying, and a number of other sources.

The State Water Resources Control Board (SWRCB), Central Valley Regional Water Quality Control Board (CVRWQCB), U.S. Environmental Protection Agency (EPA), U.S. Geological Survey (USGS), DWR, and others have ongoing monitoring programs designed to characterize water quality conditions and identify potential toxicants and contaminant exposure to Chinook salmon and other aquatic resources within the Plan Area. Programs are in place to regulate point source discharges as part of the National Pollutant Discharge Elimination System (NPDES) program as well as programs to establish and reduce total daily maximum loads of various constituents entering the Delta. Changes in regulations have also been made to help reduce chemical exposure and reduce the adverse impacts to aquatic resources and habitat conditions within the Plan Area. These monitoring and regulatory programs are ongoing. Regulations and changes in monitoring and management of agricultural pesticide and herbicide chemicals and their application, education on the effects of urban runoff and chemical discharges, and refined treatment processes have been adopted over the past several decades in an effort to reduce the adverse effects of chemical pollutants on salmon and other aquatic species.

In the final listing determination of the ESU, acid mine runoff from Iron Mountain Mine, located adjacent to the upper Sacramento River, was identified as one of the main threats to winter-run Chinook salmon (Upper Sacramento River Fisheries and Riparian Habitat Advisory Council 1989). Acid mine drainage, including elevated concentrations of metals, produced from the abandoned mine degraded spawning habitat of winter-run Chinook salmon and resulted in high mortality. Storage limitations and limited availability of dilution flows have caused downstream copper and zinc levels to exceed salmonid tolerances and resulted in documented fish kills in the 1960s and 1970s (USBR 2004). The EPA's Iron Mountain Mine remediation program and 2002 restoration plan has removed toxic metals in acidic mine drainage from the Spring Creek watershed with a state-of-the-art lime neutralization plant. Contaminant loading into the Sacramento River from Iron Mountain Mine has shown measurable reductions since the early 1990s. Pollution from Iron Mountain Mine is no longer considered to be a main factor threatening the winter-run Chinook salmon ESU.

Concern has been expressed regarding the potential to resuspend toxic materials into the water column where they may adversely affect salmon through seasonal floodplain inundation, habitat construction projects, channel and harbor maintenance dredging, and other means. For example, mercury deposits exist at a number of locations within the Central Valley and Delta, including the Yolo Bypass. Seasonal inundation of floodplain areas, such as within the Yolo Bypass, has the potential to create anaerobic conditions that contribute to the methylation of mercury, which increases toxicity. Additionally, there are problems with scour and erosion of these mercury deposits by increased seasonal flows. Similar concerns exist regarding creating aquatic habitat by flooding Delta islands or disturbance created by levee setback construction or other habitat enhancement measures. The potential to increase toxicity as a result of habitat modifications designed to benefit aquatic species is one of the factors that needs to be considered when evaluating the feasibility of habitat enhancement projects within the Central Valley.

Sublethal concentrations of toxics may interact with other stressors on salmonids, such as increasing their vulnerability to mortality as a result of exposure to seasonally elevated water temperatures, predation or disease (Werner 2007). For example, Clifford et al. (2005) found in a laboratory setting that juvenile fall-run Chinook salmon exposed to sublethal levels of a common pyrethroid, esfenvalerate, were more susceptible to infectious hematopoietic necrosis virus than those not exposed to esfenvalerate. Although not tested on winter-run Chinook salmon, a similar response is likely.

Increased water temperature. Water temperature is among the physical factors that affect quality of habitat for salmonid adult holding, spawning and egg incubation, juvenile rearing, and migration. Adverse sublethal and lethal effects can result from exposure to elevated water temperatures at sensitive lifestages, such as during incubation or rearing. The Central Valley is the southern limit of Chinook salmon geographic distribution and increased water temperatures are often recognized as an important stressor to California populations. Water temperature criteria for various lifestages of salmonids in the Central Valley have been developed by NMFS (2009). The tolerance of winter-run Chinook salmon to water temperatures depends on life stage, acclimation history, food availability, duration of exposure, health of the individual, and other factors, such as predator avoidance (Myrick and Cech 2004, USBR 2004). Higher water temperatures can lead to physiological stress, reduced growth rates, pre-spawning mortality, reduced spawning success, and increased mortality of salmon (Myrick and Cech 2001). Temperature can also indirectly influence disease incidence and predation (Waples et al. 2008). Exposure to seasonally elevated water temperatures may occur as a result of reductions in flow, as a result of upstream reservoir operations, reductions in riparian vegetation, channel shading, local climate and solar radiation. The installation of the Shasta Temperature Control Device in 1998, in combination with reservoir management to maintain the cold water pool within Shasta Reservoir, has reduced many of the temperature issues on the Sacramento River. Water temperature management on the Sacramento River has been specified in the NMFS biological opinion and has been identified as one of the factors contributing to the observed increase in adult winter-run Chinook salmon abundance in recent years. During dry years, however, the release of cold water from Shasta Dam is still limited. As the river flows further downstream, particularly during the warm spring, summer, and early fall months, water temperatures continue to increase until they reach thermal equilibrium with atmospheric conditions. As a result of the longitudinal gradient of seasonal water temperatures, the coldest temperatures and best areas for winter-run Chinook salmon spawning and rearing are typically located immediately downstream of Keswick Dam.

Increased temperature can also arise from a reduction in shade over rivers by tree removal (Watanabe et al. 2005). Because river water is typically in thermal equilibrium with atmospheric conditions by the time it enters the Delta, this issue is caused primarily from actions upstream of the Delta. As a result of the relatively wide channels that occur within the Delta, the effects of additional riparian vegetation on reducing water temperatures within the Delta are minimal.

The effects of climate change and global warming patterns, in combination with changes in precipitation and seasonal hydrology in the future, have been identified as important factors that may adversely affect the health and long-term viability of Sacramento River winter-run Chinook salmon (Crozier et al. 2008). The rate and magnitude of these potential future environmental changes, and their effect of habitat quality and availability for winter-run Chinook salmon, however, are subject to a high degree of uncertainty.

A2.6 Relevant Conservation Efforts

Since the listing of Sacramento River winter-run Chinook salmon, several habitat and harvest-related problems that were identified as factors contributing to the decline of the species have been addressed and improved through restoration and conservation actions. The impetus for initiating restoration actions stems primarily from the following: (1) ESA section 7 consultation Reasonable and Prudent Alternatives on temperature, flow, and operations of the CVP and SWP (NMFS 2009b); (2) Regional Water Quality Control Board decisions requiring compliance with Sacramento River water temperature objectives which resulted in the installation of the Shasta Temperature Control Device in 1998; (3) a 1992 amendment to the authority of the CVP through the Central Valley Improvement Act to give fish and wildlife equal priority with other CVP objectives; (4) fiscal support of habitat improvement projects from the California Bay Delta Authority (CALFED) Bay-Delta Program (e.g., installation of a fish screen on the Glenn-Colusa Irrigation District diversion); (5) establishment of the CALFED Environmental Water Account ; (6) EPA actions to control acid mine runoff from Iron Mountain Mine; and, (7) ocean harvest restrictions implemented in 1995.

Results of monitoring at the CVP and SWP fish salvage facility and extensive experimentation over the past several decades have lead to the identification of a number of management actions designed to reduce or avoid the potentially adverse impacts of SWP and CVP export operations on salmon. Many of these actions have been implemented through SWRCB water quality permits (D-1485, D-1641), biological opinions issued on project export operations by NMFS, USFWS, and DFG, as part of CALFED programs (e.g., Environmental Water Account), and as part of Central Valley Project Improvement Act actions. As a result of these requirements, multiple conservation efforts exist to enhance habitat and reduce entrainment of Chinook salmon by the SWP and CVP export facilities.

The artificial propagation program for winter-run Chinook salmon at Livingston Stone National Fish Hatchery, located on the mainstem of the Sacramento River, has operated for conservation purposes since the early 1990s. The increased natural escapement over the last several years has led to the termination of both captive broodstock programs located at University of California at Davis' Bodega Marine Laboratory and Livingston Stone National Fish Hatchery.

Biological opinions for SWP and CVP operations (e.g., NMFS 2009b) and other federal projects involving irrigation and water diversion and fish passage, for example, have improved or minimized adverse impacts to salmon in the Central Valley. In 1992, an amendment through the Central Valley Project Improvement Act gave protection of fish and wildlife equal priority with other CVP objectives. From this act arose several programs that have benefited listed salmonids. The Anadromous Fish Restoration Program is engaged in monitoring, education, and restoration projects designed to contribute toward doubling the natural populations of select anadromous fish species residing in the Central Valley. Restoration projects funded through the Anadromous Fish Restoration Program include fish passage, fish screening, riparian easement and land acquisition, development of watershed planning groups, instream and riparian habitat improvement, and gravel replenishment. The Anadromous Fish Screen Program combines federal funding with state and private funds to prioritize and construct fish screens on major water diversions mainly in the upper Sacramento River. The goal of the Water Acquisition Program is to acquire water supplies to meet the habitat restoration and enhancement goals of the Central Valley Project Improvement Act, and to improve the ability of the U.S. Department of the Interior to meet regulatory water quality requirements. Water has been used to improve fish habitat for Central Valley salmon, with the primary focus on listed Chinook salmon and steelhead, including winter-run Chinook salmon, by maintaining or increasing instream flows (e.g., Environmental Water Account) on the Sacramento River at critical times, and to reduce salmonid entrainment at the SWP and CVP export facilities through reducing seasonal diversion rates during periods when protected fish species are vulnerable to export related losses.

Two programs included under CALFED, the Ecosystem Restoration Program (ERP) and the Environmental Water Account, were created to improve conditions for fish, including winter-run Chinook salmon, in the Central Valley. As part of developing the ERP, a series of conceptual models (DRERIP) have been constructed to provide a framework for identifying and assessing the potential benefits and/or consequences of potential restoration actions. The DRERIP models are being used to evaluate potential BDCP conservation measures, as well as restoration actions as part of the ERP. Restoration actions implemented by the ERP include the installation of fish screens, modification of barriers to improve fish passage, habitat acquisition, and instream habitat restoration. The majority of these actions address key factors and stressors affecting listed salmonids. Additional ongoing actions include efforts to enhance fishery monitoring, and improvements to hatchery management to support salmonid production through hatchery releases.

A major CALFED ERP action currently underway is the Battle Creek Salmon and Steelhead Restoration Project. Although winter-run Chinook salmon do not currently inhabit Battle Creek, they occurred there historically. CALFED is funding the establishment of a second independent population of winter-run Chinook salmon in the upper Battle Creek watershed using the artificial propagation program as a source of fish. The project will restore 77 km (48 miles) of habitat in Battle Creek to support steelhead and Chinook salmon spawning and juvenile rearing at a cost of over $90 million. The project includes removal of five small hydropower diversion dams, construction of new fish screens and ladders on another three dams, and construction of several hydropower facility modifications to ensure the continued hydropower operations. It is thought that this restoration effort is the largest cold water restoration project to date in North America.

As part of CALFED and CVPIA programs, many of the largest water diversions located on the Sacramento River and Delta (e.g., Glenn Colusa Irrigation District, Reclamation District 1001 Princeton diversion, RD 108 Wilkins Slough pumping plant, Sutter Mutual Water Company Tisdale pumping plant, Contra Costa Water District's Old River and Alternative Intake Project intake, and others) have been equipped with positive barrier fish screens, although the majority of smaller water diversions located on the Sacramento River and Delta remain unscreened. Reclamation District 108 has also designed and constructed a new fish screen and pumping plant (Poundstone Pumping Plant) located on the Sacramento River that consolidates and eliminates three currently existing unscreened water diversions. These fish screening projects are specifically intended to reduce and avoid entrainment losses of juvenile winter-run Chinook salmon and other fish inhabiting the river.

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) was formed to guide the implementation of CALFED Ecosystem Restoration Plan elements within the Delta (DFG 2007b). The DRERIP team has created a suite of ecosystem and species conceptual models, including winter-run Chinook salmon, that document existing scientific knowledge of Delta ecosystems. The DRERIP Team has used these conceptual models to assess the suitability of actions proposed in the Ecosystem Restoration Plan for implementation. DRERIP conceptual models were used in the analysis of proposed BDCP conservation measures.

The Central Valley Salmonid Project Work Team, an interagency technical working group led by DFG, drafted a proposal to develop a Chinook salmon escapement monitoring plan that was selected by the CALFED ERP Implementing Agency Managers for directed action funding. Long-term funding for implementation of the monitoring plan still needs to be secured.

Recent habitat restoration initiatives sponsored and funded primarily by the CALFED ERP have funded 29 projects (approximately $24 million) designed to restore ecological function to 9,543 acres (8,091 acres within the Bay Region and the remaining acres located in the Delta and Eastside Tributaries Regions of the CALFED action area) of shallow-water tidal and marsh habitats within the Bay-Delta. Restoration of these areas primarily involves flooding lands previously used for agriculture, thereby creating additional rearing habitat for juvenile salmonids. Similar habitat restoration is imminent adjacent to Suisun Marsh (i.e., at the confluence of Montezuma Slough and the Sacramento River) as part of the Montezuma Wetlands project, which is intended to provide for commercial disposal of material dredged from San Francisco Estuary in conjunction with tidal wetland restoration.

The U.S. EPA's Iron Mountain Mine remediation involves the removal of toxic metals in acidic mine drainage from the Spring Creek Watershed with a state-of-the-art lime neutralization plant. Contaminant loading into the Sacramento River from Iron Mountain Mine, and other mining operations, has shown measurable reductions since the early 1990s. Decreasing the heavy metal contaminants that enter the Sacramento River should increase the survival of salmonid eggs and juveniles. However, during periods of heavy rainfall upstream of the Iron Mountain Mine, Reclamation substantially increases Sacramento River flows to dilute heavy metal contaminants being spilled from the Spring Creek debris dam. This rapid change in flows can cause juvenile salmonids to become stranded or isolated in side channels below Keswick Dam.

In 2001, a new fish screen was constructed at the Anderson Cottonwood Irrigation District Diversion Dam and a state-of-the-art fish ladder was installed to address the threats caused by the diversion dam. As described in the final listing determination for the ESU (70 FR 37160), the flashboard gates and inadequate fish ladders at the diversion dam blocked passage for upstream migrant winter-run Chinook salmon. The seasonal operation of the dam created unsuitable habitat upstream of the dam by reducing flow velocity over the incubating eggs, reducing egg survival. Evaluation of the fish ladder is ongoing.

To help reduce the effects of the RBDD operation on migration of adult and juvenile salmonids and other species, management has changed in recent years to maintain the dam gates in the open position for a longer period of time and thereby facilitate greater upstream and downstream migration. Changes in dam operations have benefited both upstream and downstream migration by salmon and have contributed to a reduction in juvenile predation mortality. In 2009, USBR received funding for the Fish Passage Improvement Project at the RBDD to build a pumping facility to provide reliable water supply for high-valued crops in Tehama, Glenn, Colusa, and northern Yolo counties while providing year-round unimpeded fish passage. This project, which is expected to be completed in late 2012, will eliminate passage issues for winter-run Chinook salmon and other migratory species.

DWR’s Delta Fish Agreement Program has approved approximately $49 million for projects that benefit salmon and steelhead production in the Sacramento-San Joaquin basins and Delta since the agreements inception in 1986. Delta Fish Agreement projects that benefit Sacramento River winter-run Chinook salmon include enhanced law enforcement efforts from San Francisco Estuary upstream into the Sacramento River, spawning gravel augmentations, and habitat enhancement projects. Through the Delta-Bay Enhanced Enforcement Program (DBEEP), initiated in 1994, a team of 10 wardens focus their enforcement efforts on salmon, steelhead, and other species of concern from the San Francisco Estuary upstream into the Sacramento and San Joaquin River basins. Enhanced enforcement programs are believed to have had significant benefits to Chinook salmon attributed to DFG, although results have not been quantified.

Harvest protective measures for Sacramento River winter-run Chinook salmon include seasonal constraints on sport and commercial fisheries south of Point Arena in an effort to reduce harvest of winter-run Chinook salmon. Ocean harvest restrictions since 1995 have led to reduced ocean harvest of winter-run Chinook salmon (i.e., Central Valley Chinook salmon ocean harvest index ranged from 0.55 to nearly 0.80 from 1970 to 1995, and was reduced to 0.27 in 2001). The state of California has established specific in-river fishing regulations and no-retention prohibitions designed to protect Sacramento River winter-run Chinook salmon. DFG has implemented enhanced enforcement efforts to reduce illegal harvests.

A2.7 RECOVERY GOALS

The Public Draft Recovery Plan for Central Valley salmonids, including Sacramento River winter-run Chinook salmon, was released by NMFS on October 19, 2009. Although not final, the overarching goal in the public draft is the removal of, among other listed salmonids, Sacramento River winter-run Chinook salmon from the federal list of Endangered and Threatened Wildlife (NMFS 2009a). Several objectives and related criteria represent the components of the recovery goal, including the establishment of at least two viable populations within each historical diversity group, as well as other measurable biological criteria.

A2.8 References

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APPENDIX A3. CENTRAL VALLEY SPRING-RUN CHINOOK SALMON (*ONCORHYNCHUS TSHAWYTSCHA*)

A3.1 LEGAL STATUS

The Central Valley spring-run Chinook salmon evolutionarily significant unit (ESU) is listed as a threatened species under the federal Endangered Species Act (ESA). The ESU includes all naturally spawned populations of spring-run Chinook salmon in the Sacramento River and its tributaries in California, including the Feather River (see Figure A-3a). The ESU was listed as threatened on September 16, 1999 (64 FR 50394).

In June 2004, the National Marine Fisheries Service (NMFS) proposed that Central Valley spring-run Chinook salmon remain listed as threatened (69 FR 33102). This proposal was based on the recognition that, although Central Valley spring-run Chinook salmon productivity trends were positive, the ESU continued to face risks from having a limited number of remaining populations (i.e., three existing populations from an estimated 17 historical populations), a limited geographic distribution, and potential hybridization with Feather River Hatchery spring-run Chinook salmon. Until recently, Feather River Hatchery spring-run Chinook salmon were not included in the ESU, yet these fish are genetically distinct from other populations in Mill, Deer, and Butte creeks.

On June 28, 2005, NMFS issued its final decision to retain the status of Central Valley spring-run Chinook salmon as threatened (70 FR 37160). This decision also included the Feather River Hatchery spring-run Chinook salmon population as part of the Central Valley spring-run Chinook salmon ESU.

Spring-run Chinook salmon was listed as a threatened species under the California ESA on February 5, 1999.

A3.2 SPECIES DISTRIBUTION AND STATUS

A3.2.1 Range and Status

Historically, spring-run Chinook salmon were predominant throughout the Central Valley occupying the upper and middle reaches (1,000 to 6,000 feet) of the San Joaquin, American, Yuba, Feather, Sacramento, McCloud and Pit rivers, with smaller populations in most tributaries with sufficient habitat for adult salmon holding over the summer months (see Figure A-3a) (Stone 1874, Rutter 1904, Clark 1929). Completion of Friant Dam extirpated the native spring-run Chinook salmon population from the San Joaquin River and its tributaries. Naturally-spawning populations of Central Valley spring-run Chinook salmon with consistent spawning returns are currently restricted to Butte Creek, Deer Creek, and Mill Creek (Good et al. 2005).

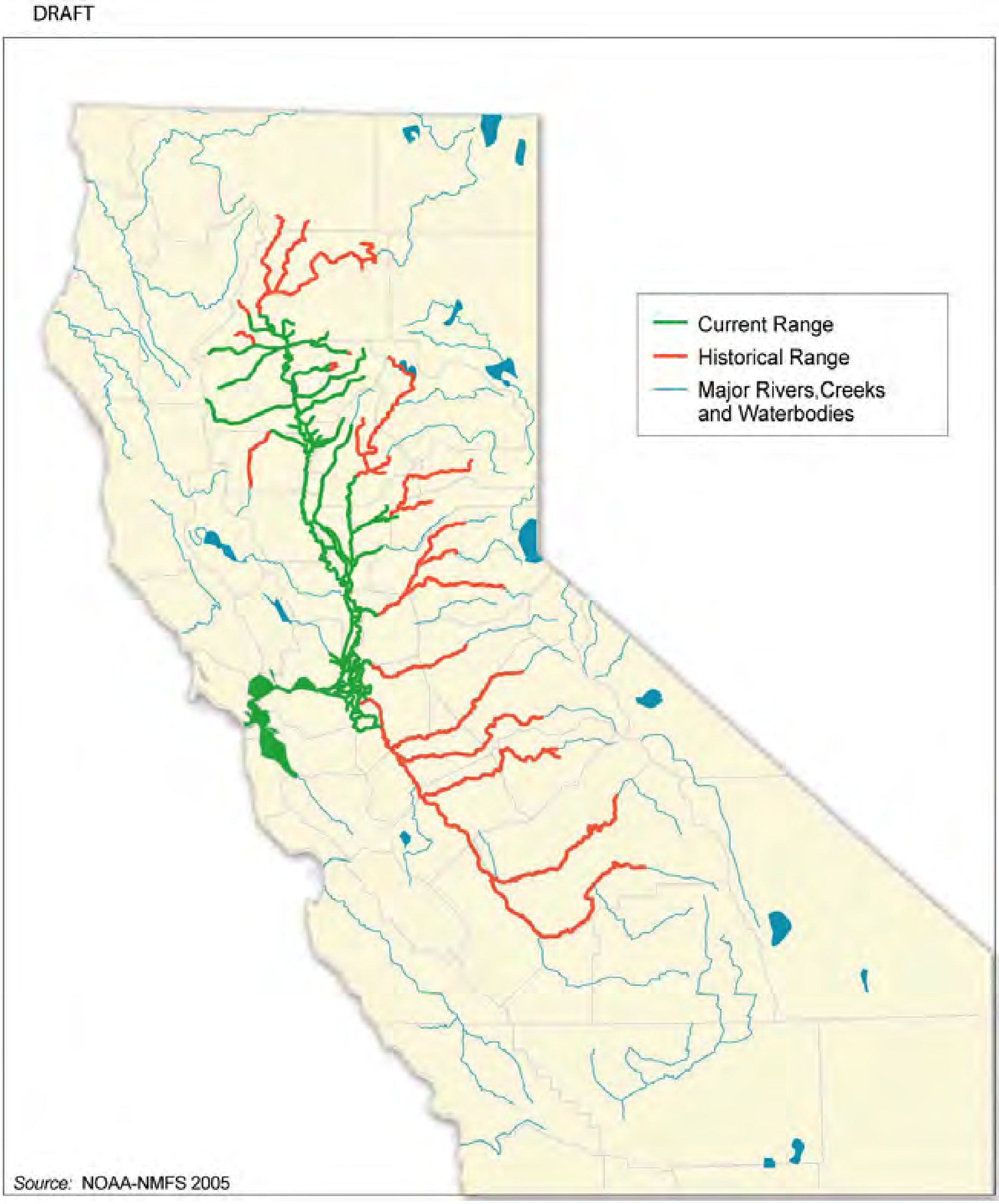

Figure A-3a. Central Valley Spring-Run Chinook Salmon Inland Range in California

There is a small spawning population that has been documented in Clear Creek (Newton and Brown 2004). In addition, the upper Sacramento River and Yuba River support small populations, but their status is not well documented. The Feather River Hatchery produces spring-run Chinook salmon on the Feather River.

Central Valley spring-run Chinook salmon were once the most abundant run of salmon in the Central Valley (Campbell and Moyle 1992). The Central Valley drainage as a whole is estimated to have supported spring-run Chinook salmon runs as large as 600,000 fish between the late 1880s and 1940s (California Department of Fish and Game [DFG] 1998). More than 500,000 Central Valley spring-run Chinook salmon were caught in the Sacramento-San Joaquin commercial fishery in 1883 (Yoshiyama et al. 1998). Population estimates of returning spring-run Chinook salmon for the years immediately preceding and after the closure of Friant Dam in February 1944 are: 35,000 in 1943, 5,000 in 1944, 56,000 in 1945, 30,000 in 1946, 6,000 in 1947, and 2,000 in 1948 (Fry 1961, Yoshiyama et al. 1998). There were occasional records of returning spring-run Chinook salmon during the 1950s and 1960s in wet years. The San Joaquin River population was essentially extirpated by the late 1940s. Populations in the upper Sacramento, Feather, and Yuba rivers were eliminated with the construction of major dams during the 1950s and 1960s.

The Central Valley spring-run Chinook salmon ESU has displayed broad fluctuations in adult abundance between 1961 and 2009 (see Figure A-3b). Adult spring-run salmon escapement to the Sacramento River system in 2009 was 3,802 fish. Sacramento River tributary populations in Mill, Deer, and Butte creeks are probably the best trend indicators for the Central Valley spring-run Chinook ESU as a whole because these streams contain the primary independent populations within the ESU. Generally, there was a positive trend in escapement in these waterways between 1992 and 2005, at which time there was a steep decline (see Figure A-3c). Estimated adult spring-run salmon escapement to Mill, Deer, and Butte creeks in 2009 was only 2,492 fish. Escapement numbers are dominated by Butte Creek returns, which represented nearly 75 percent of fish returning to these three creeks since 2000. Adult spring-run salmon escapement to Butte Creek in 2009 was approximately 2,059 fish, or 83 percent of escapement to these three creeks. During the period between 1992 and 2009, there have been significant habitat improvements in these watersheds, including the removal of several small dams and increases in summer flows, as well as reduced ocean salmon harvest and a favorable terrestrial and marine climate. The significant recent declines in adult fall-run Chinook salmon escapement has resulted in significant curtailment of the commercial and recreational salmon fisheries, which is expected to also increase the level of protection and benefit the Central Valley spring-run Chinook salmon population.

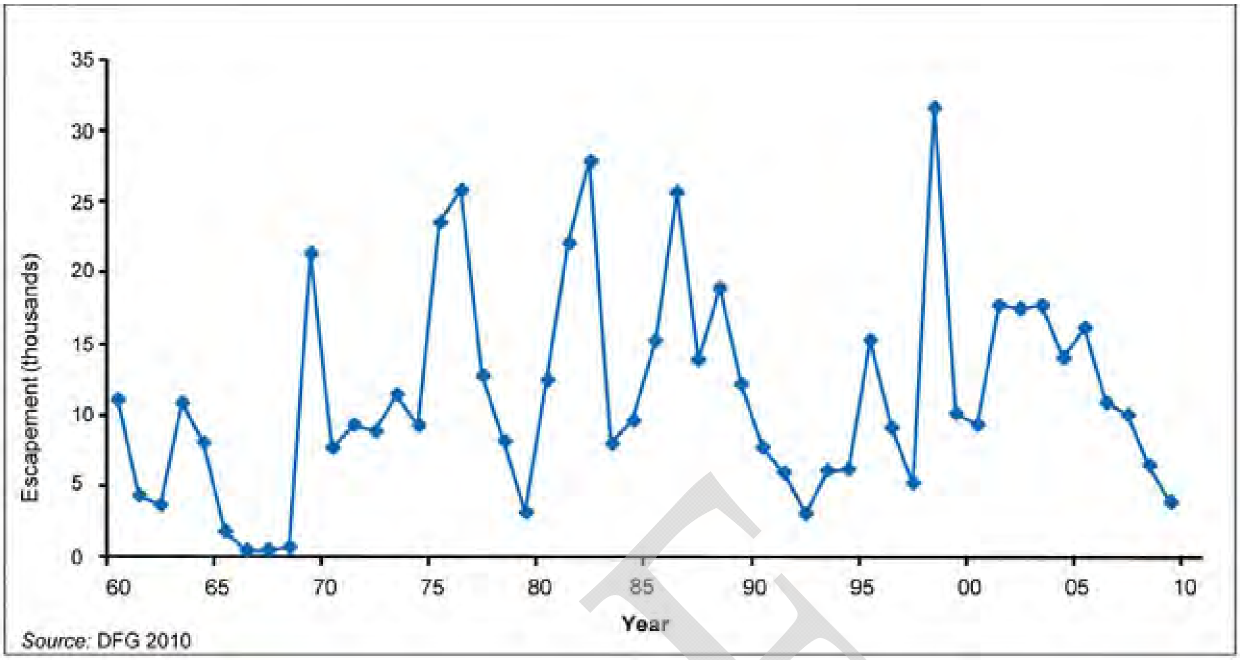

Figure A-3b. Estimate Historical Spawner Escapement of Spring-Run Chinook Salmon throughout the Central Valley (1960-2009)

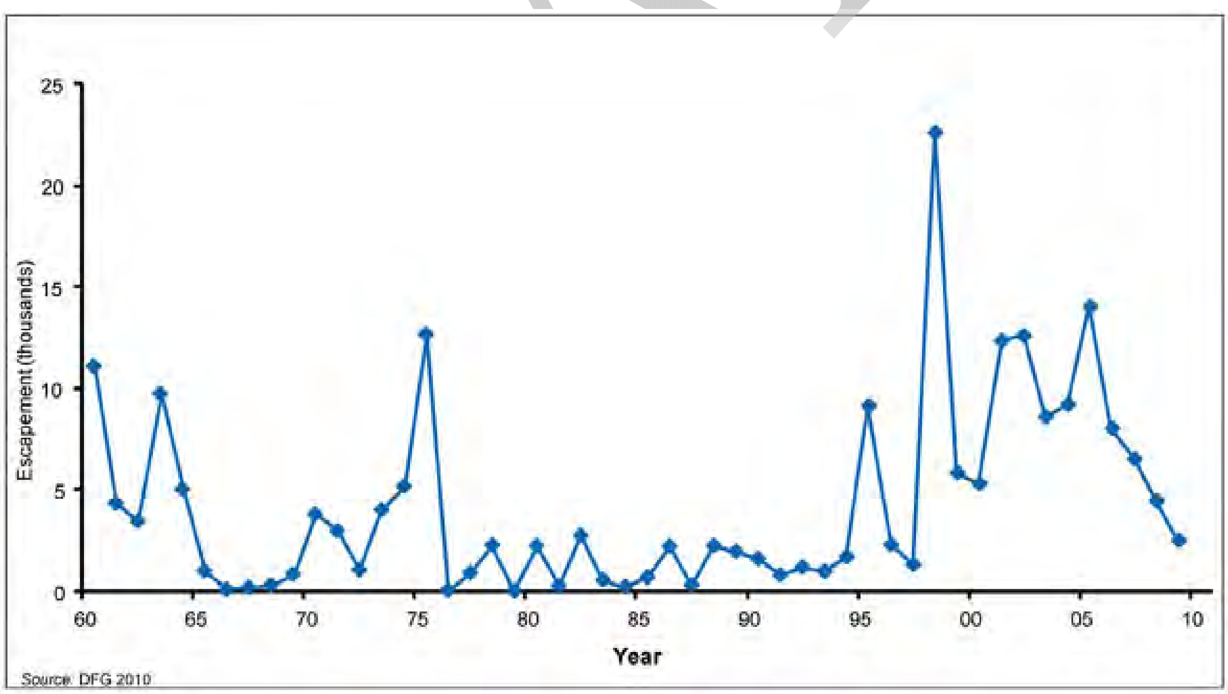

Figure A-3c. Estimated Historical Spawner Escapement of Spring-Run Chinook Salmon in Mill, Deer, and Butte Creeks (1960-2009)

On the Feather River, significant numbers of spring-run Chinook salmon, as identified by run timing, return to the Feather River Hatchery. However, coded-wire tag information from these hatchery returns and results of genetic testing indicate that substantial introgression has occurred between fall-run and spring-run Chinook salmon populations within the Feather River due to hatchery practices and the geographic and temporal overlap with spawning fall-run in the river.

Although recent Central Valley spring-run Chinook salmon population trends are negative, annual abundance estimates display a high level of variation. The overall number of Central Valley spring-run Chinook salmon remains well below estimates of historical abundance. Central Valley spring-run Chinook salmon have some of the highest population growth rates in the Central Valley, but other than Butte Creek and the hatchery-influenced Feather River, population sizes are very small relative to fall-run Chinook salmon populations (Good et al. 2005).

The viability of an ESU that is essentially represented by three populations located within the same ecoregion is vulnerable to changes in the environment through a lack of spatial geographic diversity. The current geographic distribution of viable populations makes the Central Valley spring-run Chinook salmon ESU vulnerable to catastrophic disturbance (Lindley et al. 2007). Such potential catastrophes include volcanic eruption of Mt. Lassen, prolonged drought conditions reducing coldwater pool adult holding habitat, and a large wildfire (approximately 30 km maximum diameter) encompassing the Deer, Mill and Butte creek watersheds. The Central Valley spring-run Chinook salmon ESU remains at a moderate to high risk of extinction because: (1) the ESU is spatially confined to relatively few remaining streams within its historical range; (2) the population continues to display broad fluctuations in abundance; and, (3) a large proportion of the population (i.e., in Butte Creek) faces the risk of high mortality rates due to high water temperatures during the adult holding period.

A3.2.2 Distribution and Status in the Plan Area

The entire population of the Central Valley spring-run Chinook salmon ESU must pass through the Plan Area as migrating adults and emigrating juveniles. Adult Central Valley spring-run Chinook salmon migrate primarily along the western edge of the Delta through the Sacramento River corridor, and juvenile spring-run Chinook salmon use the Delta, Suisun Marsh, and Yolo Bypass for migration and rearing.

A3.3 Habitat Requirements and Special Considerations

Critical habitat for spring run Chinook salmon ESU was updated on September 2, 2005 with an effective date of January 2, 2006 (70 FR 52488). Designated critical habitat includes 1,158 miles of stream habitat in the Sacramento River basin and 254 square miles of estuarine habitat in the San Francisco-San Pablo-Suisun Bay complex (70 FR 52488, Figure A-3d). Critical habitat includes stream reaches such as those of the Feather and Yuba rivers, Big Chico, Butte, Deer, Mill, Battle, Antelope, and Clear creeks, and the Sacramento River and Delta.

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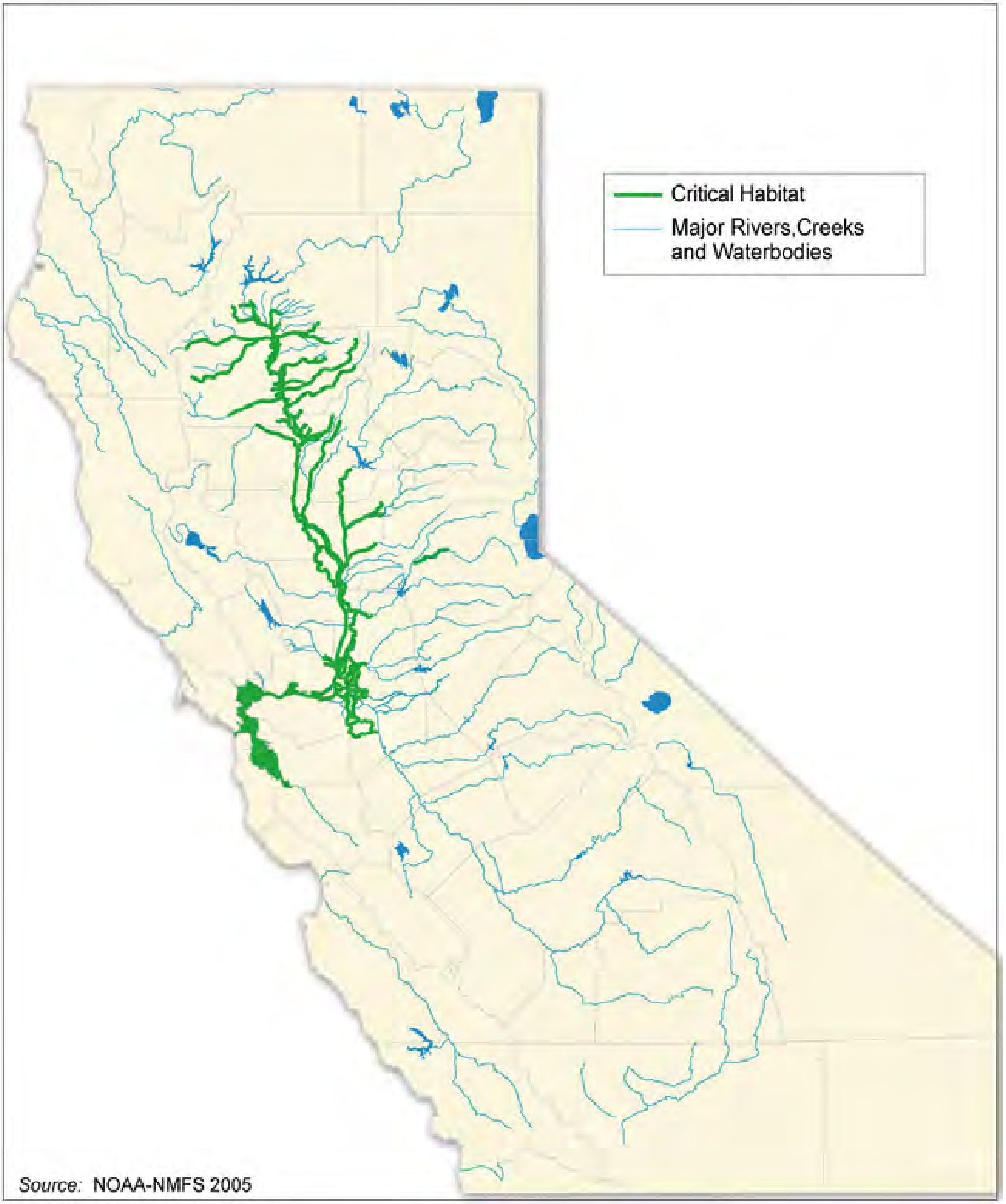

Figure A-3d. Central Valley Spring-Run Chinook Salmon Inland Designated Critical Habitat in California

This habitat is comprised of physical and biological features considered essential to the conservation of the species, including space for individual and population growth and for normal behavior; cover; sites for breeding, reproduction, and rearing of offspring; and habitats protected from disturbance or are representative of the historical geographical and ecological distribution of the species.

Central Valley spring-run Chinook salmon habitats are also protected under the Magnuson-Stevens Fishery Conservation and Management Act as Essential Fish Habitat (EFH). Those waters and substrate necessary to spring-run Chinook salmon for spawning, breeding, feeding, or growth to maturity are included as EFH and are presented in Figure A-3e. Critical Habitat and EFH are managed differently from a regulatory standpoint, but are biologically equal for the conservation of Central Valley spring-run Chinook salmon.

The Primary Constituent Elements (PCEs) considered essential for conservation are: (1) freshwater spawning sites, (2) freshwater rearing sites, (3) freshwater migration corridors, (4) estuarine rearing and migration areas, (5) nearshore marine areas, and (6) offshore marine areas.

A3.3.1 Freshwater Spawning Habitat

Freshwater spawning sites are those stream reaches with water quantity (instream flows) and quality conditions (e.g., water temperature and dissolved oxygen) and substrate suitable to support spawning, egg incubation, and larval development. Most spawning habitat in the Central Valley for spring-run Chinook salmon is located in areas directly downstream of dams containing suitable environmental conditions for spawning and incubation. Historically, spring-run Chinook salmon migrated upstream into high elevation steep gradient reaches of the rivers and tributaries for spawning. Access to the majority of these historical spawning areas has been blocked by construction of major Central Valley dams and reservoirs. Currently, Central Valley spring-run Chinook salmon spawn on the mainstem Sacramento River between the Red Bluff Diversion Dam (RBDD) and Keswick Dam, and in tributaries such as the Feather River and Mill, Deer, and Butte creeks. There is currently an effort underway to re-establish a self-sustaining population of spring-run Chinook salmon on the San Joaquin River downstream of Friant Dam. Spawning habitat has a high conservation value as its function directly affects the spawning success and reproductive potential of listed salmonids.

A3.3.2 Freshwater Rearing Habitat

Freshwater rearing sites are those with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; suitable water quality; availability of suitable prey and forage to support juvenile growth and development; and natural cover such as shade, submerged and overhanging large wood, log jams, beaver dams, aquatic vegetation, large woody debris, rocks and boulders, side channels, and undercut banks. Both spawning areas and migratory corridors comprise rearing habitat for juveniles, which feed and grow before and during their outmigration.

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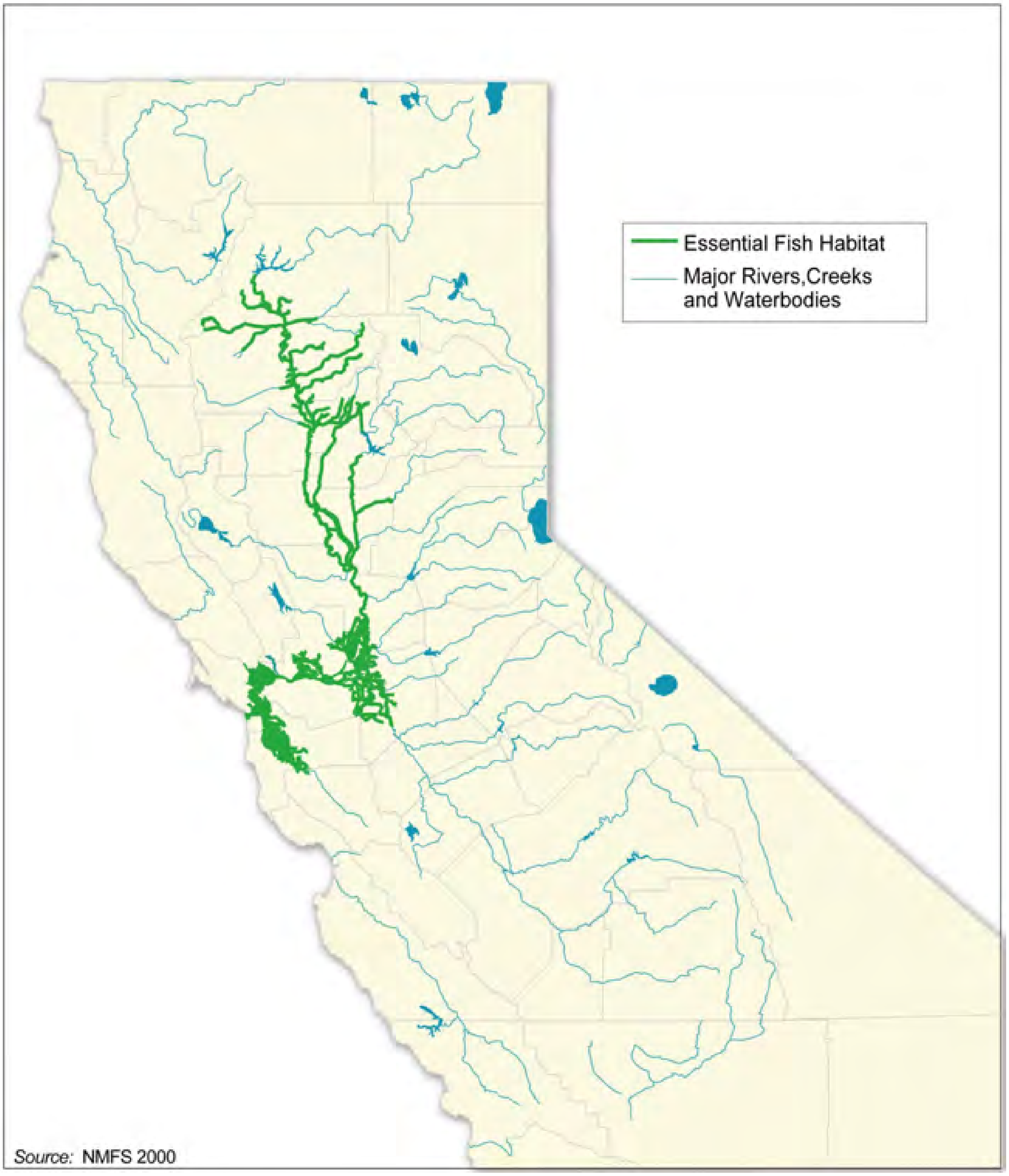

Figure A-3e. Central Valley Spring-Run Chinook Salmon Inland Essential Fish Habitat in California

Non-natal, intermittent tributaries are also used for juvenile rearing. Rearing habitat condition is strongly affected by habitat diversity and complexity, food supply, and presence of predators. Some of these more complex, productive habitats with floodplain connectivity are still present in limited amounts within the Central Valley (e.g., the lower Cosumnes River, Sacramento River reaches with set-back levees [i.e., primarily located upstream of the City of Colusa]). However, the channeled, leveed, and riprapped river reaches and sloughs that are common along the Sacramento and San Joaquin rivers and throughout the Delta typically have low habitat complexity, low abundance of food organisms, and offer little protection from predatory fish and birds. Freshwater rearing habitat also has a high conservation value, as the juvenile life stage of salmonids is dependent on the function of this habitat for successful survival and recruitment to the adult population.

A3.3.3 Freshwater Migration Corridors

Freshwater migration corridors for spring-run Chinook salmon, including river channels, channels through the Delta, and the Bay-Delta estuary, support mobility, survival, and food supplies for juveniles and adults. Migration corridors should be free from obstructions (passage barriers and impediments to migration), have favorable water quantity (instream flows) and quality conditions (seasonal water temperatures), and contain natural cover such as submerged and overhanging large wood, native aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Migratory corridors for spring-run Chinook salmon are located downstream of the spawning areas and include the lower Sacramento River, lower Feather River, tributaries providing suitable adult holding and spawning habitat, the Delta, and the San Francisco Bay complex extending to coastal marine waters. Efforts are currently underway to re-establish a spring-run salmon population on the San Joaquin River downstream of Friant Dam that would use the lower river and Delta as part of the migration corridor. These corridors allow the upstream passage of adults and the downstream emigration of juvenile salmon. Migratory corridor conditions are strongly affected by the presence of passage barriers, which can include dams, unscreened or poorly screened diversions, and degraded water quality. For freshwater migration corridors to function properly, they must provide adequate passage, provide suitable migration cues, reduce false attraction, avoid areas where vulnerability to predation is increased, and avoid impediments and delays in both upstream and downstream migration. For this reason, freshwater migration corridors are considered to have a high conservation value.

Results of mark-recapture studies conducted using juvenile Chinook salmon (typically fall-run or late fall-run Chinook salmon, which are considered to be representative of juvenile spring-run salmon) released into both the Sacramento and San Joaquin rivers have shown high mortality during passage downstream through the rivers and Delta (Brandes and McLain 2001, Newman and Rice 2002, Manly 2004, San Joaquin River Group Authority 2007, Hanson 2008, Low and White undated). Mortality for juvenile salmon is typically greater in the San Joaquin River than in the Sacramento River (Brandes and McLain 2001). In both rivers, mortality is typically greater in years when spring flows are reduced and water temperatures are increased. Results of survival studies have shown that closing the Delta Cross Channel gates and installation of the Head of Old River Barrier to reduce the movement of juvenile salmon into the Delta contribute to improved survival of emigrating juvenile Chinook salmon (Brandes and McLain 2001, Manly 2004, San Joaquin River Group Authority 2010, Low and White undated). Observations at the State Water Project (SWP) and Central Valley Project (CVP) fish salvage facilities have shown that very few of the marked salmon (typically fewer than 1 percent) are entrained and salvaged at the export facilities (San Joaquin River Group Authority 2007, Hanson 2008, California Department of Water Resources [DWR] and U.S. Bureau of Reclamation [USBR] unpubl. data). Although the factors contributing to high juvenile mortality have not been quantified, results of acoustic tagging experiments and anecdotal observations suggest that exposure to adverse water quality conditions (e.g., elevated water temperatures, toxic chemicals) and vulnerability to predation are two of the factors contributing to the high juvenile mortality observed in the rivers and Delta (San Joaquin River Group Authority 2007). Additional acoustic tagging experiments are currently underway to better assess factors affecting migration pathways, migration rates, effects of SWP and CVP exports on migration, and reach-specific survival rates for emigrating juvenile Chinook salmon (Lindley et al. 2008, MacFarlane et al. 2008a, Michel et al. 2008, Perry et al. 2008).

A3.3.4 Estuarine Areas

Estuarine migration and juvenile rearing habitats should be free of obstructions (i.e., dams and other barriers) and provide suitable water quality, water quantity (river and tidal flows), and salinity conditions to support juvenile and adult physiological transitions between fresh and salt water. Natural cover, such as submerged and overhanging large wood, native aquatic vegetation, and side channels, provide juvenile foraging habitat and cover from predators. Tidal wetlands and seasonally inundated floodplains have also been identified as high value foraging and rearing habitats for juvenile salmon migrating downstream through the estuary. Estuarine areas contain a high conservation value as they function to support juvenile Chinook salmon growth, smolting, avoidance of predators, and provide a transition to the ocean environment.

A3.3.5 Ocean Habitats

Although ocean habitats are not part of the critical habitat listing for Central Valley spring-run Chinook salmon, biologically productive coastal waters are an important habitat component for the ESU. Juvenile Chinook salmon inhabit near-shore coastal marine waters for a period of typically two to four years before adults return to Central Valley rivers to spawn. During their marine residence Chinook salmon forage on krill, squid, and other marine invertebrates as well as a variety of fish such as northern anchovy and Pacific herring. These features are essential for conservation because, without them, juveniles cannot forage and grow to adulthood.

Results of oceanographic studies have shown the variation in ocean productivity off the West Coast within and among years. Changes in ocean currents and upwelling have been identified as significant factors affecting nutrient availability, phytoplankton and zooplankton production and the availability of other forage species in near-shore surface waters. Ocean conditions during the salmon's ocean residency period can be important, as indicated by the effect of the 1983 El Niño on the size and fecundity of Central Valley fall-run Chinook salmon (Wells et al. 2006). Although the effects of ocean conditions on Chinook salmon growth and survival have not been investigated extensively, recent observations since 2007 have shown a significant decline in the abundance of adult Chinook salmon and coho salmon returning to California rivers and streams (fall-run adult returns to the Sacramento and San Joaquin rivers were the lowest on record; Pacific Fishery Management Council 2008) that is thought to be the result of declines in ocean productivity and associated high mortality rates during the period when these fish were rearing in near-shore coastal waters (MacFarlane et al. 2008b). The importance of changes in ocean conditions on growth, survival, and population abundance of Central Valley Chinook salmon is currently undergoing further investigation.

A3.4 LIFE HISTORY

Chinook salmon typically mature between two and six years of age (Myers et al. 1998). Freshwater entry and spawning timing generally are thought to be related to local water temperature and flow regimes. Runs are designated on the basis of adult migration timing; however, distinct runs also differ in the degree of maturation at the time of river entry, thermal regime and flow characteristics of their spawning site, and the actual time of spawning (Myers et al. 1998). Spring-run Chinook salmon tend to enter freshwater as immature fish, migrate far upriver, hold in cool water pools for a period of months during the spring and summer, and delay spawning until the early fall.

Information on the migration rates of Central Valley spring-run Chinook salmon in freshwater is scant, but a general description of migration rates can be found in Appendix A4, *Central Valley fall-/late fall-run Chinook salmon.*

Adult Central Valley spring-run Chinook salmon begin their upstream migration in late January and early February (DFG 1998) and enter the Sacramento River between March and September, primarily in May and June (Table A-3a) (Yoshiyama et al. 1998, Moyle 2002). Lindley et al. (2006) reported that adult Central Valley spring-run Chinook salmon enter native tributaries from the Sacramento River primarily between mid-April and mid-June. Typically, spring-run Chinook salmon utilize mid- to high-elevation streams that provide appropriate seasonal water temperatures and sufficient flow, cover, and pool depth to allow over-summering while conserving energy and allowing their gonadal tissue to mature (Yoshiyama et al. 1998).

Chinook salmon spawn in clean, loose gravel in swift, relatively shallow riffles or along the margins of deeper reaches where suitable water temperature, depth, and velocity favor redd construction and adequate oxygenation of incubating eggs. Chinook salmon spawning typically occurs in gravel beds located at the tails of holding pools (U.S. Fish and Wildlife Service [USFWS] 1995). Fry emergence generally occurs at night. Upon emergence, fry swim or are displaced downstream (Healey 1991). The daily migration of juvenile spring-run Chinook salmon passing RBDD is highest in the four hour period prior to sunrise (Martin et al. 2001).

Table A-3a. Temporal Occurrence of (a) Adult and (b) Juvenile Central Valley Spring-Run Chinook Salmon in the Sacramento River. Darker shades indicate months of greatest relative abundance.

(a) Adult

Location	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
[1,2]Sac. River basin			M, M	M, M	H, H	H, H	M, M	M, M	M, M			
[3]Sac. River			M, M	M, M	M, M	M, M	M, M					
[4]Mill Creek			L, L	M, H	H, H	H, M	M, L	L, –				
[4]Deer Creek			L, L	M, H	H, H	H, M	M, –					
[4]Butte Creek		M, M	M, M	M, M	M, M	M, M	M, M					

(b) Juvenile

Location	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
[5]Sac. River Tribs	M, M	M, M	M, M							M, M	H, H	H, H
[6]Upper Butte Creek	H, H	H, H	M, M	M, M	M, M	L, L				L, L	L, L	H, H
[4]Mill, Deer, Butte creeks	H, H	H, H	M, M	M, M	M, M	L, L				L, L	L, L	L, L
[3]Sac. River at RBDD	H, H	L, L	L, L	L, L							H, H	H, H
[7]Sac. River at KL	H, H	L, L	L, L	L, L							H, H	H, H
[8*]Chipps Island (trawl)	H, H	L, L	L, L	L, L							H, H	H, H
Relative Abundance:	H = High				M = Medium				L = Low			

* By the time spring-run Chinook salmon yearlings reach Chipps Island they cannot be distinguished with confidence from fall-run Chinook salmon yearlings.

Sources: [1]Yoshiyama et al. 1998; [2]Moyle 2002; [3]Myers et al. 1998; [4]Lindley et al. 2006; [5]DFG 1998; [6]McReynolds et al. 2005; Ward et al. 2002, 2003; [7]Snider and Titus 2000,[8]USFWS 2001

Fry may continue downstream to the estuary and rear, or may take up residence in the stream for a period from weeks to a year (Healey 1991). Fry seek streamside habitats containing beneficial characteristics such as riparian vegetation and associated substrates that provide aquatic and terrestrial invertebrates, predator avoidance cover, and slower water velocities for resting (NMFS 1996).

Spring-run Chinook salmon fry emerge from the gravel from November to March (Moyle 2002) and the emigration timing is highly variable, as they may migrate downstream as young-of-the year or as juveniles or yearlings. The modal size of fry migrants at approximately 40 mm between December and April in Mill, Butte, and Deer creeks reflects a prolonged emergence of fry from the gravel (Lindley et al. 2006). Studies in Butte Creek found that the majority of Central Valley spring-run Chinook salmon migrants are fry occurring primarily during December, January, and February, and that fry movements appeared to be influenced by flow (Ward et al. 2002, 2003, McReynolds et al. 2005). Small numbers of Central Valley spring-run Chinook salmon remained in Butte Creek to rear and migrated as yearlings later in the spring. Juvenile emigration patterns in Mill and Deer creeks are very similar to patterns observed in Butte Creek, with the exception that juveniles from Mill and Deer creeks typically exhibit a later young-of-the year migration and an earlier yearling migration (Lindley et al. 2006).

Once juveniles emerge from the gravel they initially seek areas of shallow water and low velocities while they finish absorbing the yolk sac (Moyle 2002). Many also disperse downstream during high-flow events. As is the case with other salmonids, there is a shift in microhabitat use by juveniles to deeper faster water as they grow. Microhabitat use can be influenced by the presence of predators, which can force juvenile salmon to select areas of heavy cover and suppress foraging in open areas (Moyle 2002). Peak movement of juvenile Central Valley spring-run Chinook salmon in the Sacramento River at Knights Landing occurs in December, and again in March and April; however, juveniles were also observed between November and the end of May (Snider and Titus 2000).

As juvenile Chinook salmon grow, they move into deeper water with higher current velocities, but still seek shelter and velocity refugia to minimize energy expenditures (Healey 1991). Catches of juvenile salmon in the Sacramento River near West Sacramento by the USFWS (1997) showed that larger juvenile salmon were captured in the main channel and smaller sized fry were typically captured along the channel margins. When the channel of the river is greater than 9 to 10 feet in depth, juvenile salmon tend to inhabit surface waters (Healey 1980). Stream flow changes and/or turbidity increases in the upper Sacramento River watershed are thought to stimulate juvenile emigration (Kjelson et al. 1982, Brandes and McLain 2001).

Within the Delta, juvenile Chinook salmon forage in shallow areas with protective cover, such as tidally influenced sandy beaches and shallow water areas with emergent aquatic vegetation (Meyer 1979, Healey 1980). Cladocerans, copepods, amphipods, and larval dipterans, as well as small arachnids and ants are common prey items (Kjelson et al. 1982, Sommer et al. 2001a, MacFarlane and Norton 2002). Though the bulk of production in Butte and Big Chico creeks emigrate as fry, yearlings can enter the Delta as early as February and as late as June (DFG 1998). Yearling-sized spring-run Chinook salmon migrants appear at Chipps Island (entrance to Suisun Bay) between October and December (Brandes and McLain 2001, USFWS 2001). It has been hypothesized that changes in habitat conditions within the Delta over the past century may have resulted in a reduction in extended juvenile salmon rearing when compared to periods when habitat for juvenile salmon rearing was more suitable.

Central Valley spring-run Chinook salmon begin their ocean life in the coastal marine waters of the Gulf of the Farallones. Upon reaching the ocean, juveniles feed on larval and juvenile fishes, plankton, and terrestrial insects (Healey 1991, MacFarlane and Norton 2002). Juveniles grow rapidly in the ocean environment with growth rates dependent on water temperatures and food availability (Healey 1991). The first year of ocean life is considered a critical period of high mortality for Chinook salmon that largely determines survival to harvest or spawning (Beamish and Mahnken 2001, Quinn 2005).

A3.5 THREATS AND STRESSORS

The following have been identified as important threats and stressors to spring-run Chinook salmon (without priority).

Reduced staging and spawning habitat. Access to most of the historical upstream spawning habitat for spring-run Chinook salmon (see Figure A-3a) has been eliminated or degraded by man-made structures (e.g., dams and weirs) associated with water storage and conveyance, flood control, and diversions and exports for municipal, industrial, agricultural, and hydropower purposes (Yoshiyama et al. 1998). Current spawning and juvenile rearing habitat is restricted to the mainstem and a few tributaries to the Sacramento River. Suitable summer water temperatures for adult and juvenile spring-run Chinook salmon holding and rearing are thought to occur at elevations over 492-1,640 feet (150-500 m), most of which are now blocked by impassible dams. Habitat loss has resulted in a reduction in the number of natural spawning populations from an estimated 17 to 3 (Good et al. 2005).

Upstream diversions and dams have decreased downstream flows and altered the seasonal hydrologic patterns. These factors have been identified as resulting in delayed upstream migration by adults, increased mortality of out-migrating juveniles, and are responsible for making some streams uninhabitable by spring-run salmon (Yoshiyama et al. 1998, DWR 2005). Dams and reservoir impoundments and associated reductions in peak flows have blocked gravel recruitment and reduced flushing of sediments from existing gravel beds, thereby reducing and degrading natal spawning grounds. Further, reduced flows may decrease attraction cues for adult spawners, causing migration delays and increases in straying (DWR 2005). Adult salmon migration delays can reduce fecundity and increase susceptibility to disease and harvest (McCullough 1999).

Dams and other passage barriers also limit the geographic locations where spring-run Chinook salmon can spawn. Within areas such as the Sacramento and Feather rivers, restrictions to upstream movement and spawning site selection for spring-run salmon may increase the risk of hybridization with fall-run salmon, as co-occurrence contributes to an increased risk of redd superimposition. In creeks that are not affected by dams, such as Deer and Mill creeks, adult spring-run Chinook salmon have a greater opportunity to migrate upstream into areas where geographic separation from fall-run salmon reduces the risk of hybridization.

The RBDD located on the Sacramento River has been identified as a barrier and impediment to adult spring-run Chinook salmon upstream migration. Although the RBDD is equipped with fish ladders, migration delays were reported when the dam gates are closed. Mortality from increased predation by Sacramento pikeminnow on juvenile salmon passing downstream through the fish ladder also affects abundance of salmon produced on the Sacramento River (Hallock 1991). To help reduce the effects of dam operation on migration of adult and juvenile salmonids and other species, management changes have occurred in recent years to maintain the dam gates in the open position for a longer period of time and thereby facilitate greater upstream and downstream migration. Changes in dam operations have benefited both upstream and downstream migration of salmon and have contributed to a reduction in juvenile predation mortality.

Reduced rearing and out-migration habitat. Juvenile spring-run Chinook salmon prefer natural stream banks, floodplains, marshes, and shallow water habitats to utilize as rearing habitat during out-migration. Channel margins throughout the Delta have been leveed, channelized, and fortified with riprap for flood protection and island reclamation, reducing and degrading the quality of natural habitat available for juvenile Chinook salmon rearing (Brandes and McLain 2001). Man-made barriers further reduce and degrade rearing and migration habitat and delay juvenile out-migration. Juvenile out-migration delays can reduce fitness and increase susceptibility to diversion screen impingement, entrainment, disease, and predation. Modification of natural flow regimes from upstream reservoir operations has resulted in dampening and altering the seasonal timing of the hydrograph, reducing the extent and duration of seasonal floodplain inundation and other flow-dependent habitat used by migrating juvenile Chinook salmon (70 FR 52488, Sommer et al. 2001a, DWR 2005). Recovery of floodplain habitat in the Central Valley has been found to contribute to increases in production in Chinook salmon (Sommer et al. 2001b), but little is known about the potential benefit available to migrating spring-run. Reductions in flow rates have resulted in increased seasonal water temperature. The potential adverse effects of dam operations and reductions in seasonal river flows, delays in juvenile emigration, exposure to a higher proportion of agricultural return flows, and exposure to reduced dissolved oxygen concentrations (e.g., Stockton Deep Water Ship Channel) have all been identified as factors that could affect the survival and success of re-establishing spring-run Chinook salmon on the San Joaquin River in the future (Regional Water Resources Control Board 2003).

Predation by non-native species. Predation on juvenile salmon by non-native fish has been identified as an important threat to spring-run Chinook salmon in areas with high densities of non-native fish (e.g., small and large mouth bass, striped bass, and catfish) that prey on out-migrating juveniles (Lindley and Mohr 2003). Non-native aquatic vegetation, such as Brazilian waterweed and water hyacinth, provide suitable habitat for non-native predators (Nobriga et al. 2005, Brown and Michniuk 2007). Predation risk may covary with increased temperatures. Metabolic rates of non-native, predatory fish increase with increasing water temperatures based on bioenergetic studies (Loboschefsky et al. 2009, Miranda et al. 2010). The low spatial complexity and reduced habitat diversity (e.g., lack of cover) of channelized waterways within the rivers and Delta reduces refuge space of salmon from predators (Raleigh et al. 1984, Missildine et al. 2001, DWR 2005, 70 FR 52488). A major concern among managers is the potential invasion of the Delta by the highly predatory northern pike. The pike, recently present in Lake Davis on the Feather River, was the target of a major eradication effort (DFG 2007a). If pike escape downstream to the Delta, they would likely be present in areas inhabited by spring-run Chinook salmon.

Increased predation mortality by native fish species, such as Sacramento pikeminnow at the RBDD, has also been identified as a factor affecting the survival of juvenile salmon within the rivers and Delta.

Harvest. Commercial and recreational harvest of spring-run Chinook salmon in the ocean and inland fisheries has been a subject of management actions by the California Fish and Game Commission and Pacific Fishery Management Council. The primary concerns focus on the effects of harvest on wild Chinook salmon produced in the Central Valley as well as the incidental harvest of listed salmon as part of the fall-run and late fall-run salmon fisheries. Naturally reproducing spring-run Chinook salmon are less able to withstand high harvest rates when compared to hatchery-based stocks. Due to reduced survivorship in incubating eggs and rearing and emigrating individuals wild salmon relative to hatchery-reared individuals, naturally reproducing populations are less able to withstand high harvest rates compared to hatchery based stocks (Knudsen et al. 1999). Because of recent changes in fishing regulations and restrictions on harvest, commercial and recreational fishing does not appear to have a significant impact on spring-run Chinook salmon populations, but continued assessment is warranted. Commercial fishing for salmon in West Coast ocean waters is managed by the Pacific Fishery Management Council, and is constrained by time and area closures to meet the Sacramento River winter-run ESA consultation standard and restrictions requiring minimum size limits and use of circle hooks for anglers. Ocean harvest restrictions since 1995 have led to reduced ocean harvest of spring-run Chinook salmon (i.e., Central Valley Chinook salmon ocean harvest index, ranged from 0.55 to nearly 0.80 from 1970 to 1995, and was reduced to 0.27 in 2001). DFG, NMFS, and Pacific Fishery Management Council are continuing to monitor and assess the effects of harvest of spring-run Chinook salmon, such that regulations can be refined and modified as new information becomes available.

Because adult spring-run Chinook salmon hold in pool habitat within a stream during the summer months they are vulnerable to illegal harvest (poaching). Various watershed groups have established public outreach and educational programs in an effort to reduce poaching. In addition, DFG wardens have increase enforcement against illegal harvest of spring-run Chinook salmon. The level and effect of illegal harvest on adult spring-run Chinook salmon abundance and population reproduction is unknown.

Reduced genetic diversity/integrity. Interbreeding of wild spring-run Chinook salmon with both wild and hatchery fall-run Chinook salmon has the potential to dilute and eventually eliminate the adaptive genetic distinctiveness and diversity of the few remaining naturally reproducing spring-run Chinook salmon populations (DFG 1995, Sommer et al. 2001b, Araki et al. 2007). Central Valley spring- and fall-run Chinook salmon spawning areas were historically isolated in time and space (Yoshiyama et al. 1998). However, the construction of dams has eliminated access to historical upstream spawning areas of spring-run salmon in the upper tributaries and streams of many river systems. Restrictions to upstream access, particularly on the Sacramento and Feather rivers has forced spring-run individuals to spawn in lower elevation areas also used by fall-run individuals, potentially resulting in hybridization of the two races. Hybridization between spring- and fall-run salmon has been identified as a particular concern on the Feather River where both runs co-occur and as a potential concern for restoration of salmon on the San Joaquin River downstream of Friant Dam. Management of the Feather River hatchery and brood stock selection practices have been modified in recent years (e.g., tagging early returning adult salmon showing phenotypic and run timing characteristics of spring-run Chinook salmon for subsequent use as selected brood stock and genetic testing of potential brood stock) in an effort to reduce potential hybridization as a result of hatchery operations. Consideration has also been given to using a physical weir to help segregate and isolate adults showing spring-run characteristics and later arriving fish showing characteristics of fall-run fish to reduce the risk of hybridization and redd superimposition within spawning areas of the river.

Investigations have been undertaken to assess the potential habitat quality and availability for spring-run Chinook salmon spawning and juvenile rearing within the reaches of the Feather River upstream of Oroville Dam that could potentially be used to expand the geographic range of spring-run salmon using trap and haul techniques. On many of the other Central Valley tributaries, such as Deer and Mill creeks, the risk of hybridization is reduced by the ability of the runs to segregate geographically within the watersheds.

Further, in an effort to improve juvenile survival and the contribution of the Feather River Hatchery to the adult spring-run Chinook salmon population, the spring-run salmon program at the hatchery has released juvenile spring-run salmon far downstream of the hatchery (San Pablo Bay) in the past, which has increased the rate of straying adults migrating back upstream (DFG 2001). Recent changes in hatchery management by DFG, however, have modified juvenile planting with a greater number of juvenile fish released into the Feather River in an effort to improve imprinting and reduce straying, which may reduce potential for hybridization with spring-run salmon in other watersheds (McReynolds et al. 2006). Half of the juvenile spring-run Chinook salmon produced at the hatchery are now released in the Feather River at Live Oak as part of an experimental program designed to improve hatchery management.

Entrainment. The vulnerability of juvenile spring-run Chinook salmon to entrainment and salvage at the SWP and CVP export facilities varies in response to multiple factors, including the seasonal and geographic distribution of juvenile salmon within the Delta, operation of Delta Cross Channel gates, hydrodynamic conditions occurring within the central and southern regions of the Delta (e.g., Old and Middle rivers), and export rates. The losses of fish to entrainment mortality has been identified as an impact to Chinook salmon populations (Kjelson and Brandes 1989). Juvenile spring-run Chinook salmon tend to be distributed within the central and southern Delta where they have an increased risk of entrainment/salvage between February and May (see Table A.-3a). The effect of changing hydrodynamics within Delta channels, such as reversed flows in Old and Middle rivers resulting from SWP and CVP export operations, has the potential to increase attraction of emigrating juveniles into false migration pathways, delay emigration through the Delta, directly or indirectly increase vulnerability to entrainment at unscreened diversions, increase the risk of predation, increase movement of migrating salmon toward the export facilities, increase the risk that these fish will be entrained into the fish salvage facilities, and increase the duration of exposure to seasonally-elevated water temperatures and other depressed water quality conditions. SWP and CVP exports have been shown to affect the tidal hydrodynamics (e.g., water current velocities and direction), and the magnitude of these effects varies in response to a variety of factors, including tidal stage and magnitude of ebb and flood tides, the rate of SWP and CVP exports, operation of the Clifton Court Forebay radial gate opening, and inflow from the upstream tributaries. Chinook salmon behaviorally respond to hydraulic cues (e.g., water currents) during both upstream adult and downstream juvenile migration through the Delta. Over the past several years additional investigations have been designed using radio or acoustically-tagged juvenile Chinook salmon to monitor their migration behavior through the Delta channels and to assess the effects of changes in hydraulic cues and SWP and CVP export operations on migration. These studies are continuing (San Joaquin River

Group Authority 2007, Brandes et al. 2008, Lindley et al. 2008, MacFarlane et al. 2008a, Michel et al. 2008, North Delta Hydrodynamic and Juvenile Salmon Migration Study 2008, Perry et al. 2008).

In addition to SWP and CVP exports, over 2,200 small water diversions exist throughout the Delta, in addition to unscreened diversions located on the tributary rivers (Herren and Kawasaki 2001). The risk of entrainment is a function of the size of juvenile fish and the slot opening of the screen mesh (Tomljanovich et al. 1978, Schneeberger and Jude 1981, Zeitoun et al. 1981, Weisberg et al. 1987, C. Hanson unpubl. data). Many of the juvenile salmon migrate downstream through the Delta during the late winter or early spring when many of the agricultural irrigation diversions are not operating or are only operating at low levels. Juvenile salmon also migrate primarily in the upper part of the water column and therefore their vulnerability to an unscreened diversion located near the channel bottom is reduced. No quantitative estimates have been developed to assess the potential magnitude of entrainment losses for juvenile Chinook salmon migrating through the rivers and Delta, and the effects of these losses on the overall population abundance of returning adult Chinook salmon is unknown. Many of the larger water diversions located within the Central Valley and Delta (e.g., Glenn Colusa Irrigation District, Reclamation District 108 Wilkins Slough, Poundstone, and Sutter Mutual Water Company Tisdale pumping plants, Contra Costa Water District Old River and Alternative Intake Project, and others) have been equipped with positive barrier fish screens to reduce and avoid the loss of juvenile Chinook salmon and other fish species.

Power plants within the Plan Area have the ability to impinge juvenile Chinook salmon on the existing cooling water system intake screens. However, use of cooling water is currently low with the retirement of older units. Further, newer units are being equipped with a closed cycle cooling system that virtually eliminates the risk of impingement of juvenile salmon.

Besides direct mortality, salmon fitness may be affected by entrainment at these diversions and delays in out-migration of smolts caused by reduced or reverse flows. Delays in migration due to water management related to the SWP and CVP operations can make juvenile salmonids more susceptible to many of the threats and stressors discussed in this section, such as predation, entrainment, angling, exposure to poor water quality and toxics, and disease. The quantitative relationships among changes in Delta hydrodynamics, the behavioral and physiological response of juvenile salmon, and the increase or decrease in risk associated with other threats are unknown, but currently the subject of a number of investigations and analyses.

Exposure to toxins. Toxic chemicals have the potential to be widespread throughout the Delta, or may occur on a more localized scale in response to episodic events (i.e., stormwater runoff, point source discharges, etc.). These toxic substances include mercury, selenium, copper, pyrethroids, and endocrine disruptors with the potential to impact fish health and condition, and adversely impact salmon distribution and abundance. Concern regarding exposure to toxic substances for Chinook salmon includes both waterborne chronic and acute exposure, but also bioaccumulation and chronic dietary exposure. For example, selenium is a naturally occurring constituent in agricultural drainage water return flows from the San Joaquin River that is then dispersed downstream into the Delta (Nichols et al. 1986). Exposure to selenium in the diet of juvenile Chinook salmon has been shown to result in toxic effects (Saiki 1986, Saiki and Lowe 1987, Hamilton et al. 1986, 1990, Hamilton and Buhl 1990). Selenium exposure has been associated with agricultural and natural drainage within the San Joaquin River basin and refining operations adjacent to San Pablo and San Francisco bays. Other contaminants of concern for Chinook salmon include, but are not limited to, mercury, copper, oil and grease, pesticides, herbicides, ammonia, and localized areas of depressed dissolved oxygen (e.g., Stockton Deep Water Ship Channel, return flows from managed freshwater wetlands, etc.). As a result of the extensive agricultural development within the Central Valley exposure to pesticides and herbicides has been identified as a significant concern for salmon and other fish species within the Plan Area (Bennett et al. 2001). In recent years changes have been made in the composition of herbicides and pesticides used on agricultural crops in an effort to reduce potential toxicity to aquatic and terrestrial species. Modifications have also been made to water system operations and discharges related to agricultural wastewater discharges (e.g., agricultural drainage water system lock-up and holding prior to discharge) and municipal wastewater treatment and discharges. Concerns remain, however, regarding the toxicity of contaminants such as pyrethroids that adsorbed to sediments and other chemicals (e.g., including selenium and mercury, as well as other contaminants) on salmon.

Mercury and other metals such as copper have also been identified as contaminants of concern for salmon and other fish as a result of direct toxicity and impacts such as those related to acid mine runoff from sites such as Iron Mountain Mine (U.S. Environmental Protection Agency [EPA] 2006). There are problems with tissue bioaccumulation that may adversely impact the fish, but also represents a human health concern (Gassel et al. 2008). These materials originate from a variety of sources including mining operations, municipal wastewater treatment, agricultural drainage within the tributary rivers and Delta, non-point runoff, natural runoff and drainage within the Central Valley, agricultural spraying, and a number of other sources. The State Water Resources Control Board (SWRCB), Central Valley Regional Water Quality Control Board (CVRWQCB), U.S. EPA, U.S. Geological Survey (USGS), DWR, and others have ongoing monitoring programs designed to characterize water quality conditions and identify potential toxicants and contaminant exposure to Chinook salmon and other aquatic resources within the Plan Area. Programs are in place to regulate point source discharges as part of the National Pollutant Discharge Elimination System (NPDES) program as well as efforts to establish and reduce total daily maximum loads (TMDL) of various constituents entering the Delta. Changes in regulations have also been made to help reduce chemical exposure and reduce the adverse impacts to aquatic resources and habitat conditions within the Plan Area. These monitoring and regulatory programs are ongoing.

Sublethal concentrations of toxics may interact with other stressors on salmonids, such as increasing their vulnerability to mortality as a result of exposure to seasonally elevated water temperatures, predation, or disease (Werner 2007). For example, Clifford et al. (2005) found in a laboratory setting that juvenile fall-run Chinook salmon exposed to sublethal levels of a common pyrethroid, esfenvalerate, were more susceptible to infectious hematopoietic necrosis virus than those not exposed to esfenvalerate. Although not tested on spring-run Chinook salmon, a similar response is likely due to the physiological similarity.

Iron Mountain Mine, located adjacent to the upper Sacramento River, has been a source of trace elements and metals that are known to adversely affect aquatic organisms (Upper Sacramento River Fisheries and Riparian Habitat Advisory Council 1989). Storage limitations and limited availability of dilution flows have caused downstream copper and zinc levels to exceed salmonid tolerances and resulted in documented fish kills in the 1960s and 1970s (USBR 2004). The Environmental Protection Agency's Iron Mountain Mine remediation program has removed toxic metals in acidic mine drainage from the Spring Creek watershed with a state-of-the-art lime neutralization plant. Contaminant loading into the Sacramento River from Iron Mountain Mine has shown measurable reductions since the early 1990s.

Increased water temperature. Water temperature is among the physical factors that affect quality of habitat for salmonid adult holding, spawning and egg incubation, juvenile rearing, and migration. Adverse sublethal and lethal effects can result from exposure to elevated water temperatures at sensitive lifestages, such as during incubation or rearing. The Central Valley is the southern limit of spring-run Chinook salmon geographic distribution, so increased water temperatures are often recognized as an important stressor to California populations. Water temperature criteria for various lifestages of salmonids in the Central Valley have been developed by NMFS (2009). The tolerance of spring-run Chinook salmon to water temperatures depends on life stage, acclimation history, food availability, duration of exposure, health of the individual, and other factors such as predator avoidance (Myrick and Cech 2004, USBR 2004). Higher water temperatures can lead to physiological stress, reduced growth rate, pre-spawning mortality, reduced spawning success, and increased mortality of salmon (Myrick and Cech 2001). Temperature can also indirectly influence disease incidence and predation (Waples et al. 2008). Exposure to seasonally elevated water temperatures may occur as a result of reductions in flow, upstream reservoir operations, reductions in riparian vegetation, channel shading, local climate and solar radiation. The installation of the Shasta Temperature Control Device in 1998, in combination with reservoir management to maintain the cold water pool, has reduced many of the temperature issues on the Sacramento River. During dry years, however, the release of cold water from Shasta Dam is still limited. As the river flows further downstream, particularly during the warm spring, summer, and early fall months, water temperatures continue to increase until they reach thermal equilibrium with atmospheric conditions. As a result of the longitudinal gradient of seasonal water temperatures, the coldest temperatures and best areas for salmon spawning and rearing are typically located immediately downstream of the dam.

Increased temperature can also arise from a reduction in shade over rivers by tree removal (Watanabe et al. 2005). Because river water is typically in thermal equilibrium with atmospheric conditions by the time it enters the Delta, this issue is caused primarily from actions upstream of the Delta. As a result of the relatively wide channels that occur within the Delta, the effects of additional riparian vegetation on reducing water temperatures are minimal.

Adult and juvenile spring-run Chinook salmon hold and rear within pools at higher elevations within the watershed. On several tributaries, pre-spawning adult mortality has been reported for adults that accumulate in high densities within a pool and are then exposed to elevated summer water temperatures. Flow reductions, resulting from natural hydrologic conditions during the summer, evapotranspiration, or surface and groundwater extractions may all contribute to exposure to elevated temperatures and increased levels of stress or mortality. In some areas groundwater wells have been used to pump cooler water into the stream to reduce oversummer temperatures. Dense riparian vegetation, streams incised into canyons that provide shading, cool water springs, and availability of deep holding pools are factors that affect summer holding and rearing conditions for spring-run Chinook salmon.

The effects of climate change and global warming patterns, in combination with changes in precipitation and seasonal hydrology in the future have been identified as important factors that may adversely affect the health and long-term viability of Central Valley spring-run Chinook salmon (Crozier et al. 2008). The rate and magnitude of these potential future environmental changes, and their effect of habitat quality and availability for spring-run Chinook salmon, however, are subject to a high degree of uncertainty.

A3.6 Relevant Conservation Efforts

Results of salvage monitoring and extensive experimentation over the past several decades have lead to the identification of a large number of management actions designed to reduce or avoid the potentially adverse impacts of SWP and CVP export operations on salmon. Many of these actions have been implemented through SWRCB water quality permits (D-1485, D-1641), biological opinions issued on project export operations by NMFS, USFWS, and DFG, as part of CALFED programs (e.g., Environmental Water Account [EWA]), and as part of actions associated with Central Valley Project Improvement Act (CVPIA). As a result of these requirements multiple conservation efforts exist to enhance habitat and reduce entrainment of Chinook salmon by the SWP and CVP export facilities.

Several habitat problems that contributed to the decline of Central Valley salmonid species are being addressed and improved through restoration and conservation actions Such actions are related to ESA Section 7 consultation, Reasonable and Prudent Alternatives, addressing temperature, flow, and operations of the Central Valley and State Water Projects; EPA actions to control acid mine runoff from Iron Mountain Mine; and the CVRWB decisions requiring compliance with Sacramento River water temperature objectives. These decisions resulted in the installation of the Shasta Temperature Control Device in 1998.

Biological opinions for SWP and CVP operations (e.g., NMFS 2009a) and other federal projects involving irrigation and water diversion and fish passage, for example, have improved or minimized adverse impacts to salmon in the Central Valley. In 1992, an amendment to the authority of the CVP through the CVPIA was enacted to give protection of fish and wildlife equal priority with other CVP objectives. From this act arose several programs that have benefited listed salmonids. The Anadromous Fish Restoration Program (AFRP) is engaged in monitoring, education, and restoration projects designed to contribute toward doubling the natural populations of select anadromous fish species residing in the Central Valley. Restoration projects funded through the AFRP include fish passage, fish screening, riparian easement and land acquisition, development of watershed planning groups, instream and riparian habitat improvement, and gravel replenishment. The Anadromous Fish Screen Program combines federal funding with state and private funds to prioritize and construct fish screens on major water diversions mainly in the upper Sacramento River. The goal of the Water Acquisition Program is to acquire water supplies to meet the habitat restoration and enhancement goals of the Central Valley Improvement Act, and to improve the ability of the U.S. Department of the Interior to meet regulatory water quality requirements. Water has been used to improve fish habitat for Central Valley salmon, with the primary focus on listed Chinook salmon and steelhead, by maintaining or increasing instream flows (EWA) on the Sacramento River at critical times, and to reduce salmonid entrainment at the SWP and CVP export facilities through reducing seasonal diversion rates during periods when protected fish species are vulnerable to export related losses.

Two programs included under CALFED, the Ecosystem Restoration Program (ERP) and the EWA, were created to improve conditions for fish, including spring-run Chinook salmon, in the Central Valley. The ERP Implementing Agency Managers selected a proposal for directed action funding written by the Central Valley Salmonid Project Work Team, an interagency technical working group led by DFG, to develop a spring-run Chinook salmon escapement monitoring plan. Long-term funding for implementation of the monitoring plan must still be secured.

A major CALFED ERP action currently underway is the Battle Creek Salmon and Steelhead Restoration Project. The project will restore 48 miles (77 km) of habitat in Battle Creek to support steelhead and Chinook salmon spawning and juvenile rearing at a cost of over $90 million. The project includes removal of five small hydropower diversion dams, construction of new fish screens and ladders on another three dams, and construction of several hydropower facility modifications to ensure the continued hydropower operations. It is thought that this restoration effort is the largest cold water restoration project to date in North America.

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) was formed to guide the implementation of CALFED ERP elements within the Delta (DFG 2007b). The DRERIP team has created a suite of ecosystem and species conceptual models, including spring-run Chinook salmon, that document existing scientific knowledge of Delta ecosystems. The DRERIP team has used these conceptual models to assess the suitability of actions proposed in the ERP for implementation. DRERIP conceptual models were used in the analysis of proposed BDCP conservation measures.

Recent habitat restoration initiatives sponsored and funded primarily by the ERP have resulted in plans to restore ecological function to 9,543 acres of shallow-water tidal and marsh habitats within the Delta. Restoration of these areas primarily involves flooding lands previously used for agriculture, thereby creating additional rearing habitat for juvenile salmonids. Similar habitat restoration is adjacent to Suisun Marsh (i.e., at the confluence of Montezuma Slough and the Sacramento River) as part of the Montezuma Wetlands project, which is intended to provide for commercial disposal of material dredged from San Francisco Estuary in conjunction with tidal wetland restoration.

The Vernalis Adaptive Management Program (VAMP) has implemented migration flow augmentation for the San Joaquin River basin to improve juvenile and adult migration for fall-run Chinook salmon (San Joaquin River Group Authority 2007). The VAMP program also includes seasonal reductions in SWP and CVP export rates that may benefit juvenile spring-run Chinook salmon during their emigration period. The program has been designed within the framework of adaptive management to improve the survival of juvenile salmonids migrating from the river through the Delta while providing an experimental framework to quantitatively evaluate the contribution of each action to salmonid survival. The incremental contribution of the VAMP conditions to overall spring-run salmon survival and adult abundance is uncertain. The VAMP experimental design and results of survival testing conducted to date is currently undergoing peer review and will also be the subject of a review conducted by the SWRCB. Based on results and recommendations from these technical reviews, the VAMP experimental design and testing program is expected to be refined.

The U.S. EPA's Iron Mountain Mine remediation involves the removal of toxic metals in acidic mine drainage from the Spring Creek Watershed with a state-of-the-art lime neutralization plant. Contaminant loading into the Sacramento River from Iron Mountain Mine has shown measurable reductions since the early 1990s. Decreasing the heavy metal contaminants that enter the Sacramento River should increase the survival of salmonid eggs and juveniles. However, during periods of heavy rainfall upstream of the Iron Mountain Mine, Reclamation substantially increases Sacramento River flows to dilute heavy metal contaminants being spilled from the Spring Creek debris dam. This rapid change in flows can cause juvenile salmonids to become stranded or isolated in side channels below Keswick Dam.

DWR's Delta Fish Agreement Program has approved approximately $49 million for projects that benefit salmon and steelhead production in the Sacramento-San Joaquin basins and Delta since the agreements inception in 1986. Delta Fish Agreement projects that benefit Central Valley spring-run Chinook salmon include water exchange programs on Mill and Deer creeks; enhanced law enforcement efforts from San Francisco Estuary upstream to the Sacramento and San Joaquin rivers and their tributaries; design and construction of fish screens and ladders on Butte Creek; and, screening of diversions in Suisun Marsh and San Joaquin River tributaries. The Spring-Run Salmon Increased Protection Project provides overtime wages for DFG wardens to focus on reducing illegal take and illegal water diversions on upper Sacramento River tributaries and adult holding areas, where the fish are vulnerable to poaching. This project covers Mill, Deer, Antelope, Butte, Big Chico, Cottonwood, and Battle creeks, and has been in effect since 1996. Through the Delta-Bay Enhanced Enforcement Program (DBEEP), initiated in 1994, a team of 10 wardens focus their enforcement efforts on salmon, steelhead, and other species of concern from the San Francisco Estuary upstream into the Sacramento and San Joaquin River basins. These two enhanced enforcement programs have likely had significant benefits to spring-run Chinook salmon attributed to DFG, although results have not been quantified.

The Mill and Deer Creek Water Exchange projects are designed to provide new wells that enable diverters to bank groundwater in place of stream flow, thus leaving water in the stream during critical migration and oversummering periods. On Mill Creek several agreements between Los Molinos Mutual Water Company, Orange Cove Irrigation District, DFG, and DWR allows DWR to pump groundwater from two wells into the Los Molinos Mutual Water Company canals to pay back Los Molinos Mutual Water Company water rights for surface water released downstream for fish. Although the Mill Creek Water Exchange project was initiated in 1990 and the agreement allows for a well capacity of 25 cfs, only 12 cfs has been developed to date. In addition, it has been determined that a base flow of greater than 25 cfs is needed during the April through June period for upstream passage of adult spring-run Chinook salmon in Mill Creek. In some years, water diversions from the creek are curtailed by amounts sufficient to provide for passage of upstream migrating adult spring-run Chinook salmon and downstream migrating juvenile steelhead and spring-run Chinook salmon.

The Feather River Hatchery is making efforts to segregate spring-run from fall-run Chinook salmon to enhance and restore the genotype of spring-run Chinook salmon in the Feather River (DFG 2001, McReynolds et al. 2006).

To help reduce the effects of the RBDD operation on migration of adult and juvenile salmonids and other species, management has changed in recent years to maintain the dam gates in the open position for a longer period of time and thereby facilitate greater upstream and downstream migration. Changes in dam operations have benefited both upstream and downstream migration by salmon and have contributed to a reduction in juvenile predation mortality. In 2009, USBR received funding for the Fish Passage Improvement Project at the RBDD to build a pumping facility to provide reliable water supply for high-valued crops in Tehama, Glenn, Colusa, and northern Yolo counties while providing year-round unimpeded fish passage. This project, which is expected to be completed in late 2012, will eliminate passage issues for spring-run Chinook salmon and other migratory species.

Seasonal constraints on sport and commercial fisheries south of Point Arena benefit spring-run Chinook salmon. DFG has implemented enhanced enforcement efforts to reduce illegal harvests. Central Valley spring-run Chinook salmon is a state listed fish that is protected by specific in-river fishing regulations.

A3.7 Recovery Goals

The Public Draft Recovery Plan for Central Valley salmonids, including spring-run Chinook salmon, was released by NMFS on October 19, 2009. Although not final, the overarching goal in the public draft is the removal of, among other listed salmonids, spring-run Chinook salmon from the federal list of Endangered and Threatened Wildlife (NMFS 2009b). Several objectives and related criteria represent the components of the recovery goal, including the establishment of at least two viable populations within each historical diversity group, as well as other measurable biological criteria.

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APPENDIX A4. CENTRAL VALLEY FALL- AND LATE FALL-RUN CHINOOK SALMON (*ONCORHYNCHUS TSHAWYTSCHA*)

A4.1 LEGAL STATUS

The Central Valley fall- and late fall-run Chinook salmon Evolutionarily Significant Unit (ESU) includes all naturally spawned populations of fall- and late fall-run Chinook salmon in the Sacramento and San Joaquin River basins and their tributaries east of Carquinez Strait, California (64 FR 50394) (see Figure A-4a and Figure A-4b, respectively). On September 16, 1999, after reviewing the best available scientific and commercial information, the National Marine Fisheries Service (NMFS) determined that listing Central Valley fall- and late fall-run Chinook salmon was not warranted. On April 15, 2004, the Central Valley fall- and late fall-run Chinook salmon ESU was identified by NMFS as a Species of Concern (69 FR 19975).

The Central Valley fall-/late fall-run Chinook salmon ESU are not listed under the California Endangered Species Act. Fall-run/late fall-run Chinook salmon are identified as a California Species of Special Concern (Moyle et al. 1995).

A4.2 SPECIES DISTRIBUTION AND STATUS

A4.2.1 Range and Status

Central Valley fall-run Chinook salmon historically spawned in all major tributaries, as well as the mainstem of the Sacramento and San Joaquin rivers (see Figure A-4a). The historical geographic distribution of Central Valley late fall-run Chinook salmon is not well understood, but is thought to be less extensive than that of fall-run (see Figure A-4b). A large percentage of fall-run Chinook spawning areas in the Sacramento and San Joaquin rivers historically inhabited the lower gradient reaches of the rivers downstream of sites now occupied by major dams, such as Shasta and Friant dams. As a result of the geographic distribution of spawning and juvenile rearing areas, fall-run Chinook salmon populations in the Central Valley were not as severely affected by early water projects that blocked access to upstream areas as were spring- and winter-runs of Chinook salmon and steelhead that used higher elevation habitat for spawning and rearing (Reynolds et al. 1993, McEwan 2001). Changes in seasonal hydrologic patterns resulting from operation of upstream reservoirs for water supplies, flood control, and hydroelectric power generation have altered instream flows and habitat conditions for fall-run Chinook salmon and other species downstream of the dams (Williams 2006).

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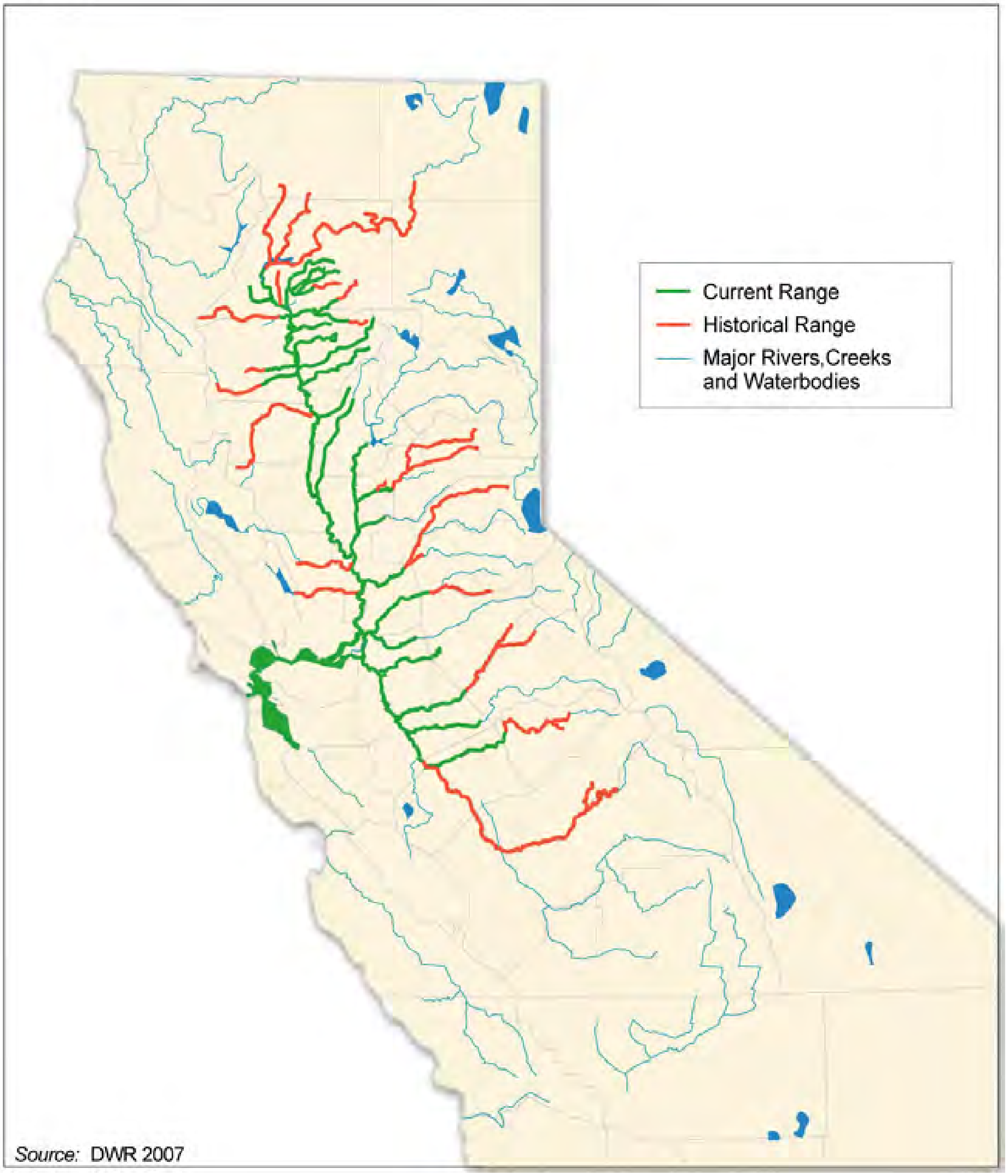

Figure A-4a. Central Valley Fall-Run Chinook Salmon Inland Range in California

Figure A-4b. Central Valley Late Fall-Run Chinook Salmon Inland Range in California

The abundance of Central Valley fall- and late fall-run Chinook salmon escapement before 1952 is poorly documented. Reynolds et al. (1993) estimated that production of fall- and late fall-run Chinook salmon on the San Joaquin River historically approached 300,000 adults and probably averaged approximately 150,000 adults. Calkins et al. (1940) estimated fall- and late fall-run Chinook salmon abundance at 55,595 adults in the Sacramento River Basin during the period 1931-1939. In the early 1960s, adult fall- and late fall-run Chinook salmon escapement was estimated to be 327,000 fish in the Sacramento River basin (U.S. Department of Fish and Game [DFG] 1965). In the mid-1960s, fall- and late fall-run Chinook salmon escapement to the San Joaquin River Basin was estimated to be about 2,400 fish, which spawned in the San Joaquin River tributaries – the Stanislaus, Tuolumne, and Merced rivers.

Long-term trends in adult fall-run Chinook salmon escapement indicate that abundance in the Sacramento River has been consistently higher than abundance in the San Joaquin River (see Figure A-4c). Escapement on the Sacramento River has been characterized by relatively high interannual variability ranging from approximately 100,000 to over 800,000 fish. Sacramento River escapement showed a marked increase in abundance between 1990 and 2003 followed by a decline in abundance over the period from 2004 through present. In 2009 adult fall-run Chinook salmon returns to the Central Valley rivers showed a substantial decline within both the Sacramento and San Joaquin river systems. Similar declines in adult escapement were also observed for coho salmon and Chinook salmon returning to other river systems in California (MacFarlane et al. 2008).

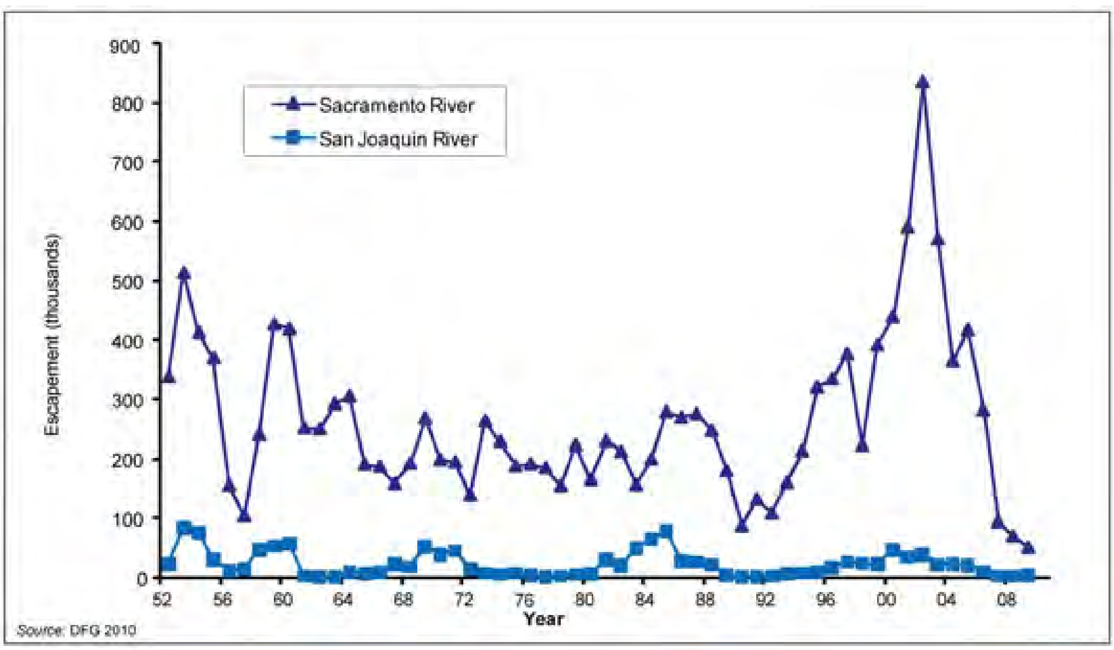

Figure A-4c. Estimated Historical Spawner Escapement of Central Valley Fall-Run Chinook Salmon (1952-2009)

A variety of factors are thought to have influenced adult escapement on both rivers, including hydrological conditions for migration, spawning, and juvenile rearing, ocean conditions, and management actions that have been implemented since the early 1990s to improve seasonal water temperatures, streamflows, modifications to Red Bluff Diversion Dam (RBDD) gate operations, improved fish passage, construction of positive barrier fish screens on larger diversions, and improved habitat conditions.

Trends in adult fall-run Chinook salmon escapement on the San Joaquin River and tributaries has been relatively low since the 1950s, ranging from several hundred adults to approximately 100,000 adults (see Figure A-4c). Results of escapement estimates have shown a relationship between adult escapement in one year and spring flows on the San Joaquin River 2.5 years earlier when the juvenile within the cohort were rearing and migrating downstream through the Delta. Adult escapement appears to be cyclical and may be related to hydrology during juvenile rearing and migration period, among other factors (San Joaquin River Group Authority 2007, DFG 2008).

Population estimates for late fall-run Chinook salmon on the San Joaquin River system are not available, but it is thought that late fall-run Chinook salmon do not regularly spawn in the tributaries of the San Joaquin River (Moyle et al. 1995). Adult escapement estimates for late fall-run Chinook salmon returning to the Sacramento River over the period from 1971 through 2009 have ranged from several hundred adults to over 40,000 adults. Adult escapement showed a general trend of declining abundance between 1971 and 1997 (see Figure A-4d). During the late 1990s and continuing through 2006 escapement has increased substantially but is characterized by high interannual variability. The 2008 and 2009 escapement estimates were lower than the previous 4 years, but were not characterized by the massive decline observed for fall-run Chinook salmon (see Figure A-4c). A number of factors have been identified that may be contributing to the observed trends and patterns in late fall-run Chinook salmon escapement to the upper Sacramento River and its tributaries.

A4.2.2 Distribution and Status in the Plan Area

The entire population of the Central Valley fall-/late fall-run Chinook salmon ESU must pass through Plan Area as adults migrating upstream and as juveniles emigrating downstream. Adult Central Valley fall-/late fall-run Chinook salmon migrating into the Sacramento River and its tributaries primarily use the western and northern portions of the Delta, whereas adults entering the San Joaquin River system to spawn use the western, central, and southern Delta as a migration pathway. Young fall-/late fall-run Chinook salmon must migrate through the Delta towards the Pacific Ocean and use the Delta, Suisun Marsh, and the Yolo Bypass for rearing to varying degrees, depending on their life stage (fry vs. juvenile) and size, river flows, and time of year.

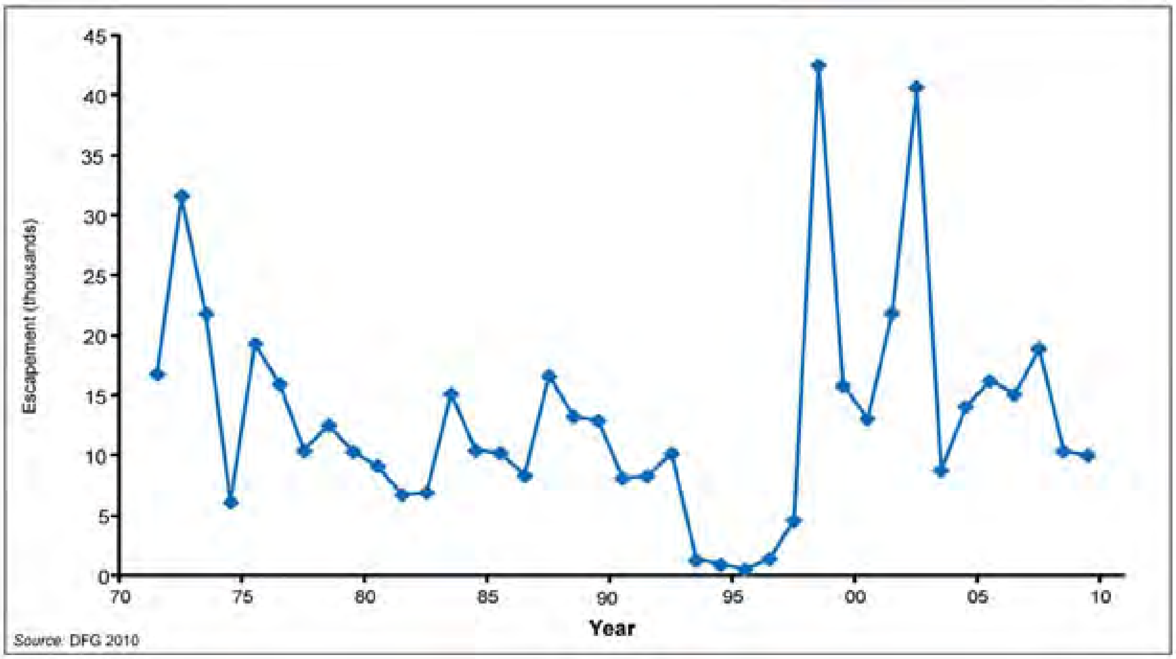

Figure A-4d. Estimated Historical Spawner Escapement of Central Valley Late Fall-Run Chinook Salmon (1971-2009) in the Sacramento River

A4.3 HABITAT REQUIREMENTS AND SPECIAL CONSIDERATIONS

Critical Habitat has not been designated for either fall-run or late fall-run Chinook salmon because the ESU is not listed under the Endangered Species Act. However, Central Valley fall- and late fall-run Chinook salmon habitats are protected under the Magnuson-Stevens Fishery Conservation and Management Act as Essential Fish Habitat. Those waters and substrate that support fall- and late fall-run Chinook salmon growth to maturity are included as Essential Fish Habitat (fall-run: see Figure A-4e; late fall-run: see Figure A-4f).

The Primary Constituent Elements (PCEs) considered essential for the conservation of Central Valley salmonids are: (1) freshwater spawning sites, (2) freshwater rearing sites, (3) freshwater migration corridors, (4) estuarine areas, (5) nearshore marine areas, and (6) offshore marine areas.

A4.3.1 Spawning Habitat

Chinook salmon spawning sites include those stream reaches with instream flows, water quality, and substrate conditions suitable to support spawning, egg incubation, and larval development. Central Valley fall-run Chinook salmon currently spawn downstream of dams on every major tributary within the Sacramento and San Joaquin river systems (with the exception of the San Joaquin River downstream of Friant Dam which is currently the subject of a settlement agreement and salmonid restoration program) in areas containing suitable environmental conditions for spawning and egg incubation.

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Figure A-4e. Central Valley Fall-Run Chinook Salmon Inland Essential Fish Habitat in California

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Figure A-4f. Central Valley Late Fall-Run Chinook Salmon Inland Essential Fish Habitat in California

Late fall-run Chinook salmon spawning is limited to the mainstem and tributaries of the Sacramento River. No Chinook salmon spawning habitat is known to occur within the Plan Area.

A4.3.2 Freshwater Rearing Habitat

Fall-/late fall-run Chinook salmon rear in streams and rivers with sufficient water flow and floodplain connectivity to form and maintain physical habitat conditions that support growth and mobility, provide suitable water quality (e.g., seasonal water temperatures) and forage species that support juvenile salmon growth, and cover such as shade, submerged and overhanging large wood, log jams, beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Both spawning areas and migratory corridors might also function as rearing habitat for juveniles, which feed and grow before and during their outmigration. Non-natal, intermittent tributaries and seasonally inundated flood control bypasses such as the Yolo Bypass also support juvenile rearing (Sommer et al. 2001). Rearing habitat quality is strongly affected by habitat complexity, food supply, and vulnerability to predators. Some of these more complex and productive habitats with floodplains are still present in limited amounts within the Central Valley (e.g., the lower Cosumnes River, Sacramento River reaches with set-back levees [i.e., primarily located upstream of the City of Colusa]). The channeled, leveed, and riprapped river reaches and sloughs common in the Sacramento-San Joaquin River and throughout the Delta typically have low habitat diversity and complexity, low abundance of food organisms, and offer little protection from predation by fish and birds. Freshwater rearing habitat has a high conservation value because the juvenile life stage of salmonids is dependent on the function of this habitat for successful growth, survival, and recruitment to the adult population.

A4.3.3 Freshwater Migration Corridors

Freshwater migration corridors for fall-run and late fall-run Chinook salmon, including river channels, channels through the Delta, and the Bay-Delta estuary, support mobility, survival, and food supply for juveniles and adults. Migration corridors should be free from obstructions (passage barriers and impediments to migration), favorable water quantity (instream flows) and quality conditions (seasonal water temperatures), and contain natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Migratory corridors are typically downstream of the spawning area and include the lower Sacramento and San Joaquin rivers, the Delta, and the San Francisco Bay complex extending to coastal marine waters. These corridors allow the upstream passage of adults and the downstream emigration of juvenile salmon. Migratory corridor conditions are strongly affected by the presence of passage barriers, which can include dams, unscreened or poorly screened diversions, and degraded water quality. For freshwater migration corridors to function properly, they must provide adequate passage, provide suitable migration cues, reduce false attraction, avoid areas where vulnerability to predation is increased, and avoid impediments and delays in both upstream and downstream migration. For this reason, freshwater migration corridors are considered to have a high conservation value. Results of mark-recapture studies conducted using juvenile Chinook salmon released into both the Sacramento and San Joaquin rivers have shown high mortality during passage downstream through the rivers and Delta. Mortality for juvenile salmon is typically greater on the San Joaquin River than for those fish emigrating from the Sacramento River. On both rivers, mortality is typically greater in years when spring flows are reduced and water temperatures are increased. Results of survival studies have shown that closing the Delta Cross Channel gates and installation of the Head of Old River Barrier, to reduce the movement of juvenile salmon into the Delta, contribute to improved survival of emigrating juvenile Chinook salmon. Observations at the State Water Project (SWP) and the Central Valley Project (CVP) fish salvage facilities have shown that very few of the marked salmon are entrained and salvaged at the export facilities. Although factors contributing to the high juvenile mortality have not been quantified, results of anecdotal observations and results of acoustic tagging experiments suggest the exposure to adverse water quality conditions leading to mortality and vulnerability to predation mortality are two of the factors contributing to the high juvenile mortality observed in the rivers and Delta.

A4.3.4 Estuarine Areas

Estuarine migration and juvenile rearing habitats should be free of obstructions (i.e., dams and other barriers) and provide suitable water quality, water quantity (river and tidal flows), and salinity conditions to support juvenile and adult physiological transitions between fresh and salt water. Natural cover, such as submerged and overhanging large wood, aquatic vegetation, and side channels, provide juvenile and adult foraging. Estuarine areas contain a high conservation value as they function to support juvenile Chinook salmon growth, smolting, avoidance of predators, and provide a transition to the ocean environment.

A4.3.5 Ocean Habitats

Biologically productive coastal waters are an important habitat component for Central Valley fall- and late fall-run Chinook salmon. Juvenile fall-run and late fall-run Chinook salmon inhabit near-shore coastal marine waters for a period of typically 2 to 4 years before adults return to Central Valley rivers to spawn . During their marine residence Chinook salmon forage on krill, squid, and other marine invertebrates as well as a variety of fish such as northern anchovy and Pacific herring. These features are essential for conservation because, without them, juveniles cannot forage and grow to adulthood.

Results of oceanographic studies have shown the variation in ocean productivity off the West Coast within and among years. Changes in ocean currents and upwelling have been identified as significant factors affecting nutrient availability, phytoplankton and zooplankton production and the availability of other forage species in near-shore surface waters. Ocean conditions at the end of the salmon’s ocean residency period can be important, as indicated by the effect of the 1983 El Niño on the size and fecundity of Central Valley fall-run Chinook salmon (Wells et al. 2006). Although the effects of ocean conditions on Chinook salmon growth and survival have not been investigated extensively, recent observations since 2007 have shown a significant decline in the abundance of adult Chinook salmon and coho salmon returning to California rivers and streams (fall-run adult returns to the Sacramento and San Joaquin rivers were the lowest on record [Pacific Fishery Management Council 2008]) that has been hypothesized to be the result of declines in ocean productivity and associated high mortality rates during the period when these fish were rearing in near-shore coastal waters (MacFarlane et al. 2008). The importance of changes in ocean conditions on growth, survival, and population abundance of Central Valley Chinook salmon is currently undergoing further investigation.

A4.4 LIFE HISTORY

The following life history information was summarized primarily from the Final Restoration Plan for the Anadromous Fish Restoration Program (2001).

Chinook salmon exhibit two characteristic freshwater life history types (Healey 1991). Stream-type adult Chinook salmon enter freshwater months before spawning, and their offspring reside in freshwater one or more years following emergence. Ocean-type Chinook salmon, in contrast, spend significantly less time in freshwater: spawning soon after entering freshwater as adults and migrating to the ocean as juvenile fry or parr within their first year. Adequate stream flows and cool water temperatures are more critical for the survival of Chinook salmon exhibiting the stream-type life history behaviors due to their residence in freshwater both as adults and juveniles over the warmer summer months.

Central Valley fall-run Chinook salmon exhibit an ocean-type life history. Adult fall-run Chinook salmon migrate through the Delta and into Central Valley rivers from July through December and spawn from October through December (see Table A-4a). Peak spawning activity usually occurs in October and November. The life history characteristics of late fall-run Chinook salmon are not well understood; however, they are thought to exhibit an ocean-type life history. Adult late fall-run Chinook salmon migrate through the Delta and into the Sacramento River from October through April and may wait one to three months before spawning from January through April (Table A-4b). Peak spawning activity occurs in February and March. Chinook salmon typically mature between 2 and 6 years of age (Myers et al. 1998). The majority of Central Valley fall-run Chinook salmon spawn at age 3.

Information on the migration rates of Chinook salmon in freshwater is scant, most of which is taken from the Columbia River basin where migration behavior information is used to assess the effects of dams on salmon travel times and passage (Matter et al. 2003). Adult Chinook salmon upstream migration rates ranged from 29 to 32 km per day in the Snake River, a Columbia River tributary (Matter et al. 2003). Keefer et al. (2004) found migration rates of adult Chinook salmon in the Columbia River ranging between approximately 10 km per day to greater than 35 km per day. Adult Chinook salmon with sonic tags have been tracked throughout the Delta and the lower Sacramento and San Joaquin rivers (CALFED Science Program 2001).

Table A-4a. Temporal Occurrence of (a) Adult and (b) Juvenile Central Valley Fall-Run Chinook Salmon in the Sacramento River and Delta. Darker shades indicate months of greatest relative abundance.

a) Adult

Location	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Delta[1]												
Sacramento (Sac) River Basin[2]												
San Joaquin River[2]												

b) Juvenile

Location	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Sac River @ Red Bluff[3]												
Delta (beach seine)[4]												
Mossdale (trawl)[4]												
West Sac River (trawl)[4]												
Chipps Island (trawl)[4]												
Relative Abundance:	= High				= Medium				= Low			

[1]State Water Project and Federal Water Project fish salvage data 1981-1988.
[2]Yoshiyama et al. 1998, Moyle 2002.
[3]Martin et al. 2001
[4]USFWS 2001.

Table A4-b. Temporal Occurrence of (a) Adult and (b) Juvenile Central Valley Late Fall-Run Chinook Salmon in the Sacramento River and Delta. Darker shades indicate months of greatest relative abundance.

a) Adult

Location	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Delta[1]												
Sacramento (Sac) River Basin[2]												

b) Juvenile

Location	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Sac River @ Red Bluff[3]												
West Sac River (trawl)[4]												
Delta (beach seine)[4]												
Chipps Island (trawl)[4]												
Relative Abundance:	= High				= Medium				= Low			

[1]State Water Project and Federal Water Project fish salvage unpublished data 1981-1988.
[2]Yoshiyama et al. 1998; Moyle 2002.
[3]Martin et al. 2001.
[4]USFWS 2001.

These fish exhibited substantial upstream and downstream movement in a random fashion while migrating upstream several days at a time. Adult salmonids migrating upstream, particularly larger salmon such as Chinook, as described by Hughes (2004), are assumed to make greater use of pool and mid-channel habitat than they are of channel margins (Stillwater Sciences 2004). Adult salmon are thought to exhibit crepuscular behavior during their upstream migrations, primarily migrating during twilight hours (Hallock et al. 1970).

Chinook salmon spawn in clean, loose gravel in swift, relatively shallow riffles; or along the margins of deeper river reaches where suitable water temperatures, depths, and velocities favor redd construction and oxygenation of incubating eggs. Chinook salmon spawning typically occurs in gravel beds located at the tails or downstream ends of holding pools (U.S. Fish and Wildlife Service [USFWS] 1995). Egg incubation for Central Valley fall-run Chinook salmon begins with spawning in October and can extend into March. Egg incubation for late fall-run salmon occurs from January through June.

Fry emergence generally occurs at night. Upon emergence from the gravel, fry swim or are displaced downstream (Healey 1991). Fry seek streamside habitats containing beneficial aspects such as riparian vegetation and associated substrates that provide aquatic and terrestrial invertebrates, predator avoidance cover, and slower water velocities for resting (NMFS 1996). These shallow water habitats have been described as more productive juvenile salmon rearing habitat than the deeper main river channels. Higher juvenile salmon growth rates, partially due to greater prey consumption rates, as well as favorable environmental temperatures have been associated with shallow water habitats (Sommer et al. 2001).

Central Valley fall-run Chinook salmon fry (i.e., juveniles shorter than two inches long) generally emerge from December through March, with peak emergence occurring by the end of January. In general, fall-run Chinook salmon fry abundance in the Delta increases following high winter flows. Most fall-run Chinook salmon fry rear in freshwater from December through June, with emigration as smolts occurring from April through June (see Table A-4a). Smolts that arrive in the estuary after rearing upstream migrate quickly through the Delta and Suisun and San Pablo Bays. A very small number (generally considered less than 5 percent) of fall-run juveniles spend over a year in fresh water and emigrate as yearling smolts the following November through April.

Central Valley late fall-run Chinook salmon fry generally emerge from April through June. Late fall-run fry rear in freshwater from April through the following April and emigrating as smolts from November through April (see Table A-4b). Juvenile fall-run Chinook salmon outmigration through the Delta is thought to be primarily a diurnal activity, whereas outmigration of juvenile late fall-run salmon through the Delta is thought to occur primarily at night (Wilder and Ingram 2006). There are a variety of possible explanations for the difference in diel activity between races, including size of fish, water temperature, flow rate, and water clarity during downstream migration. Once downstream movement has commenced, individuals may continue this movement until reaching the estuary or they may reside in the stream for a time period that varies from a few weeks to a few months (Healey 1991). Juvenile Chinook salmon migration rates vary considerably and likely depend on physiological stage of the fish and hydrologic conditions. Kjelson et al. (1982) found Chinook salmon fry traveled downstream as fast as 30 km per day in the Sacramento River. Sommer et al. (2001) found rates ranging from approximately 1 km to greater than10 km per day in the Yolo Bypass. As juvenile Chinook salmon grow, they move into deeper water with higher current velocities, but still seek shelter and velocity refugia to minimize energy expenditures (Healey 1991). Catches of juvenile salmon in the Sacramento River near West Sacramento by the USFWS (1997) indicate that larger juveniles were captured in the main channel and smaller sized fry along the channel margins. Where the river channel is greater than 9 to 10 feet in depth, juvenile salmon tend to inhabit the surface waters (Healey 1980). Stream flow and/or turbidity increases in the upper Sacramento River basin are thought to stimulate juvenile emigration (Kjelson et al. 1982, Brandes and McLain 2001).

As Chinook salmon begin to smolt (i.e., make the physiological changes necessary for life in salt water), they are found rearing further downstream where ambient salinity reaches 1.5 to 2.5 parts per thousand (Healey 1980, Levy and Northcote 1981, USFWS unpubl. data). Within the Delta, juvenile Chinook salmon forage in shallow areas with protective cover, such as tidally influenced sandy beaches and shallow vegetated zones (Meyer 1979, Healey 1980). Cladocerans, copepods, amphipods, and dipteran larvae dipteral, as well as small arachnids and ants, are common prey items (Kjelson et al. 1982, Sommer et al. 2001).

Juvenile Chinook salmon movements within the estuarine habitat are dictated by the interaction between tidally driven saltwater intrusions through the San Francisco Bay and fresh water outflow from the Sacramento and San Joaquin rivers. Juvenile Chinook salmon follow rising tides into shallow water habitats from the deeper main channels, and return to the main channels when the tides recede (Levy and Northcote 1981, Healey 1991). Juvenile Chinook salmon were found to spend about 40 days migrating through the Delta to the mouth of San Francisco Bay and grew little in length or weight until they reached the Gulf of the Farallones Islands (MacFarlane and Norton 2002). Based on the mainly ocean-type life history observed (i.e., fall-run Chinook salmon), MacFarlane and Norton (2002) concluded that unlike other salmonid populations in the Pacific Northwest, Central Valley Chinook salmon smolts currently show little estuarine dependence and may benefit from expedited ocean entry. However, this may not be the case for emigrating fry that rear for a longer period within the Delta and estuary before emigrating to coastal marine waters. In addition, it has been hypothesized that changes in habitat conditions within the Delta over the past century may have resulted in a reduction in extended juvenile salmon rearing when compared to periods during which habitat for juvenile fall-run and late fall-run salmon rearing was more suitable.

Central Valley Chinook salmon begin their ocean life in the coastal marine waters of the Gulf of the Farallones from where they distribute north and south along the continental shelf primarily between Point Conception and Washington State (Healey 1991). Upon reaching the ocean, juvenile Chinook salmon feed on larval and juvenile fishes, plankton, and terrestrial insects (Healey 1991, MacFarlane and Norton 2002). Chinook salmon grow rapidly in the ocean environment with growth rates dependent on water temperatures and food availability (Healey 1991). The first year of ocean life is considered a critical period of high mortality for Chinook salmon that largely determines survival to harvest or spawning (Beamish and Mahnken 2001, Quinn 2005).

Recovery of coded-wire tagged Chinook salmon from the Feather River Hatchery in the ocean recreational and commercial fisheries (Pacific States Marine Fisheries Commission Regional Mark Information System database) indicates that Central Valley fall-run Chinook salmon adults are broadly distributed along the Pacific Coast from Northern Oregon to Monterey. Recovery of late fall-run coded-wire tagged Chinook salmon from the Coleman Hatchery in the ocean recreational and commercial fisheries (Pacific States Marine Fisheries Commission Regional Mark Information System database) indicates that Central Valley late fall-run Chinook salmon adults are the most broadly distributed along the Pacific Coast of the Central Valley salmon, ranging from British Columbia to Monterey.

Like other ocean-type Chinook salmon, Central Valley fall- and late fall-run Chinook salmon remain near the coast throughout their ocean life (Healey 1983, 1991, Myers et al. 1984). Central Valley fall- and late fall-run Chinook salmon remain in the ocean for 2 to 5 years. Fall-run Chinook salmon mature in the ocean before returning to freshwater to spawn. Late fall-run Chinook salmon may return to freshwater as immature adults as indicated by a 1 to 3 month delay in spawning once reaching the spawning grounds.

A4.5 THREATS AND STRESSORS

The following have been identified as important threats and stressors to fall- and late fall-run Chinook salmon (without priority). Additionally, recent record low numbers of fall-run Chinook salmon adult returns to the Central Valley (Pacific Fishery Management Council 2008) suggest that ocean conditions may be an important stressor to the ESU (MacFarlane et al. 2008), although the mechanisms driving this potential effect are not well understood.

Reduced staging and spawning habitat. Access to the upper extent of the historical upstream spawning habitat for fall- and late fall-run Chinook salmon (see Figures A-4a and A-4b, respectively) has been eliminated or degraded by man-made structures (e.g., dams and weirs) associated with water storage and conveyance, flood control, and diversions and exports for, municipal, industrial, agricultural, and hydropower purposes (Yoshiyama et al. 1998). Because spawning locations of fall- and late fall-run Chinook salmon are typically in the lower reaches of rivers, fall-/late fall-run Chinook salmon have been less affected by dam construction relative to other Central Valley salmonids. Spawning habitat for fall- and late fall-run Chinook salmon is still widely distributed within the Sacramento River basin, but more limited within the San Joaquin River basin.

Upstream diversions and dams have decreased downstream flows and altered the seasonal hydrologic patterns. These factors have been identified as contributing to delays in upstream migration by adults, increased mortality of out-migrating juveniles, and responsible for making some streams uninhabitable by fall-/late fall-run salmon (Yoshiyama et al. 1998, California Department of Water Resources [DWR] 2005). Dams and reservoir impoundments and associated reductions in peak flows have blocked gravel recruitment and reduced flushing of sediments from existing gravel beds, reducing and degrading natal spawning grounds. Further, reduced flows can lower attraction cues for adult spawners, causing straying and delays in spawning (DWR 2005). Adult salmon migration delays can reduce fecundity and increase susceptibility to disease and harvest (McCullough 1999) Because fall-run Chinook salmon spawn shortly after entering freshwater, a delay in migration can have large impacts to pre-spawning mortality and spawning success relative to other races of Chinook salmon.

The RBDD located on the Sacramento River has been identified as a barrier and impediment to adult upstream migration. Although the RBDD is equipped with fish ladders, migration delays were reported when the dam gates are closed. Mortality as a result of increased predation by Sacramento pikeminnow on juvenile salmon passing downstream through the fish ladder has also been identified as a factor affecting abundance of salmon produced on the Sacramento River (Hallock 1991). To help reduce the effects of dam operation on migration of adult and juvenile salmonids and other species, management changes have occurred in recent years to maintain the dam gates in the open position for a longer period of time, facilitating greater upstream and downstream migration. Changes in dam operations have benefited both upstream and downstream migration and have contributed to a reduction in juvenile predation mortality.

Reduced rearing and out-migration habitat. Natural migration corridors for juvenile fall- and late fall-run Chinook salmon consist of a mosaic of complex habitat types, including stream banks, floodplains, marshes, and shallow water areas which are used as rearing habitat during out-migration. Much of the Sacramento and San Joaquin river corridor and Delta have been leveed, channelized, and modified with riprap for flood protection, thereby reducing and degrading the quality and availability of natural habitat for rearing and emigrating juvenile Chinook salmon (Brandes and McLain 2001). Juvenile out-migration delays associated with man-made passage impediments can reduce fitness and increase susceptibility to diversion screen impingement, entrainment, disease, and predation. Modification of natural flow regimes from upstream reservoir operations has resulted in dampening of the hydrograph, reducing the extent and duration of seasonal floodplain inundation and other flow-dependent habitat used by migrating juvenile Chinook salmon (70 FR 52488, Sommer et al. 2001, DWR 2005). Recovery of floodplain habitat in the Central Valley has been found to contribute to increases in production in Chinook salmon (Sommer et al. 2001). Reductions in flow rates have resulted in increased water temperature and residence time, and reduced dissolved oxygen levels in localized areas of the Delta (e.g., Stockton Deep Water Ship Channel). Reduced dissolved oxygen levels in the San Joaquin River during summer and fall have been identified as a water quality barrier to salmon migration (Central Valley Regional Water Quality Control Board 2007).

Predation by non-native species. Predation on juvenile salmon by non-native fish has been identified as an important threat to fall- and late fall-run Chinook salmon in areas with high densities of non-native fish (e.g., small and large mouth bass, striped bass, and catfish) that prey on out-migrating juvenile salmon (Lindley and Mohr 2003). Non-native aquatic vegetation, such as Brazilian waterweed and water hyacinth, provide suitable habitat for non-native predators (Nobriga et al. 2005, Brown and Michniuk 2007). Predation risk may covary with increased temperatures. Metabolic rates of non-native, predatory fish increase with increasing water temperatures based on bioenergetic studies (Loboschefsky et al. 2009, Miranda et al. 2010). Upstream gravel pits and flooded ponds attract non-native predators because of their depth and lack of cover for juvenile salmon (DWR 2005). The low spatial complexity and reduced habitat diversity (e.g., lack of cover) of channelized waterways within the rivers and Delta reduces refuge space of salmon from predators (Raleigh et al. 1984, Missildine et al. 2001, 70 FR 52488). A major concern is the potential invasion of the Delta by the highly predatory northern pike. The pike, recently present in Lake Davis on the Feather River, is currently the target of a major eradication effort (DFG 2007a). If eradication fails and pike escape downstream to the Delta, they would likely be present in areas inhabited by fall- and late fall-run Chinook salmon.

Predation by native species, such as the Sacramento pikeminnow, in the Sacramento River at locations such as the RBDD has also been identified as a potentially significant source of mortality on juvenile salmonids.

Harvest. Commercial or recreational harvest of fall- and late fall-run Chinook salmon populations in the ocean and inland fisheries has been a subject of management actions by the California Fish and Game Commission and the Pacific Fishery Management Council. Coastal marine waters offshore of San Francisco Bay are a mixed stock fishery comprised of both wild and hatchery produced salmon. As a result of differences in survival rates for eggs incubation, rearing, and emigration, juvenile salmon produced in streams and rivers have relatively low survival rates compared to Central Valley salmon hatcheries, which have relatively high survival rates. Therefore, naturally reproducing Chinook salmon populations are less able to withstand high harvest rates compared to hatchery-based stocks (Knudsen et al. 1999). The ocean fishery for fall- and late fall-run Chinook salmon is supplemented by hatchery enhancement programs (USFWS 1999, Williams 2006). The Coleman National Fish Hatchery produces approximately 12 million fall-run and one million late fall-run Chinook salmon juveniles each year to mitigate for habitat loss from construction of Shasta and Keswick dams (Williams 2006). Fall-run Chinook salmon are also produced at hatcheries on the Feather, American, Mokelumne, and Merced rivers (Williams 2006). Harvest as a result of the commercial and recreational fisheries may ultimately be having detrimental effects to wild spawners in this mixed stock fishery, but few data are available. Commercial fishing for salmon is managed by the Pacific Fishery Management Council and is constrained by time and area to meet the Sacramento River winter-run ESA consultation standard and restrictions requiring minimum size limits and use of circle hooks for anglers.

Beginning in 2007, Central Valley hatcheries have implemented a proportional marking program (tagging a set percentage of salmon produced in each hatchery) that is designed to provide improved information on the effects of harvest on various stocks of Chinook salmon. The program also provides information on ocean migration patterns, growth and survival for fish released at various lifestages and locations, the contribution of hatcheries to the adult population, straying among hatcheries and watersheds, the relative contribution of in-river versus hatchery production, and other data that will assist managers in refining harvest regulations. Results of coded wire tag (CWT) mark-recapture studies and data from the proportional marking program are continually being reviewed and analyzed each year and used to modify harvest regulations and Central Valley salmon management.

Reduced genetic diversity/integrity. Artificial propagation programs (hatchery production) for fall- and late fall-run Chinook salmon in the Central Valley present multiple threats to wild (in-river spawning) Chinook salmon populations, including genetic introgression by hatchery origin fish that spawn naturally and interbreed with local wild populations (USFWS 2001, U.S. Bureau of Reclamation [USBR] 2004, Goodman 2005). It is now recognized that Central Valley hatcheries are a significant and persistent threat to wild Chinook salmon and steelhead populations and fisheries (NMFS 2009a). Interbreeding with hatchery fish contributes directly to reduced genetic diversity and introduces maladaptive genetic changes to the wild population (DFG 1995, CALFED 2004, Myers et al. 2004, Araki et al. 2007). In addition, releasing hatchery smolts downstream of hatcheries has resulted in an increase in straying rates, further reducing genetic diversity among populations (Williamson and May 2005). Central Valley hatcheries are currently undergoing a detailed review by NMFS and DFG as part of a comprehensive hatchery master plan process. Various techniques and actions have been identified for reducing the effects of hatchery production on the genetic characteristics of Chinook salmon as part of the hatchery review. These include, but are not limited to, seasonally selecting brood stock for use in the hatchery in proportion to adult escapement to the river, selecting brood stock from various age classes (including grilse) that represents the age structure of the wild population, use of tagging and genetic testing to select brood stock, increasing the number of adults used as brood stock to increase genetic diversity, reduce interbasin transfer of eggs and fry, and imprinting juveniles to reduce straying among watersheds. These and other hatchery management methods (e.g., reduction of the use of antibiotics, juvenile release strategies to reduce impacts to wild rearing juveniles, volitional releases, etc.) are expected to reduce the potential risk of hatchery production on the genetics and success of wild populations; however, artificial selection for traits that assure individual success in a hatchery setting (e.g., rapid growth and tolerance to crowding) are difficult to avoid (USBR 2004).

The potential for inter-breeding between Central Valley spring- and fall-run salmon stocks is generally identified as a genetic concern (Yoshiyama et al. 1998), however some studies indicate no evidence of natural hybridization among Chinook salmon runs despite the spatial and temporal overlap (Banks et al. 2000). Spring- and fall-run Chinook salmon were historically isolated in time and space during spawning; however, the construction of dams and reduction in flows has eliminated access to historical spawning areas of spring-run salmon in the upper tributaries and streams, forcing spring-run salmon to spawn in lower elevation areas also used by fall-run salmon (Yoshiyama et al. 1998). Although hybridization between spring- and fall-run salmon has been identified as a particular concern on the Feather River where both runs co-occur and as a potential concern for future restoration of salmon on the San Joaquin River downstream of Friant Dam, the genotypic proportions in the Butte Creek spring-run cluster farther from the fall-run versus the spring-run from Deer and Mill creeks, not closer as expected under the hybridization hypothesis (Banks et al. 2000). Deer and Mill creeks, as many of the other Central Valley tributaries, has a reduced risk of hybridization by the ability of the runs to segregate geographically within the watersheds.

Entrainment. The vulnerability of fall- and late fall-run Chinook salmon to entrainment and salvage at the SWP and CVP export facilities varies in response to multiple factors, including the seasonal and geographic distribution of juvenile salmon within the Delta, operation of Delta Cross Channel gates and Head of Old River Barrier, hydrodynamic conditions occurring within the central and southern regions of the Delta (e.g., Old and Middle rivers), and export rates. The losses of fish to entrainment mortality has been identified as an impact to Chinook salmon populations (Kjelson and Brandes 1989). Juvenile fall-run Chinook salmon tend to be distributed within the central and southern Delta where they have an increased risk of entrainment/salvage between January and April (see Table A-4a). Juvenile late fall-run Chinook salmon tend to be distributed within the Delta primarily between December and January and again between April and May (see Table A-4b). The effect of changing hydrodynamics within Delta channels, such as reversed flows in Old and Middle rivers resulting from SWP and CVP export operations, has the potential to increase attraction of emigrating juveniles into false migration pathways, delay emigration through the Delta, and directly or indirectly increase vulnerability to entrainment at unscreened diversions, risk of predation, and the duration of exposure to seasonally elevated water temperatures and other water quality conditions. SWP and CVP exports have been shown to affect the tidal hydrodynamics (e.g., water current velocities and direction). The magnitude of these hydrodynamic effects vary in response to a variety of factors that include the tidal stage and magnitude of ebb and flood tides, the rate of SWP and CVP exports, operation of the Clifton Court Forebay radial gate opening, and inflow from the upstream tributaries. Chinook salmon behaviorally respond to hydraulic cues (e.g., water currents) during both upstream adult and downstream juvenile migration through the Delta. During the past several years additional investigations have been designed using radio or acoustically-tagged juvenile Chinook salmon to monitor their migration behavior through the Delta channels and assess the effects of changes in hydraulic cues and SWP and CVP export operations on migration (Holbrook et al. 2009, Perry et al. 2010, San Joaquin River Group Authority 2010). These studies are ongoing

Besides direct mortality, salmon fitness may be affected by entrainment at diversions and delays in out-migration of smolts caused by reduced or reverse flows. Delays in migration due to water operations related to SWP and CVP export facilities can make juvenile salmonids more susceptible to many of the threats and stressors discussed in this section, such as predation, entrainment, harvest, exposure to toxins, etc. The quantitative relationships among changes in Delta hydrodynamics, the behavioral and physiological response of juvenile salmon, and the increase or decrease in risk associated with other threats is unknown, but the subject of a number of current investigations and analyses.

In addition to SWP and CVP exports, over 2,200 small water diversions exist throughout the Delta, in addition to unscreened diversions located on the tributary rivers (Herren and Kawasaki 2001). The risk of entrainment is a function of the size of juvenile fish and the slot opening of the screen mesh (Tomljanovich et al. 1978, Schneeberger and Jude 1981, Zeitoun et al. 1981, Weiserg et al. 1987, C. Hanson unpubl. data). Many of the juvenile salmon migrate downstream through the Delta during the late winter or early spring when many of the agricultural irrigation diversions are not operating or are only operating at low levels. Juvenile salmon also migrate primarily in the upper part of the water column and, as a result, their vulnerability to an unscreened diversion located near the channel bottom is reduced. No quantitative estimates have been developed to assess the potential magnitude of entrainment losses for juvenile Chinook salmon migration through the rivers and Delta, or the effects of these losses on the overall population abundance of returning adult fall-run and late fall-run Chinook salmon. Many of the larger water diversions located within the Central Valley and Delta (e.g., Glenn Colusa Irrigation District, Reclamation District 108 Wilkins Slough and Poundstone pumping plants, Sutter Mutual Water Company Tisdale pumping plant, Contra Costa Water District Old River and Alternaitve Intake Project intake, and others) have been equipped with positive barrier fish screens to reduce and avoid the loss of juvenile Chinook salmon and other fish species.

Power plants within the Plan Area have the ability to impinge juvenile Chinook salmon on the existing cooling water system intake screens. However, use of cooling water is currently low with the retirement of older units. Further, newer units are being equipped with a closed cycle cooling system that virtually eliminates the risk of impingement of juvenile salmon.

Exposure to toxins. Toxic chemicals have the potential to be wide spread throughout the Delta, or may occur on a more localized scale in response to episodic events (stormwater runoff, point source discharges, etc.). These toxic substances include mercury, selenium, copper, pyrethroids, and endocrine disruptors with the potential to impact fish health and condition, and adversely impact salmon distribution and abundance. Concern regarding exposure to toxic substances for Chinook salmon includes waterborne chronic and acute exposure, as well as bioaccumulation and chronic dietary exposure. For example, selenium is a naturally occurring constituent in agricultural drainage water return flows from the San Joaquin River that is subsequently dispersed downstream into the Delta (Nichols et al. 1986). Exposure to selenium in the diet of juvenile Chinook salmon has been shown to result in toxic effects (Saiki 1986, Hamilton et al. 1986, 1990, Saiki and Lowe 1987, Hamilton and Buhl 1990). Selenium exposure has been associated with agricultural and natural drainage within the San Joaquin River basin and refining operations adjacent to San Pablo and San Francisco bays. Other contaminants of concern for Chinook salmon include, but are not limited to: mercury, copper, oil and grease, pesticides, herbicides, and ammonia. As a result of the extensive agricultural development within the Central Valley, exposure to pesticides and herbicides has been identified as a significant concern for salmon and other fish species within the Plan Area (Bennett et al. 2001). Mercury and other metals such as copper have also been identified as contaminants of concern for salmon and other fish as a result of direct toxicity and tissue bioaccumulation adversely impacting fish (U.S. Environmental Protection Agency [EPA] 2006), as well as representing a human health concern

(Gassel et al. 2008). These materials originate from a variety of sources including mining operations, municipal wastewater treatment, agricultural drainage within the tributary rivers and Delta, non-point runoff, natural runoff and drainage within the Central Valley, agricultural spraying, and a number of other sources. The State Water Resources Control Board (SWRCB), Central Valley Regional Water Quality Control Board (CVRWQCB), U.S. EPA, U.S. Geological Survey (USGS), DWR, and others have ongoing monitoring programs designed to characterize water quality conditions and identify potential toxicants and contaminant exposure to Chinook salmon and other aquatic resources within the Plan Area. Programs are in place to regulate point source discharges as part of the National Pollutant Discharge Elimination System (NPDES) as well as programs to establish and reduce total daily maximum loads (TMDL) of various constituents entering the Delta. Changes in regulations have also been made to help reduce chemical exposure and reduce the adverse impacts to aquatic resources and habitat conditions within the Plan Area. These monitoring and regulatory programs are ongoing.

Sublethal concentrations of toxins may interact with other stressors to cause adverse effects to salmonids, such as increasing their vulnerability to mortality as a result of exposure to seasonally elevated water temperatures, predation, or disease (Werner 2007). For example, Clifford et al. (2005) found in a laboratory setting that juvenile fall-run Chinook salmon exposed to sublethal levels of a common parathyroid, esfenvalerate, were more susceptible to infectious hematopoietic necrosis virus than those not exposed to esfenvalerate. Juvenile Chinook salmon have a relatively extended period of Delta and estuarine residence of several months (Quinn 2005), which increases exposure and susceptibility to toxic substances in these areas. Adult migrating Chinook salmon may be less affected by these toxins because they are not feeding, and thus not bioaccumulating toxic exposure, and they are moving rapidly through the system.

Iron Mountain Mine, located adjacent to the upper Sacramento River, has been a source of trace elements and metals that are known to adversely affect aquatic organisms (Upper Sacramento River Fisheries and Riparian Habitat Advisory Council 1989). Storage limitations and limited availability of dilution flows have caused downstream copper and zinc levels to exceed salmonid tolerances and resulted in documented fish kills in the 1960s and 1970s (USBR 2004). The Environmental Protection Agency's Iron Mountain Mine remediation program has removed toxic metals in acidic mine drainage from the Spring Creek watershed with a state-of-the-art lime neutralization plant. Contaminant loading into the Sacramento River from Iron Mountain Mine has shown measurable reductions since the early 1990s.

Increased water temperature. Water temperature is among the physical factors that affect quality of habitat for salmonid adult holding, spawning and egg incubation, juvenile rearing, and migration. Adverse sublethal and lethal effects can result from exposure to elevated water temperatures at sensitive lifestages, such as during incubation or rearing. The Central Valley is the southern limit of Chinook salmon geographic distribution. As a result, increased water temperatures are often recognized as a particularly important stressor to California populations. Water temperature criteria for various lifestages of salmonids in the Central Valley have been developed by NMFS (2009). The tolerance of fall-run and late fall-run Chinook salmon to water temperatures depends on life stage, acclimation history, food availability, duration of exposure, health of the individual, and other factors such as predator avoidance (Myrick and Cech 2004, USBR 2004). Higher water temperatures can lead to physiological stress, reduced growth rate, delayed passage, *in vivo* egg mortality of spawning adults, pre-spawning mortality, reduced spawning success, and increased mortality of salmon (Myrick and Cech 2001). Temperature can also indirectly influence disease incidence and predation (Waples et al. 2008). Exposure to seasonally elevated water temperatures may occur as a result of reductions in flow as a result of upstream reservoir operations, reductions in riparian vegetation, channel shading, local climate and solar radiation. The installation of the Shasta Temperature Control Device in 1998, in combination with reservoir management to maintain the cold water pool, has reduced many of the temperature issues on the Sacramento River. During dry years, however, the release of cold water from Shasta Dam is still limited. As the river flows further downstream, particularly during the warm spring, summer, and early fall months, water temperatures continue to increase until they reach thermal equilibrium with atmospheric conditions. As a result of the longitudinal gradient of seasonal water temperatures, the coldest water and, therefore, the best areas for salmon spawning and rearing are typically located immediately downstream of the dam.

Increased temperature can also arise from a reduction in shade over rivers by tree removal (Watanabe et al. 2005). Because river water is typically in thermal equilibrium with atmospheric conditions by the time it enters the Delta, this issue is caused primarily from actions upstream of the Delta. As a result of the relatively wide channels that occur within the Delta, the effects of additional riparian vegetation on reducing water temperatures are minimal. The effects of climate change and global warming patterns, in combination with changes in precipitation and seasonal hydrology in the future have been identified as important factors that may adversely affect the health and long-term viability of Central Valley spring-run Chinook salmon (Crozier et al. 2008). The rate and magnitude of these potential future environmental changes, and their effect of habitat quality and availability for fall- and late fall-run Chinook salmon, however, are subject to a high degree of uncertainty.

A4.6 RELEVANT CONSERVATION EFFORTS

Results of salvage monitoring and extensive experimentation over the past several decades have led to identification of a large number of management actions designed to reduce or avoid the potentially adverse impacts of SWP and CVP export operations on salmon. Many of these actions have been implemented through SWRCB water quality permits (D-1485, D-1641), biological opinions issued on project export operations by NMFS, USFWS, and DFG, as part of CALFED programs such as the Environmental Water Account (EWA), and as part of CVPIA actions. As a result of these requirements, multiple conservation efforts exist to reduce entrainment of Chinook salmon by the SWP and CVP export facilities.

Several habitat problems that contributed to the decline of Central Valley salmonid species are being addressed and improved through restoration and conservation actions related to Endangered Species Act (ESA) Section 7 consultation, Reasonable and Prudent Alternatives, addressing temperature, flow, and operations of the Central Valley and State Water Projects, the Central Valley Regional Water Board decisions requiring compliance with Sacramento River water temperature objectives that resulted in installation of the Shasta Temperature Control Device in 1998, and EPA actions to control acid mine runoff from Iron Mountain Mine.

Biological opinions for SWP and CVP operations (e.g., NMFS 2009b) and other federal projects involving irrigation and water diversion and fish passage, for example, have improved or minimized adverse impacts to salmon in the Central Valley. In 1992, an amendment to the authority of the CVP through the Central Valley Project Improvement Act was enacted to give protection of fish and wildlife equal priority with other Central Valley Project objectives. From this act arose several programs that have benefited listed salmonids. The Anadromous Fish Restoration Program (AFRP) is engaged in monitoring, education, and restoration projects designed to contribute toward doubling the natural populations of select anadromous fish species residing in the Central Valley. Restoration projects funded through the AFRP include fish passage, fish screening, riparian easement and land acquisition, development of watershed planning groups, instream and riparian habitat improvement, and gravel replenishment. The Anadromous Fish Screen Program combines federal funding with state and private funds to prioritize and construct fish screens on major water diversions mainly in the upper Sacramento River. The goal of the Water Acquisition Program is to acquire water supplies to meet the habitat restoration and enhancement goals of the Central Valley Project Improvement Act (CVPIA), and to improve the ability of the U.S. Department of the Interior to meet regulatory water quality requirements. Water has been used to improve fish habitat for Central Valley salmon, with the primary focus on listed Chinook salmon and steelhead that provide incidental benefits to fall-run and late fall-run Chinook salmon by maintaining or increasing instream flows (Environmental Water Account) on the Sacramento River and the San Joaquin River at critical times, and to reduce salmonid entrainment at the SWP and CVP export facilities through reducing seasonal diversion rates during periods when protected fish species are vulnerable to export related losses.

Two programs included under CALFED, the Ecosystem Restoration Program (ERP) and the Environmental Water Account (EWA), were created to improve conditions for fish, including fall-run and late fall-run Chinook salmon, in the Central Valley. Restoration actions implemented by the ERP include the installation of fish screens, modification of barriers to improve fish passage, habitat acquisition, and instream habitat restoration. The majority of these actions address key factors and stressors affecting listed salmonids that incidentally benefit fall-run and late fall-run Chinook salmon. Additional ongoing actions include efforts to enhance fishery monitoring, and improvements to hatchery management to support salmonid production through hatchery releases.

A major CALFED ERP action currently underway is the Battle Creek Salmon and Steelhead Restoration Project. The project will restore 48 miles (77 km) of habitat in Battle Creek to support steelhead and Chinook salmon spawning and juvenile rearing at a cost of over $90 million. The project includes removal of five small hydropower diversion dams, construction of new fish screens and ladders on another three dams, and construction of several hydropower facility modifications to ensure the continued hydropower operations. It is thought that this restoration effort is the largest cold water restoration project to date in North America.

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) was formed to guide the implementation of CALFED ERP elements within the Delta (DFG 2007b). The DRERIP team has created a suite of ecosystem and species conceptual models, including fall-/late fall-run Chinook salmon, that document existing scientific knowledge of Delta ecosystems. The DRERIP team has used these conceptual models to assess the suitability of actions proposed in the ERP for implementation. DRERIP conceptual models were used in the analysis of proposed BDCP conservation measures.

The Vernalis Adaptive Management Program (VAMP) has implemented migration flow augmentation for the San Joaquin River basin to improve juvenile and adult migration for fall-run Chinook salmon (San Joaquin River Group Authority 2010). The VAMP program also includes seasonal reductions in SWP and CVP export rates and installation of the Head of Old River Barrier to further improve the survival of downstream migrating salmon. The program has been designed within the framework of adaptive management to improve the survival of juvenile salmon migrating from the river through the Delta while also providing an experimental framework to quantitatively evaluate the contribution of each action to fall-run Chinook salmon survival. Preliminary results of the VAMP survival studies have shown evidence that juvenile Chinook salmon survival is positively correlated with San Joaquin River flows during the spring emigration period, however no statistically significant relationship between juvenile salmon survival and SWP/CVP exports has been detected. The range of flows and SWP/CVP export rates that can be tested under the VAMP experimental design is relatively small (e.g., river flows from approximately 2000 to 7000 cfs with SWP and CVP export rates ranging from 1500 to 3000 cfs). In addition, during the experimental period installation of the Head of Old River Barrier has been precluded by federal court order to protect delta smelt. As a result of these and other factors, the level of additional protection that the VAMP has provided to naturally produced Chinook salmon during emigration downstream from the San Joaquin River and Delta, and the incremental contribution of the VAMP conditions to overall salmon survival and adult abundance, is uncertain. The VAMP experimental design and results of survival testing conducted to date is currently undergoing peer review and will also be the subject of a review conducted by the SWRCB. Based on results and recommendations from these technical reviews, the VAMP experimental design and testing program, as well as flow management for juvenile salmon migration on the San Joaquin River, is expected to be refined.

A4.7 RECOVERY GOALS

Because fall-run and late fall-run Chinook salmon are not listed for protection under either the federal or California ESA formal recovery goals will not be established. As part of other fishery management programs, such as the CVPIA and the SWRCB salmon doubling goal, goals and objectives have been established for Central Valley Chinook salmon.

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70 FR 52488. 2005. Final Rule: Endangered and Threatened Species; Designation of Critical Habitat for Seven Evolutionarily Significant Units of Pacific Salmon and Steelhead in California. Federal Register. 70: 52488

APPENDIX A5. DELTA SMELT *(HYPOMESUS TRANSPACIFICUS)*

A5.1 LEGAL STATUS

The U.S. Fish and Wildlife Service (USFWS) determined that delta smelt warranted listing as a threatened species under the federal Endangered Species Act (ESA) effective April 5, 1993. The listing decision was based on a substantial reduction in delta smelt abundance within the Bay-Delta estuary in a variety of fishery sampling programs, threats to its habitat, and the inadequacy of regulatory mechanisms to protect delta smelt (58 FR 12863). The delta smelt was listed as a threatened species under the California ESA on December 9, 1993. The Sacramento-San Joaquin Delta Native Fishes Recovery Plan, which includes delta smelt, was completed in 1996 (USFWS 1996). The recovery plan identified a number of specific criteria related to delta smelt abundance and geographic distribution that had to be met as a condition for assessing whether the species could be considered to have recovered and be eligible for potential de-listing. During the late 1990s and early 2000s, delta smelt met the criteria set out in the recovery plan. In response to several law suits, the USFWS conducted a five-year status review for delta smelt and, on March 31, 2004, concluded that delta smelt abundance remained relatively low compared to historical levels and that many of the threats to the species identified at the time of listing were still in existence, precluding de-listing of the species (USFWS 2004). Subsequent indices of delta smelt abundance based on results of California Department of Fish and Game (DFG) fishery sampling have shown that the abundance of delta smelt, in addition to other pelagic fish species, has declined substantially in recent years (collectively referred to as pelagic organism decline [POD]), reaching record low levels of abundance. In March 2006, the Center for Biological Diversity, the Bay Institute, and the Natural Resources Defense Council filed an emergency petition with USFWS requesting that the status of delta smelt be elevated from threatened to endangered under the federal ESA (Center for Biological Diversity et al. 2006). The emergency petition was not approved by USFWS. However, the USFWS on July 10, 2008 announced in a 90-day finding that consideration for reclassification of delta smelt was warranted and, after an information collection stage, a status review would be initiated (73 FR 39639). On April 7, 2010, the USFWS ruled that the change in status from threatened to endangered was warranted, but precluded by other higher priority listing actions (75 FR 17667).

An emergency petition was filed in February 2007 to the California Fish and Game Commission to elevate the status of delta smelt from threatened to endangered under the California ESA (the Bay Institute et al. 2007). On March 4, 2009, the California Fish and Game Commission elevated the status of delta smelt to endangered under the California ESA.

A5.2 SPECIES DISTRIBUTION AND STATUS

A5.2.1 Range and Status

Delta smelt are endemic to the Bay-Delta estuary (see Figure A-5a) (Moyle 2002). The geographic distribution of delta smelt occurs primarily downstream of Isleton on the Sacramento River, downstream of Mossdale on the San Joaquin River, and Suisun Bay and Suisun Marsh. Delta smelt have also been collected in the Petaluma and Napa rivers. Delta smelt adults occur primarily in the tidally influenced low salinity region of Suisun Bay and the freshwater regions of the Delta and the Sacramento and San Joaquin rivers (Moyle 2002). The downstream location of the low salinity habitat for delta smelt is typically located in Suisun Bay, extending further to the west in response to high delta outflows and further to the east in response to low delta outflows. Delta smelt have been collected in Carquinez Strait, the Napa River, and even as far downstream as San Pablo Bay in wet years (Moyle 2002). In September or October, adults begin upstream movement towards freshwater sloughs and channels of the western Delta to spawn. Spawning takes place between February and July, but appears to be greatest during mid-April and May (Bennett 2005). Spawning can occur in the Sacramento River as far upstream as Sacramento, the Mokelumne River system, and the Cache Slough region (Moyle 2002). Since 1982, the center of adult delta smelt abundance in the fall has been the northwestern Delta in the channel of the Sacramento River near Decker Island. In any month, two or more life stages (adult, larvae, and juveniles) of delta smelt have the potential to be present in Suisun Bay (Wang 1991, DWR and USBR 1994, Moyle 2002). Delta smelt are also found seasonally in Suisun Marsh.

Results of multiple long-term monitoring programs that include a variety of sampling methods have consistently shown that the abundance of delta smelt inhabiting the Bay-Delta system has been extremely low since 2001 (see Figure A-5b). The observed decline in delta smelt abundance is consistent with declines of other pelagic species in the Delta. The decline in pelagic fish species abundance within the estuary has prompted a large set of investigations funded by the Interagency Ecological Program (IEP), CALFED, and other sources to identify and examine various factors that may be causing these declines (Resources Agency 2007). Indices of delta smelt abundance in the fall, as reflected in the DFG fall mid-water trawl (FMWT) surveys were the lowest on record in 2006 (see Figure A-5b).

A5.2.2 Distribution and Status in the Plan Area

Delta smelt occur throughout the Delta, Suisun Bay and Suisun Marsh, and within the Napa and Petaluma rivers (see Figure A-5a). Multiple permanent sites sampled by DFG and USFWS using many different collection methods intended to sample various life history stages of delta smelt provide a basis for examining trends in abundance of delta smelt under different hydrologic conditions as well as the temporal and geographic distribution of the species within and among years (see Figure A-5c).

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Figure A-5a. Delta Smelt Inland Range in California

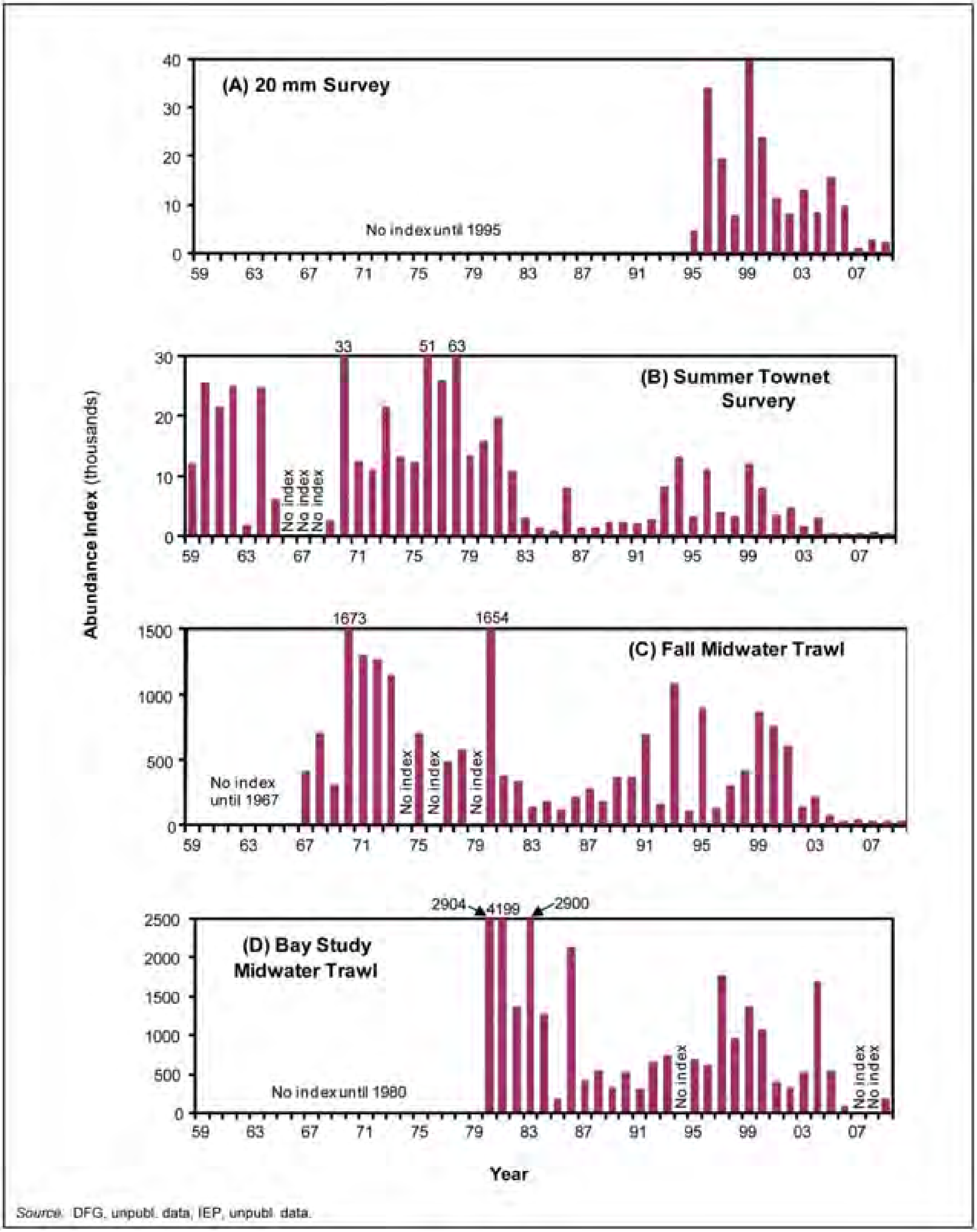

Figure A-5b. Annual Abundance Indices of Delta Smelt from 1959-2009 in (A) 20-mm Trawl Survey, (B) Summer Townet Survey, (C) Fall Midwater Trawl, and (D) Bay Study Midwater Trawl

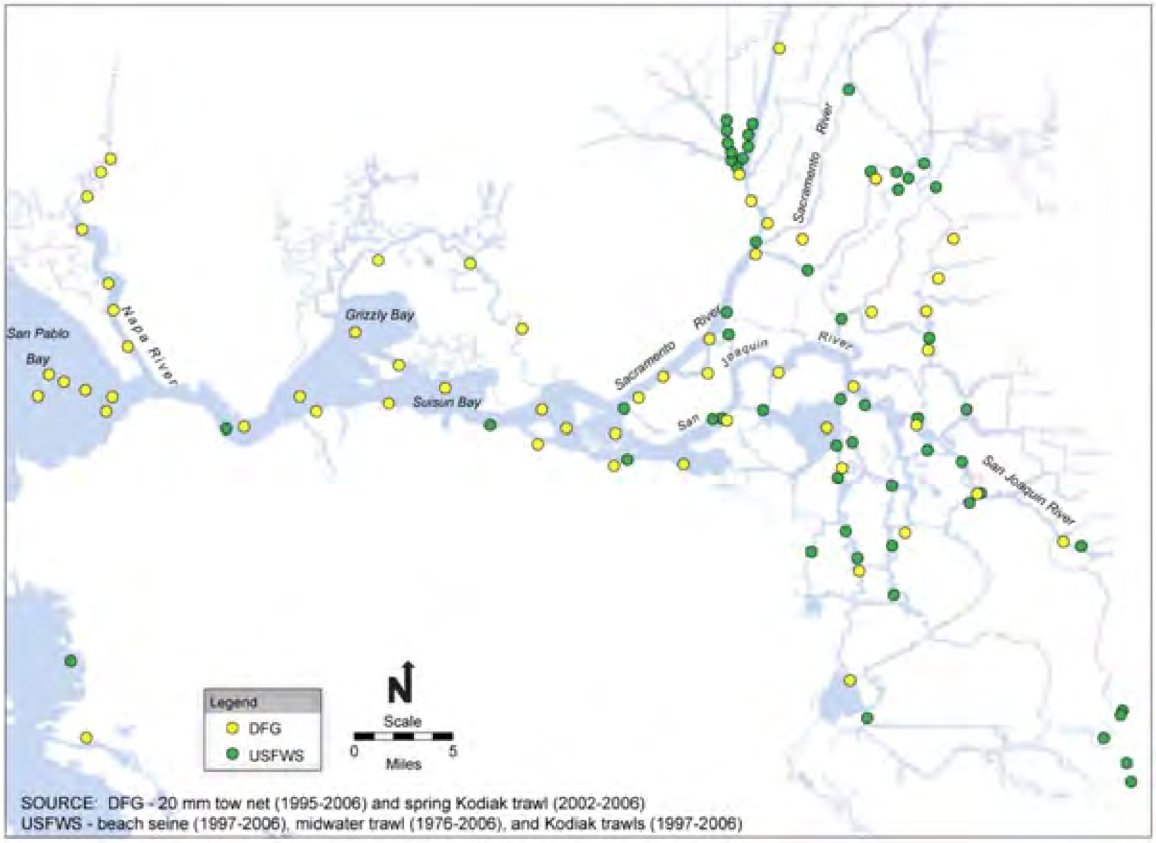

Figure A-5c. Historical Sampling Locations where Delta Smelt Have Been Captured Since 1976

Results of these fishery surveys, in addition to past records and habitat conditions for delta smelt, have been used to determine the current trends in abundance (see Figure A-5b). Trends in all four indices shown in Figure A-5b indicate that delta smelt population size has been at historical lows over the past several years.

Recent evidence suggests that a fairly large proportion of the delta smelt population over-summers in the Cache Slough region (Sommer et al. 2009). It is suspected that turbidity and prey abundance in the region are sufficient to preclude young delta smelt to migrate downstream towards the south and western Delta.

A5.3 HABITAT REQUIREMENTS AND SPECIAL CONSIDERATIONS

Critical habitat was designated by USFWS for the delta smelt under the federal ESA effective January 18, 1995 (59 FR 65256). The designated critical habitat extends throughout Suisun Bay (including Grizzly and Honker bays), the length of Goodyear, Suisun, Cutoff, first Mallard and Montezuma sloughs, and the contiguous waters of the legal Delta (see Figure A-5d) (59 FR 65256).

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Figure A-5d. Delta Smelt Designated Critical Habitat

Designation of critical habitat for delta smelt was intended to provide additional protection under section 7 of the ESA with regard to activities that require federal agency action.

Delta smelt inhabit the low salinity (brackish water/fresh water interface) waters in the upper Bay-Delta estuary. Bennett (2005) found that over 90 percent of juvenile and pre-adult delta smelt caught in the DFG Summer Townet Survey and DFG Fall Midwater Trawl Survey, respectively, were collected in salinities lower than 6 practical salinity units (psu) (Bennett 2005).

Because the location of the low salinity zone is determined by the interaction of river outflow and tidal inflow of marine water from San Francisco Bay, the daily distribution of adult delta smelt can vary by many kilometers (Bennett 2005) in response to the tidal dynamics of the estuary. The location of the low salinity zone during the late winter and spring (e.g., February-June), commonly referred to as the X2 location (location of the 2 parts per thousand [ppt] bottom salinity isohaline), has been used as an indicator of habitat conditions for delta smelt and other estuarine fish and macroinvertebrates. The location of X2, which varies seasonally and inter-annually, is used as one of the parameters in assessing the effects of changes in freshwater outflow on estuarine habitat conditions.

Delta smelt are most often collected in shallow, low-salinity water upstream of the low salinity zone (about 0.5-6 psu) (Kimmerer 2004), except during spawning (K. Fleming, DFG, pers. comm.). Moyle et al. (1992) reported that delta smelt were collected primarily from waters with a mean salinity of 2 ppt and having a mean temperature of 15 °C (59 °F), but were found in salinities ranging from 0-14 ppt and at temperatures ranging from 6 °C to 23 °C (43 °F to 73 °F). A correlation has also been observed between the geographic distribution and occurrence of sub-adult and adult delta smelt in the State Water Project (SWP) and Central Valley Project (CVP) fish salvage and turbidity within the Delta (D. Fullerton unpubl. data.). Sub-adult and adult delta smelt densities are positively correlated with turbidity. Two hypotheses have been suggested for the observed correlation that include: (1) greater feeding ability; and (2) greater predator avoidance in higher turbidity. Delta smelt larvae require high microzooplankton densities during the spring months to support rapid growth and development (Miller 2007).

A5.4 LIFE HISTORY

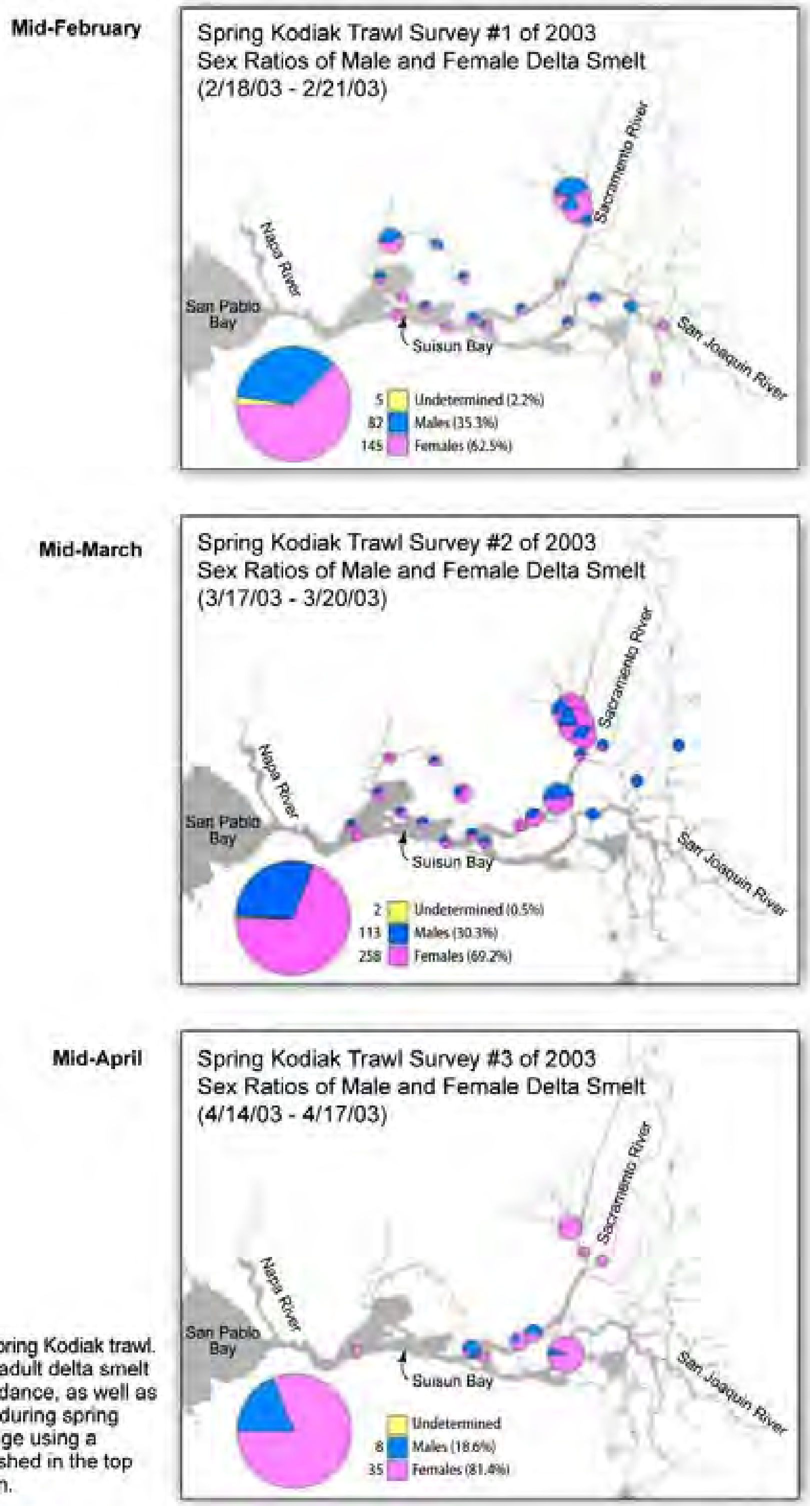
Delta smelt inhabit open surface waters of the Delta and Suisun Bay, where they may gather together in loose aggregations. Delta smelt are semi-anadromous, spawning in freshwater areas within the Delta and tributaries (the exact spawning location of delta smelt is unknown) from February to July at water temperatures ranging from approximately 7°C to 22°C (45°F to 72°F; Wang 1986, Bennett 2005). Shortly before spawning, adult smelt migrate upstream to disperse widely into river channels and tidally-influenced backwater sloughs (Radtke 1966, Wang 1991, Moyle 2002). Although the exact location of delta smelt spawning is unknown, sampling of larval smelt in the Delta suggests spawning occurs in the Sacramento River, Barker, Lindsey, Cache, Georgiana, Prospect, Beaver, Hog, and Sycamore sloughs, in the San Joaquin River off Bradford Island including Fisherman's Cut, False River along the shore zone between Frank's and Webb tracts, and possibly other areas (Wang 1991). Recent DFG sampling has suggested that spawning is often centered in Cache Slough and the lower end of the Sacramento Deep-Water Ship Channel (DFG 2007a). Although delta smelt spawning behavior has not been observed in the wild (Moyle et al. 1992), it is thought that their adhesive, demersal eggs attach to substrates such as cattails, tules, tree roots, and submerged branches in shallow waters (Wang 1991, Moyle 2002). Laboratory experiments indicate that delta smelt spawn mainly at night, broadcasting their eggs while swimming against the current. Cultured delta smelt broadcast eggs mainly over gravel, but preferred substrates in the wild are unknown. Eggs incubate from eight to fifteen days, depending upon water temperature (Bennett 2005). Temperatures that are optimal for survival of embryos and larvae have not yet been determined, although survival of newly spawned larvae and older delta smelt appear to decrease at temperatures over 20 °C (68 °F) (Swanson and Cech 1995, Bennett 2005). Delta smelt of all sizes are found in the main channels of the Delta and Suisun Marsh and the open waters of Suisun Bay, where the waters are well oxygenated and temperatures are relatively cool, usually lower than 20-22 °C (68-72 °F) in summer. Although delta smelt tolerate a wide range of temperatures (less than 6 °C [43 °F] to greater than 25 °C [77 °F]), warmer water temperatures restrict their distribution more than colder water temperatures (Swanson and Cech 1995). Over 90 percent of juvenile and pre-adult delta smelt caught in the DFG Summer Townet Survey and DFG FMWT Survey, respectively, were collected at water temperatures lower than 20 °C (68 °F; Bennett 2005). When not spawning, delta smelt tend to concentrate near the low salinity zone, where primary productivity and zooplankton densities are typically greatest (Knutson and Orsi 1983, Orsi and Mecum 1986). Other than newly hatched larvae, all life stages of delta smelt are found in greatest abundance in the top 2 m of the water column and are not usually in close association with the shoreline (Moyle 2002).

Newly hatched delta smelt larvae have a large oil globule that makes them semi-buoyant, allowing the larvae to maintain themselves just off the bottom (R. Mager, unpublished data), where they feed on rotifers and other microscopic prey. Once the swim bladder develops, larvae become more buoyant and rise higher in the water column. It is thought that, at this stage (16-18 mm total length), delta smelt take advantage of tidal flows to move downstream until they reach the low salinity zone or the area immediately upstream of it. Net downstream flows are thought to be important for physical transport of planktonic larval delta smelt towards suitable rearing habitat in the western Delta and Suisun Bay. Prior to 2004, intermediate outflow years tended to produce the greatest abundance of delta smelt, although production was highly variable among years and in response to environmental conditions such as Delta outflow (Moyle 2002, Bennett 2005). It has been hypothesized that very low flows into and through the Delta were insufficient to transport larvae downstream to suitable rearing habitat where sufficient food resources were available to support growth and development. It has also been hypothesized that very high delta outflows may have flushed larval delta smelt downstream into the western region of Suisun Bay or San Pablo Bay where larval and juvenile rearing conditions and habitat suitability are reduced. In recent years, however, low flows appear to provide better habitat conditions for delta smelt than in earlier years (Bennett pers. comm. 1).

Feeding success is highly dependent upon prey densities (Nobriga 2002). Miller and Mongan (2006) have shown a strong correlation between the spatial and temporal co-occurrence of early lifestages of delta smelt and densities of suitable zooplankton for forage and subsequent delta smelt abundance at older lifestages. Growth is rapid and juveniles grow to 40-50 mm total length by early August (Erkkila et al. 1950; Ganssle 1966; Radtke 1966). Delta smelt reach 55-70 mm standard length in 7-9 months (Moyle 2002). Growth during the next 3 months slows down considerably (only 3-9 mm total), presumably because most of the energy ingested is directed towards gonadal development (Erkkila et al. 1950; Radtke 1966).

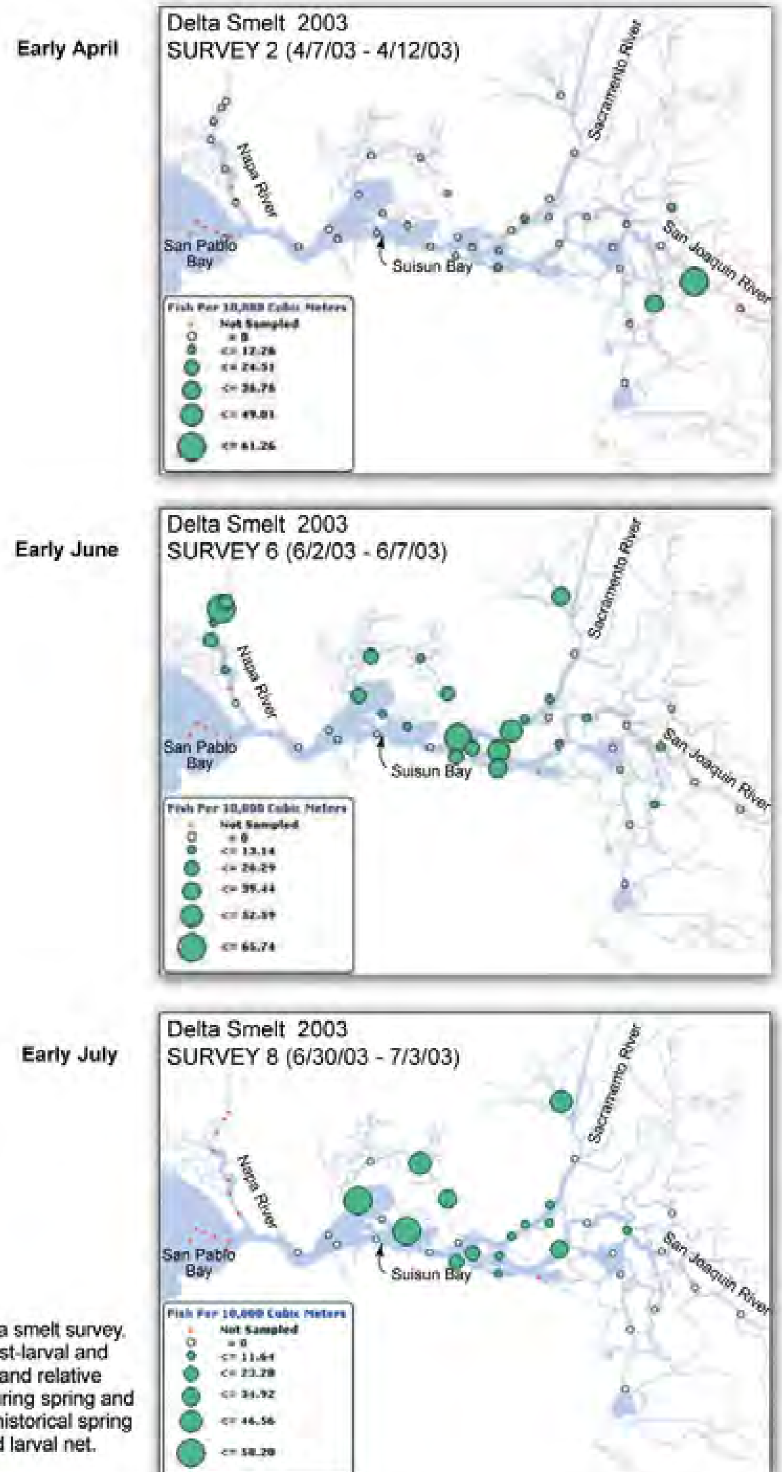
Yearly surveys by DFG (e.g., spring Kodiak trawl and 20 mm survey) provide the ability to track the geographic distribution of delta smelt within the estuary. Kodiak trawls target adult spawning delta smelt in spring months; the 20 mm townet survey targets post-larval and juvenile delta smelt from approximately March-August. Spatial patterns in the abundance of adults from the Spring Kodiak trawl and post-larval/juveniles from the 20 mm survey are shown in Figures A-5e and A-5f, respectively, based on sampling results from surveys conducted in 2003, which was a normal water year. Results of fishery surveys suggest that the geographic distribution of pre-spawning adult delta smelt in the winter and early spring does not vary substantially in response to seasonal and inter-annual variation in inflows to the Delta. Instead, it has been hypothesized that the distribution of pre-spawning delta smelt is a response to staging and foraging prior to spawning and associations with suitable habitat conditions, such as substrate, for spawning. The geographic distribution of larval and early juvenile lifestages of delta smelt appears to be influenced by freshwater inflows to the Delta during the late winter and spring. It has been hypothesized that higher Delta inflows result in faster larval planktonic transport rates from the upstream spawning habitat to the downstream estuarine portions of the Delta. In addition, when Delta inflows are high, the location of the low salinity zone is further west (downstream) and larval and early juvenile delta smelt are frequently observed further downstream within Suisun Bay. Fecundity of delta smelt is relatively low. Mager (1996) reported a length/fecundity range spanning 1,196 eggs for a 56-mm female to 1,856 eggs for a 66-mm female. Captive-reared females may be more fecund than the same size wild female; however, the variability in the length-fecundity relationship also appears to be greater for captive females (B. Baskerville-Bridges, pers. comm. as cited in Bennett 2005). The abrupt change from a single-age, adult cohort during spawning in spring to a population dominated by juveniles in summer suggests strongly that most adults die after they spawn (Radtke 1966, Moyle 2002). However, a small unknown fraction of the adult delta smelt population may survive to become two-year-old fish and spawn in the subsequent year (Moyle 2002). It has been hypothesized that because of their larger size and increased fecundity, two-year-old adults may exert a small or intermittent, but important, reproductive influence in years following poor recruitment (Bennett 2005).

In a near-annual fish like delta smelt, maximizing recruitment success is vital to the long-term persistence of the population. However, investigations using the Beverton-Holt model have found that stock-recruitment relationships accounted for only approximately one quarter of the variability observed in recruitment (Sweetnam and Stevens 1993, Bennett 2005).



Source: DFG 2003, 20 mm Spring Kodiak trawl. This annual survey monitors adult delta smelt distribution and relative abundance, as well as sex ratio and gonadal stage, during spring throughout their historical range using a variable mesh Kodiak trawl fished in the top 6 feet (1.8 m) of water column. For more information see http://www.delta.dfg.ca.gov/data/skt/

Figure A-5e. Example of Distribution of Adult Delta Smelt in Spring-Summer of a Representative Above Normal Water Year



Source: DFG 2003, 20 mm delta smelt survey. This annual survey monitors post-larval and juvenile delta smelt distribution and relative abundance every two weeks during spring and early summer throughout their historical spring range using a 1600 µm egg and larval net. For more information see http://www.delta.dfg.ca.gov/data/20mm/description.asp

Figure A-5f. Example of Distribution of Post-Larval/Juvenile Delta Smelt in Spring-Summer of a Representative Above Normal Water Year

The weak stock-recruitment relationship does indicate, however, that factors affecting the numbers of spawning adults (e.g., entrainment, toxics, and predation) can influence delta smelt abundance (cohort strength) the following year.

Results of more recent evaluations suggest that density-dependent mortality may influence the number of juveniles that reach pre-adulthood in some years, even at the current low level of abundance (Bennett 2005).

Delta smelt feed primarily on planktonic copepods, cladocerans, amphipods, and, to a lesser extent, on insect larvae. Larger delta smelt may also feed on the mysid shrimp, *Neomysis*. The most important food organism for all sizes of delta smelt appears to be the euryhaline copepod, *Eurytemora*, although the non-native *Pseudodiaptomus* has become a major part of the diet since its introduction (Moyle et al. 1992, Nobriga 2002). Nobriga (2002) noted that decades-long declines in the abundance of zooplankton prey organisms such as *Eurytemora* and *Pseudodiaptomus* indicate that delta smelt prey densities have also declined. Recent unpublished analyses by Miller and Mongan (2006) suggest that a decline in the co-occurrence of juvenile delta smelt and their prey may have contributed to their decline in abundance.

A5.5 THREATS AND STRESSORS

There are multiple threats and stressors to delta smelt that appear to act in complicated and synergistic ways to influence the distribution and abundance of delta smelt (Moyle 2002). Individual stressors affect delta smelt at different times based on environmental conditions. Delta smelt are particularly vulnerable to these threats and stressors because of their short life span, low fecundity, low current abundance, and limited geographic range.

Reduced food availability. Reduced food availability in the Bay-Delta estuary has been identified as a major stressor to delta smelt (Resources Agency 2007). The co-occurrence of suitable food supplies (zooplankton) and various life stages of delta smelt (e.g., larval and juvenile life stages) as appears to be an important factor affecting delta smelt survival and abundance (Feyrer et al. 2007, Miller 2007). Histological examination of liver and other tissue collected from delta smelt has shown evidence of necrosis and pathology related to reduced foraging and depleted energy reserves. Furthermore, the size of delta smelt has declined through time. There are at least seven mechanisms briefly described here (without priority) that potentially contribute to the observed reduction in zooplankton prey densities.

First, levee construction, island reclamation, and channelization within the Delta has resulted in a substantial reduction in intertidal and shallow-water subtidal wetland/emergent marshes and open water habitat throughout the Delta. Historically, Delta wetlands and shallow-water habitat was expansive and provided large areas of estuarine and freshwater habitat that was highly productive. The significant reduction in tidal and shallow-water subtidal habitat, and an associated reduction in emergent vegetation, nutrient cycling, and the production of phytoplankton, zooplankton, macroinvertebrates, and other aquatic organisms that provide food resources for delta smelt has been identified as a major factor affecting habitat conditions within the Delta for species such as delta smelt.

Second, much of the seasonally inundated floodplain habitat in the Delta and tributary rivers has been eliminated by levees and reclamation. As a result of levee construction, flood control, and increased reservoir storage, the frequency of inundation on floodplains that still exist has been reduced (Resources Agency 2007). Floodplains are highly productive due to their shallow, warm, low velocity water (Sommer et al. 2001a, b) and input of organic material and nutrients from the terrestrial community (Booth et al. 2006). Floodplains are a key source of nutrients and organic material for the Bay-Delta estuary (Sommer et al. 2001a, Harrell and Sommer 2003).

Third, hydraulic residence time in the Delta has declined as a result of increased channelization and passage of Sacramento River water through the Delta Cross Channel into the central and southern Delta to meet water quality standards and supplies for the SWP and CVP exports. The decreased hydraulic residence time reduces the time available for production of phytoplankton and zooplankton that provide food for delta smelt and other aquatic species and for bacteria to use nutrients and organic carbon (Jassby et al. 2002, Kimmerer 2002a, 2004, Resources Agency 2007).

Fourth, the presence of non-native species has reduced the abundance of food available to delta smelt. The efficient filter feeding and high abundance of the overbite clam has dramatically reduced phytoplankton and zooplankton abundance in Suisun Bay, the western Delta, and Suisun Marsh since its introduction in the mid 1980s (Kimmerer and Orsi 1996). The Asian clam has also reduced phytoplankton abundance in the Delta, which likely reduced zooplankton abundance (Jassby et al. 2002, Thompson 2007). Other non-native zooplanktivores that likely compete for limited available food resources with delta smelt include threadfin shad, inland silverside, and wakasagi.

Fifth, the zooplankton community inhabiting the Bay-Delta estuary has changed multiple times since the 1970s as non-native species have established and outcompeted other zooplankton species (Resources Agency 2007, Sommer 2007). These changes in the zooplankton species composition have affected the quality of food resources available to delta smelt because some of the non-native species do not appear to be as suitable a food resource as the native species (Resources Agency 2007). Most recently, *Limnoithona*, a non-native cyclopoid copepod, invaded the Delta. This copepod is smaller than preferred forage species, *Pseudodiaptomus* and *Eurytemora* (Lott 1998), may be protected from predators by spines (Orsi and Ohtsuka 1999), and, therefore, is thought to be lower quality food for delta smelt (Resources Agency 2007). Preliminary laboratory work by Sullivan et al. (2007, 2008) indicates that larval delta smelt consume these copepods according their size. Also, adult delta smelt, which are larger and need greater amounts of food, may prefer the larger *Pseudodiaptomus* and *Eurytemora* over *Limnoithona*. A decrease in foraging efficiency and/or the availability of suitable prey for various lifestages of delta smelt would result in reduced growth, survival, and reproductive success contributing to reduced population abundance.

Sixth, SWP and CVP exports and the over 2,200 in-Delta agricultural diversions (Herren and Kawasaki 2001) export phytoplankton, zooplankton, nutrients, and organic material that would otherwise support the base of the food web in the Delta, thus reducing food availability for delta smelt (Jassby and Cloern 2000, Resources Agency 2007).

Seventh, it has been hypothesized that exposure of phytoplankton and zooplankton to toxics (e.g., pesticides, herbicides) that enter the Delta from point and non-point sources contribute to the observed low abundance of zooplankton prey species for delta smelt and other species inhabiting the Bay-Delta (Weston et al. 2004, Luoma 2007, Werner 2007). In addition to direct impacts of toxics on delta smelt, such as liver damage and other pathologic symptoms, the indirect effect of toxics on reducing zooplankton and phytoplankton abundance is thought to result in reduced availability of food resources for delta smelt.

Municipal wastewater treatment plants, particularly the Sacramento Regional County Sanitation District's wastewater treatment plant, discharges high loads of ammonia directly into the Sacramento River in the North Delta (Jassby 2008). Results of a recent investigations suggest that high concentrations of ammonium, the ionized form of ammonia, can inhibit diatom production in San Francisco and San Pablo bays (Wilkerson et al. 2006, Dugdale et al. 2007), which could disrupt the foodweb, ultimately resulting in reduced food for delta smelt and other Delta fish species. The source of this ammonium in the bays is unknown, but could come from wastewater treatment plants. Recent preliminary investigations have also examined the role of ammonium in inhibiting freshwater diatom production in the Delta, although results are inconclusive (Parker and Dugdale 2008).

Reduced rearing habitat. Availability of rearing habitat for delta smelt is less dependent on physical substrate and more dependent on water column conditions. There is evidence that the availability and suitability of delta smelt rearing habitat varies with location of the low salinity zone, measured as X2 (Moyle et al. 1992) , although there is no long-term trend indicating that X2 has changed nor is there strong evidence that X2 predicts delta smelt abundance (Armor et al. 2006). Guerin et al. (2006) reported correlations between reductions in fall delta outflow, salinity changes, and indices of delta smelt abundance. State Water Board Decision 1641 (D1641, State Water Resources Control Board [SWRCB] 2000) establishes criteria for maintenance of X2 at specific locations within Suisun Bay and the western Delta by month and water year type. The maintenance of this standard substantially affects when water can be exported from the Delta at the CVP and SWP pumps. SWP and CVP exports were reduced to protect aquatic resources in the spring with a resulting increase in export operations during the summer and fall.

The location of the low salinity zone within Suisun Bay and the western Delta varies in response to the magnitude of freshwater outflow from the Delta and saltwater intrusion from San Francisco and San Pablo bays. The low salinity zone, when positioned over shallow water shoal areas in Suisun Bay in response to Delta outflows, is thought to result in highly productive conditions (Moyle et al. 1992, Bennett et al. 2002, Kimmerer 2004, Bennett 2005). Aasen

(1999) observed higher abundance of delta smelt in shallow water shoal habitat compared to adjacent deep water channels and Hobbs et al. (2006) found evidence that the health and survival of delta smelt were greater in habitats associated with shallow water. When located upstream of the confluence of the Sacramento and San Joaquin rivers, however, the low salinity zone is confined to the deep river channels, resulting in a smaller total surface area, few shoal areas, swifter, more turbulent water currents, and lower zooplankton productivity (USFWS 2004).

Feyrer et al. (2007) developed an index of fall habitat quality for delta smelt based on statistical regression models of delta smelt catches in DFG fishery sampling at specific sampling locations throughout the Delta and Suisun Bay and water quality parameters (salinity, turbidity, and water temperature) measured for each sample. There is substantial debate over whether this index is meaningful to the delta smelt population.

As the geographic distribution of delta smelt shifts upstream with X2, individuals may become more vulnerable to entrainment by the SWP and CVP export facilities and other diversions within the interior of the Delta.

The Suisun Marsh Salinity Control Gates function to decrease salinity in managed wetlands of Suisun Marsh to support crops that attract waterfowl to duck clubs located throughout the marsh. When in operation, generally from October through May, the control gates near Collinsville divert up to 2,500 cubic feet per second (cfs) of freshwater from upstream flows into the marsh. Because the minimum outflow standard during fall months is 5,000 cfs, a significant proportion of total Delta outflow (up to 50 percent) does not flow through the eastern Suisun Bay region. This diversion moves X2 upstream resulting in a measurable increase in salinity in eastern Suisun Bay, which may correspond to a decrease in low salinity habitat for delta smelt (Fullerton 2007)

Elevated water temperatures. Delta smelt are sensitive to exposure to elevated water temperatures (Swanson and Cech 1995). During the late spring, summer, and early fall months water temperatures within the central and southern regions of the Delta typically exceed 25 °C (77 °F), which has been found to be close to the incipient lethal temperature for delta smelt. During these warmer periods of the year, results of fishery sampling have shown that delta smelt avoid inhabiting the central and southern regions of the Delta and are typically located downstream in Suisun Bay and Suisun Marsh. It is generally thought that water temperatures within the Delta vary in response to seasonal air temperatures and solar radiation, and are largely independent of freshwater inflow to the Delta during the summer months (flow rate has been identified as a factor affecting water temperatures in the rivers; however, the influence decreases with distance downstream in the lower rivers and Delta). As a result of coastal fog and marine conditions along the coast and within San Francisco Bay, water temperatures during the summer typically decrease within Suisun Bay when compared to conditions further upstream within the Delta. Although water temperatures are cooler within Suisun Bay during the summer months, water temperatures in excess of 20 °C (68 °F) are typical. Under these warmer summer conditions, delta smelt rearing in Suisun Bay and Suisun Marsh would be stressed by exposure to elevated water temperatures and experience higher metabolic demands and a greater demand for food supplies to maintain individual health and a positive growth rate. Stresses experienced by rearing delta smelt during the warmer summer months, which include the synergistic effects of salinity and seasonally elevated water temperatures, have been hypothesized to be a potentially significant factor affecting delta smelt survival, abundance, and subsequent reproductive success within the Bay-Delta estuary.

Reduced turbidity. Delta smelt appear to have specific turbidity requirements that can influence predation risk and foraging efficiency. Turbidity is a significant predictor of delta smelt occurrence in the Delta (Feyrer et al. 2007, Resources Agency 2007, Nobriga et al. 2008, Grimaldo et al. 2009). That is, delta smelt occurrence increases with higher turbidity. Fullerton (unpubl. data) has demonstrated a correlation between the occurrence of delta smelt and elevated levels of turbidity (above approximately 12 nephelometric turbidity units). It is thought that delta smelt require turbidity for both successful foraging (Baskerville-Bridges et al. 2004) and predator escape (Feyrer et al. 2007), and that turbidity is an important cue for delta smelt spawning migrations (Grimaldo et al 2009). Results of laboratory studies indicate that, in low turbidity waters, delta smelt move to the edge of aquaria and stop swimming, presumably to reduce vulnerability to predation (D. Fullerton unpubl. data). Results of laboratory studies have also demonstrated that delta smelt reduce or stop foraging when turbidity is low and actively forage when turbidity is increased. It was hypothesized that increased turbidity levels provide a more favorable background and contrast that allows delta smelt a better opportunity to detect and effectively capture zooplankton prey.

Turbidity levels have declined in the Bay-Delta estuary since the 1970s (Kimmerer 2004, Wright and Schoellhamer 2004, Feyrer et al. 2007, Fullerton 2007). This trend can be attributed to multiple causes. First, upstream sediment inputs have been reduced due to a range of anthropogenic actions (Jassby et al. 2002, Kimmerer 2004), including depletion of erodable sediments from hydraulic mining in the 1800s, river bank protection, trapping of sediments by dams and reservoirs, levee construction that has reduced floodplain inundation and channel meanders, and changes in land use (Wright and Shoellhamer 2004). Wright and Shoellhamer (2004) estimated that the yield of suspended sediments from the Sacramento River declined by approximately one half from 1957 to 2001.

Second, the distribution and abundance of non-native aquatic plant species, particularly Brazilian waterweed (*Egeria*), have increased dramatically over the past 20 years (Nobriga et al. 2005, Brown and Michniuk 2007). Brazilian waterweed can reduce turbidity by reducing local water velocities and trapping fine suspended sediments (Grimaldo and Hymanson 1999, Nestor et al. 2003, Hobbs et al. 2006).

Third, the high filtering efficiency of the overbite clam has dramatically reduced phytoplankton and zooplankton abundance in the western Delta and Suisun Bay since its introduction (Kimmerer and Orsi 1996, Jassby et al. 2002, Kimmerer 2002b, 2004). The reduction in phytoplankton in the water column may contribute to increased water clarity and reduced turbidity in the Delta.

Fourth, hydraulic residence time in the Delta has declined as a result of increased channelization and the movement of water from the Sacramento River into the interior Delta channels to improve water quality and provide increased supplies to the SWP and CVP exports. SWP and CVP export operations have also directly resulted in changes in the hydrodynamics within Delta channels such as Old and Middle rivers which affect hydraulic residence time. Reduced hydraulic residence time reduces the ability of phytoplankton and bacteria to incorporate nutrients and carbon, ultimately reducing the abundance of these organisms in the water column (Jassby et al. 2002, Kimmerer 2002a, 2004, Resources Agency 2007). This reduction in phytoplankton and zooplankton abundance reduces the turbidity within the Bay-Delta estuary.

The observed reduction in Bay-Delta turbidity has the potential, in combination with other factors such as the effects of non-native species, to fundamentally alter the trophic dynamics of the estuary for species such as delta smelt.

Reduced spawning habitat. Although delta smelt spawning has not been observed within the Bay-Delta estuary, it is generally thought that spawning occurs in shallow, low-salinity upstream areas with sand or gravel substrate on which to deposit adhesive egg sacs (Moyle et al. 2004). Such habitat could occur in Cache Slough or in shallow shoals located in the Deep Water Ship Channel (Bennett 2007). The primary causes of reduced spawning habitat are believed to be reclamation, channelization, and riprapping of historical intertidal and shallow subtidal wetlands.

Non-native species. Predation by introduced species has been identified as a potential stressor on smelt populations (Sommer et al. 2007, Baxter et al. 2008), but the importance of predation on delta smelt abundance is thought to be low (Stevens 1966 as cited in Nobriga and Feyrer 2008, Feyrer et al. 2003, Nobriga and Feyrer 2007, 2008, Nobriga 2009a, Hanson 2009). There are several potential non-native fish predators of delta smelt that have been introduced into the Delta (Bennett 2005). Delta smelt have historically been a minor prey item of juvenile and subadult striped bass in the Delta (Stevens 1966, Bennett 2005), although predation does occur (M. Nobriga, pers. comm.). More recent studies indicate that delta smelt are rarely found in the stomachs of striped bass, largemouth bass or other nearshore predators (Feyrer and Nobriga 2008, Nobriga and Feyrer 2008). Delta smelt have also been reported from the stomach contents of white catfish and black crappie in the Delta (Turner and Kelley 1966). Threadfin shad and inland silversides, both planktivores, possibly eat delta smelt eggs, larvae, and small juveniles. Dense aggregations of silversides occur in shoreline habitats where delta smelt are thought to spawn and may consume delta smelt eggs and larvae (Bennett 2005). The largest single source of predation on delta smelt is thought to occur at or near the SWP and CVP south Delta pumping facilities (Sommer et al. 2007), and especially at Clifton Court Forebay. This predation is related to the number of smelt that are drawn to this area because of export-related changes in hydrology (Grimaldo et al. 2009, Kimmerer et al. 2009).

Competition with inland silversides could have a potentially large impact on delta smelt. Silversides are highly abundant throughout the delta smelt geographic range, their diet range encompasses that of delta smelt, and they spawn repeatedly throughout late spring, summer, and fall, thus providing silversides with a competitive advantage over delta smelt (Bennett 2005).

Wakasagi can occur in the delta smelt geographic range and have similar life requirements. Thus, they likely compete for food and spawning sites. Wakasagi have a higher tolerance to salinity and temperature and a wider geographic range than delta smelt, suggesting that they have a competitive advantage over delta smelt. Furthermore, the introduction of wakasagi has created the potential for a loss of genetic integrity of delta smelt, although the probability that hybridization could be successful is low (Moyle 2002). The two species are not closely related genetically and, although first generation hybrids have been collected, all of them have been sterile (Stanley et al. 1995, Trenham et al. 1998). If wakasagi abundance in delta smelt habitat were to increase dramatically, the risk of genetic introgression would be enhanced (Bennett 2005), although this does not appear to be a large concern at this time (K. Fisch pers. comm.). The recent decline in delta smelt abundance has likely made the species vulnerable to inbreeding and genetic drift, leading to decreased genetic variation and reduced evolutionary fitness (Center for Biological Diversity et al. 2006). However, no estimates currently exist for the minimum viable population size of delta smelt, nor have studies been conducted to evaluate changes in genetic diversity.

It has been hypothesized that the greatest impact of a non-native species on delta smelt is that resulting from colonization of the Bay-Delta estuary by the overbite clam. The clam has been identified as one of the major causes of the dramatic changes observed in the composition and abundance of the delta smelt zooplankton prey base. Because of its high filtration efficiency and dense populations in the western Delta and Suisun Bay, the clam has reduced phytoplankton and zooplankton abundance throughout the region (Kimmerer and Orsi 1996). The euryhaline copepod, *Eurytemora*, was historically the primary prey for all life stages of delta smelt. After the introduction of the overbite clam, the abundance of *Eurytemora* declined sharply, being replaced over much of its range by *Pseudodiaptomus* (Kimmerer and Orsi 1996, Bennett 2005). Although *Eurytemora* is still abundant during early spring, the population is replaced by *Pseudodiaptomus* in later spring, creating a period of low copepod abundance. Low food abundance can cause poor feeding success by larval and juvenile delta smelt, leading to slow growth, liver abnormalities associated with starvation, and, ultimately, reduced survival for cohorts that begin feeding during the period of low copepod abundance (Bennett 2005). In addition to the low copepod abundance period, *Pseudodiaptomus* are faster swimmers than *Eurytemora* and may lead to lower foraging efficiency, starvation, and reduced growth rates for delta smelt (Moyle 2002). Recent evidence suggests that the overbite clam may further negatively impact delta smelt by reducing their foraging efficiency by filtering large quantities of phytoplankton from the water column and increasing water clarity, potentially leading to the inability of delta smelt to forage effectively (Herbold, pers. comm.). The increase in water clarity may also increase the vulnerability of delta smelt to visual predators.

Brazilian waterweed and water hyacinth are fast growing and abundant aquatic plants that have had detrimental effects to the Bay-Delta aquatic ecosystem (Grimaldo and Hymanson 1999, Brown and Michniuk 2007, Feyrer et al. 2007). These non-native plant species grow in dense aggregations can indirectly affect delta smelt by reducing dissolved oxygen levels and reducing nearby flow rates, resulting in local reductions in suspended sediment concentrations and turbidity within the water column. Furthermore, because of the three dimensional structure and shade they provide, these aquatic plants likely create excellent habitat for non-native predators of delta smelt, primarily centrarchids (Nobriga et al. 2005). Because Brazilian waterweed has recently spread by as much as 10 percent per year in areal coverage (Ustin et al. 2008), its negative impacts on delta smelt may increase in future years.

Entrainment. Despite the number of delta smelt that have been entrained by the SWP and CVP export facilities and over 2,200 smaller diversions in the Delta (Herren and Kawasaki 2001), the direct impacts of water diversions on the overall population dynamics of delta smelt is not well understood and there is disagreement among experts about the magnitude of these impacts (Bennett 2005).

Several studies have been conducted that show correlative relationships between SWP and CVP exports and indices of delta smelt abundance, suggesting that entrainment may negatively impact delta smelt abundance (USFWS 2008). These relationships do not establish causality, but they are an indicator that salvage should be considered. Kimmerer (2008) reported results of an analysis of the potential effects of SWP and CVP entrainment losses on larval and adult delta smelt. Results of these analyses suggest that losses of adult delta smelt had a median value of 15 percent (range 1-50 percent) while the seasonal losses for juvenile delta smelt had a median value of 13 percent (range of 0-25 percent). Kimmerer (2008) concluded that the effect of these losses on population abundance of delta smelt was obscured by a 50-fold variation in the overall survival of delta smelt survival between summer and fall.

Guerin et al. (in review) found significant correlations between SWP winter salvage of adult smelt and subsequent FMWT index of delta smelt with 1 and 2 year lags over the past 12 years. More recent work shows that SWP winter salvage of adult delta smelt normalized to the prior FMWT correlates strongly with subsequent FMWT for delta smelt over a longer record.

Bennett (unpubl. data) found a significant negative correlation between winter and early spring salvage and delta smelt survival estimates (Brown and Kimmerer 2001). Swanson (2005) found that winter exports (December through March) were significantly negatively correlated with both the juvenile delta smelt abundance index from DFG summer townet surveys and the sub-adult and adult delta smelt abundance index from DFG FMWT surveys, although SWP and CVP exports explained only 15.5 and 2.4 percent of variation in juvenile and sub-adult/adult abundance indices, respectively. Herbold et al. (2005) reported that delta smelt salvage density relative to apparent abundance has increased markedly since 2002, concurrent with the POD. Manly and Chotkowski (unpubl. data) found a statistically significant correlation between delta smelt abundance and total exports, but the relationship explained only a small proportion of overall variation in delta smelt abundance (Miller 2007). As a result, Manly and Chotkowski assert that exports do not appear to play a large role in controlling delta smelt population abundance relative to other stressors (e.g., reduced food availability).

The risk of entrainment to delta smelt varies seasonally and among years. The most important entrainment risk has been hypothesized to occur during winter when pre-spawning adults migrate into the Delta in preparation for spawning (Moyle 2002, Bureau of Reclamation 2004). Patterns in SWP and CVP salvage data support this hypothesis (DFG, unpubl. data). Bennett (2005) has hypothesized that larger female delta smelt spawn earlier in the winter and are, therefore, more vulnerable to entrainment by export facilities. Larger females are more fecund, spawn repeatedly, and can produce more offspring with higher fitness than smaller females. As a result, Bennett hypothesized that entrainment during winter months may have a disproportionately large impact on the overall population dynamics of delta smelt than entrainment during other periods of the year.

Analyses conducted by P. Smith (unpubl. data) and J. Johns (unpubl. data) present results of an analysis of the relationship between the magnitude of reverse flows in Old and Middle rivers during the winter (January-February) and salvage of pre-spawning delta smelt at the SWP and CVP export facilities. Smith found a linear relationship between reverse flows and delta smelt salvage for January and February combined. Johns found a non-linear relationship between reverse flows and delta smelt salvage separately by month. Results of the non-linear model were statistically significant and showed that delta smelt salvage remained relatively low when reverse flows in Old and Middle rivers were below approximately -5,000 cfs. As reverse flows increased to greater than 5,000 cfs, delta smelt salvage increased substantially. Results of these analyses were used as the basis for a 2007 federal court decision regarding interim operational restrictions on SWP and CVP exports (Wanger decision) and the December 2008 delta smelt biological opinion for SWP and CVP operations by the USFWS (2008).

Entrainment risk for delta smelt has largely been based on analyses of SWP and CVP fish salvage. The fish salvage operation, however, only identifies and counts those individual fish greater than 20 mm in length. As a result, larval delta smelt smaller than 20 mm are not included in fish salvage estimates. Results of several preliminary estimates of the potential magnitude of larval delta smelt entrainment at the SWP and CVP export facilities have been made, as well as estimates of the population size of delta smelt that are intended to put entrainment losses into an population-level framework for evaluation (Hanson unpublished data). Estimates of entrainment losses for larval delta smelt and estimates of population abundance have been based on extrapolations from results of the DFG 20 mm delta smelt survey. These preliminary estimates have been criticized on the basis of a number of assumptions that are required to make the population and entrainment loss estimates that have not been tested or validated. Recognizing that larval delta smelt are vulnerable to SWP and CVP entrainment losses that may vary in magnitude and potential effect on the population among years, the federal district court ordered that a study be conducted beginning in 2008 to monitor the densities of larval delta smelt vulnerable to SWP and CVP entrainment losses for use in the future in determining whether or not additional protective measures would be required to reduce potentially adverse impacts associated with larval delta smelt entrainment.

Nobriga and Matica (2000) and Nobriga et al. (2004) found low and inconsistent entrainment of juvenile delta smelt by small agricultural diversions near Sherman Island; the low entrainment rates were hypothesized to be the result of juvenile delta smelt occurring offshore of the intake location and in the upper portions of the water column. Cook and Buffaloe (1998) also reported that unscreened agricultural diversions entrained low numbers of delta smelt. However, many agricultural diversions are located within primary delta smelt habitat and could potentially entrain delta smelt for a large proportion of the year. It has been hypothesized that, although juvenile and adult delta smelt may avoid entertainment at unscreened water diversions, planktonic larvae are expected to be distributed within the water column and have weak swimming performance. Therefore, larvae may be vulnerable to higher entrainment losses than predicted by results of investigations of juvenile and adult smelt. Therefore, the combined effect of location, abundance, and duration of agricultural diversions on delta smelt survival could be high.

Power plants located within the Plan Area at Pittsburg and Antioch have the potential to entrain large numbers of fish, including delta smelt and other covered fish species, particularly because these species may be located near these facilities for much of the year (Matica and Sommer 2005, C. Hanson unpubl. data). However, use of cooling water is currently low with the retirement of older units. According to recent regulations by the SWRCB, units at these two plants must be equipped with a closed cycle cooling system by 2017that eliminates fish entrainment.

Exposure to toxins. Exposure of delta smelt to toxic substances can result from point and non-point sources associated with agricultural, urban, and industrial land uses. The Delta serves as the receiving waters for a wide variety and large volume of toxic substances, including agricultural pesticides, herbicides, endocrine disruptors, heavy metals, and other agricultural and urban products (Thompson et al. 2000, Moyle 2002). Kuivila and Moon (2004) sampled pesticide concentrations within the Delta and west to Chipps Island for 3 years (1998-2000) during April-June. Their water samples contained multiple pesticides, but at individual concentrations well below lethal 96-hr LC50 concentrations for fishes. A reported toxic event in the winter of 2007 (toxicity was demonstrated using water samples collected from the Delta under laboratory conditions; no tests were performed using delta smelt) coincided temporally and spatially with delta smelt spawning in the Cache Slough region of the Delta and was also detected further downstream in the lower Sacramento River near Sherman Island (DWR, unpubl. data). Indications of toxicity also were detected within Suisun Bay during the summer of 2007 (S. Ford pers comm.). Although no specific causal link has been established, these toxic events coincided with low abundance indices of larval and juvenile delta smelt observed in the 2007 DFG 20 mm townet and summer townet surveys. Bioassay studies conducted as part of the POD studies found two instances of significant larval delta smelt mortality in samples collected from the Sacramento River in June and July 2007 that had relatively low turbidity and salinity and moderate levels of ammonia (Werner unpublished data, as cited in Baxter et al. 2008) . There have been multiple studies indicating that toxics have little direct effect on delta smelt (Resources Agency 2007, Werner et al. 2007, Bennett unpubl. data).

The short life span (1-2 years) and location of their food source in the food web (zooplankton are primary consumers) reduce the ability of toxic chemicals to bioaccumulate in the tissue of delta smelt (Moyle 2002). Their location in the upper portion of the water column may further reduce the probability of some toxic impacts by those chemicals that are sequestered quickly by sediments (i.e., pyrethroids; B. Herbold pers. comm).

Ammonia discharged from municipal wastewater treatment plants may contribute to localized toxicity in delta smelt, although results are highly variable. Werner et al. (2008) found that water samples near the Sacramento Regional County Sanitation District's wastewater treatment plant effluent reduced 4-day survival of larval delta smelt in 2006, but did not affect survival even after 7 days in 2007. Furthermore, there were two instances of significant larval delta smelt mortality from POD bioassays collected from the Sacramento River in June and July 2007 that had relatively low turbidity and salinity and moderate levels of ammonia (Werner unpubl. data, as cited in Baxter et al. 2008). The form and toxicity of ammonia/um changes based on pH and it has been hypothesized that changes in pH of the Delta receiving waters may change in response to algal growth, discharges from managed wetlands and duck clubs, and agricultural return flows that result in ammonia toxicity. These potential water quality interactions and the effects of discharging ammonia from a number of wastewater treatment plants located throughout the Sacramento and San Joaquin rivers, Delta, Suisun Bay and Suisun Marsh on the health and survival of delta smelt and other aquatic species are under investigation.

Consistent evidence of direct toxicity of contaminants to smelt within the Delta is lacking (Werner et al. 2008); however, there is growing evidence that toxics may have indirect effects on delta smelt. For example, invertebrate prey of delta smelt are affected by toxics (Weston et al. 2004, Luoma 2007, Werner 2007), reducing food availability. Additionally, the nitrate uptake by and production of phytoplankton, the base of the food web that supports delta smelt, may be inhibited by ammonia concentrations in the North Delta as has been demonstrated for phytoplankton in San Francisco and San Pablo bays (Dugdale et al. 2007). There is also evidence that toxics may cause sublethal impacts to delta smelt that make them more vulnerable to other sources of mortality (Werner 2007). Most, if not all, pyrethroids are potent neurotoxicants (Bradbury and Coats 1989, Shafer and Meyer 2004) and have immunosuppressive effects (Madsen et al. 1996, Clifford et al. 2005). In addition, these compounds and their breakdown products can act as endocrine disrupting compounds by disrupting hormone-related functions (Go et al. 1999, Tyler et al. 2000, Perry et al. 2006, Sun et al. 2007). Esfenvalerate, a common pyrethroid insecticide, has been shown to increase the susceptibility of juvenile fall-run Chinook salmon to infectious hematopoietic necrosis virus (Clifford et al. 2005), and reduce swimming ability and increase susceptibility to predation in larval fathead minnows (Floyd et al. 2008). In delta smelt, exposure to environmentally relevant pyrethroid concentrations resulted in significant swimming abnormalities, which were strongly linked with downregulation of genes involved in neuromuscular activity (Connon et al. 2009).

Exposure to copper contamination can also result in significant sublethal effects on Delta fish species, with implications for their vulnerability to other stressors. Environmentally relevant copper concentrations are shown to result in significant immunosuppressive effects (Hetrick et al. 1979) and impair olfactory function and eliminate the predator avoidance response in fish (Sandahl et al. 2006; Werner et al. in press). Swimming abnormalities have been observed after exposure to copper concentrations as low as one quarter of the chemical's LC50 values (Little and Finger 1990; Oros and Werner 2005). Dissolved copper causes acute toxicity to the calanoid copepod, *Eurytemora affinis*, in the north and south Delta (Teh 2009) and impairs the sensory function of juvenile salmonids (Hecht et al. 2007), specifically related to predator avoidance behavior. Moreover, specific concentrations of dissolved copper correspond to sublethal endpoints such as primary production and salmonid growth (Hecht et al. 2007). Delta smelt may be affected in a similar way. Additionally, negative synergistic effects have been documented such that the presence of copper in combination with ammonia is more toxic to aquatic organisms than either toxicant individually (Herbert and Vandyke 1964).

A5.6 Relevant Conservation Efforts

Pursuant to the CALFED objective of ecosystem restoration, the CALFED agencies developed the Ecosystem Restoration Plan (ERP) and the Environmental Water Account (EWA) for the purpose of restoring habitat and recovering at-risk populations like delta smelt in the Bay-Delta estuary (CALFED 2000). The ERP was intended to improve aquatic and terrestrial habitats and natural processes to support stable, self-sustaining populations through an adaptive management process, and the EWA was intended to provide increased water supply reliability while assuring the availability of sufficient water to meet fishery protection and restoration and recovery needs, as part of the overall ERP. Additional enhancement and protective actions are also being identified as part of mitigation programs for various projects, biological opinions, and regional conservation planning efforts.

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) was formed to guide the implementation of CALFED ERP elements within the Delta (DFG 2007b). The DRERIP team has created a suite of ecosystem and species conceptual models, including a conceptual model for delta smelt, that document existing scientific knowledge of Delta ecosystems. The DRERIP team has used these conceptual models to assess the suitability of actions proposed in the ERP for implementation. DRERIP conceptual models have been used in the analysis of proposed BDCP conservation measures.

Various projects exist to benefit delta smelt and several other native fish species. For example, in 2007, Westlands Water District acquired land located in the southern end of the Yolo Bypass that is thought to be high value habitat for delta smelt. Designs for potential habitat enhancement projects within the Yolo Bypass are being developed and evaluated. Objectives of these potential actions include enhancing the frequency and duration of access to seasonally inundated floodplain habitat to benefit species such as juvenile Chinook salmon and splittail, as well as to increase nutrient cycling and food production for delta smelt and other species. Wildlands, Inc. has established a mitigation bank to offset site-specific impacts to fish species, such as delta smelt, near Kimball Island in the western Delta. Access to aquatic habitats, such as the waters adjacent to Kimball Island, may provide direct benefits to delta smelt, as well as indirect benefits associated with increased nutrient cycling, phytoplankton and zooplankton production, and an associated increase in food supplies for delta smelt and other aquatic resources. Furthermore, work funded by CALFED and implemented by the Natural Heritage Institute and DWR is intended to improve and protect habitat in Dutch Slough for delta smelt, splittail, and juvenile salmonids.

The Delta Smelt Working Group is a group of scientists under the auspices of the Interagency Ecological Program, Bureau of Reclamation, and DWR that makes recommendations on water operations for the protection of delta smelt. The group uses a delta smelt risk assessment matrix, which consists of month by month criteria that, when exceeded, will trigger a meeting of the group and possible management recommendations.

In January 2005, the Interagency Ecological Program established the Pelagic Organism Decline (POD) work team to investigate the causes of the observed rapid decline in populations of pelagic organisms, including delta smelt, in the upper San Francisco Bay estuary (Baxter et. al. 2008). Since then, numerous studies have been conducted to determine the cause of the POD. Based on results of these studies and relevant studies undertaken by others, the work team has developed conceptual models to discern an understanding of the factors causing POD and to provide a basis from which to identify actions to address POD. Resources Agency has also prepared a Pelagic Fish Action Plan in March 2007 to address POD (Resources Agency 2007). The action plan identifies 17 actions that are being implemented or that are under active evaluation to help stabilize the Delta ecosystem and improve conditions for pelagic fish.

In 2007, the Federal District Court, Eastern District of California, Fresno Division (Judge Wanger) issued a court order for interim actions to protect delta smelt pending completion of a new biological opinion by the USFWS on SWP and CVP operations. The court ruling remained in effect until the new biological opinion was approved in December 2008. In the interim period, export operations of the SWP and CVP during the winter and spring months were restricted based on the magnitude of reverse flows in Old and Middle rivers and the geographic distribution and risk to delta smelt of entrainment at the export facilities. During the winter and spring months, SWP and CVP exports were limited to reverse flows of not greater than -5,000 cfs and may be reduced to as low as -2,000 cfs when delta smelt are at high risk of being entrained. These operating restrictions were intended to provide protection to delta smelt, reduce the potential risk of entrainment losses to the overall abundance, and reduce the effects of operations on population viability of delta smelt. The operating restrictions, in combination with other export limitations (e.g., SWRCB D-1641, operations to reduce the incidental take of winter-run and spring-run Chinook salmon and steelhead) have resulted in reductions in water supply deliveries to SWP and CVP contractors.

In December 2008, the USFWS released a biological opinion on the proposed operations of DWR and USBR, indicating that "coordinated operations of CVP and SWP diversion facilities, as proposed, are likely to jeopardize the continued existence of delta smelt" (USFWS 2008). The new biological opinion supplanted the 2007 Judge Wanger court decision when approved. The biological opinion details reasonable and prudent alternative actions to reduce the likelihood of jeopardy that include improvements to flow conditions, restoration of tidal marsh and associated subtidal habitat in the Delta and Suisun Marsh, and a comprehensive monitoring plan.

A5.7 Recovery Goals

The USFWS recovery strategy for delta smelt is contained in the Sacramento-San Joaquin Delta Native Fishes Recovery Plan (USFWS 1996), which also includes the longfin smelt, Sacramento splittail, green sturgeon, Sacramento perch, and three races of Chinook salmon. The objective of the Delta Native Fishes Recovery Plan for delta smelt is to remove delta smelt from the federal list of threatened species through restoration of its abundance and geographic distribution. The basic strategy for recovery is to manage the estuary in such a way that it provides better habitat for native fish in general and delta smelt in particular. The Recovery Plan defines restoration as a return of the population to pre-decline levels.

Based on the available information at the time, the 1996 recovery plan outlined a number of measurable criteria that could be used to evaluate the status of delta smelt. Delta smelt were to be considered restored when its population dynamics and distribution pattern within the estuary were similar to those that existed in the pre-decline 1967-1981 period. Restoration was to be assessed when the species satisfied both distributional and abundance criteria. The abundance criteria outlined in the 1996 recovery plan for delta smelt were met and the USFWS conducted a status review of the species in compliance with the terms of a settlement agreement. After reviewing the available information, the USFWS concluded that significant threats to the population recovery of delta smelt remain and that delta smelt should continue to be listed as a threatened species under the federal ESA.

Since 1996, new significant findings regarding the status and biology of and threats to delta smelt have emerged. The USFWS has the responsibility to review and update the recovery plan for these species. To accomplish this task, USFWS has formed the Delta Native Fishes Recovery Team to assist in the preparation of this updated recovery plan. An updated recovery plan is currently expected to be released in the near future.

A5.8 REFERENCES

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A5.8.2 Federal Register Notices Cited

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A5.8.3 Personal Communications

Bill Bennett [1] (Professor of Biology, UC Davis) phone conversation with Rick Wilder and Pete Rawlings about factors influencing the distribution and abundance of delta smelt. July 17, 2007.

Bill Bennett [2] (Professor of Biology, UC Davis) discussion with Rick Wilder, Pete Rawlings, and Chuck Hanson about causes of reduced rearing habitat to delta smelt. January 23, 2008.

Kathleen Fisch (PhD Student, UC Davis) email to Rick Wilder about delta smelt-wakasagi hybrid incidence. October 4, 2010.

Kevin Fleming (CDFG) email to Victoria Poage (USFWS) about habitat of delta smelt. April 13, 2007.

Steve Ford (DWR) communication with Victoria Poage (USFWS) about toxicity to delta smelt. 2008.

Bruce Herbold (EPA) presentation to Water Education Foundation Delta Tour about the Pelagic Organism Decline, Clarksburg, CA. June 6, 2007.

Matt Nobriga (Biologist, DFG). Phone conversation with Rick Wilder about non-native species in the Delta. April 14, 2008.

APPENDIX A6. LONGFIN SMELT *(SPIRINCHUS THALEICHTHYS)*

A6.1 LEGAL STATUS

Longfin smelt is not currently listed under the federal Endangered Species Act (ESA). However, the species was recently listed as threatened under the California ESA. The Bay-Delta population of longfin smelt was petitioned for threatened status under the Federal ESA in 1992. However, the petition was denied because the population was surviving well in areas outside the Bay-Delta estuary. The population was deemed insignificant to the entire species and was not deemed sufficiently reproductively isolated to warrant ESA listing (59 FR 869). More recent evidence from electrophoretic analysis has shown minor differences in allele frequencies between longfin smelt populations inhabiting Lake Washington in Washington state and those in the San Francisco Bay-Delta estuary, but gene frequencies differed enough to suggest that current gene flow between these two populations is restricted (Stanley et al. 1995). The Bay-Delta population appears to be more geographically isolated from other West Coast longfin smelt populations than previously thought (Moyle 2002). In 2007, the Bay Institute, Center for Biological Diversity, and Natural Resources Defense Council (2007a, b) petitioned to have the Bay-Delta longfin smelt population listed as a threatened species under both the California and Federal ESAs. On May 6, 2008, the U.S. Fish and Wildlife Service (USFWS) ruled that a status review for longfin smelt was warranted (73 FR 24911). On April 9, 2009, the USFWS determined that the Bay-Delta population did not meet the legal criteria for protection as a species subpopulation under the ESA (74 FR 16169).

In December 2007, the California Department of Fish and Game (DFG) completed a preliminary review of the longfin smelt petition (DFG 2007a) and concluded that there was sufficient information to warrant further consideration by the California Fish and Game Commission. On February 7, 2008 the California Fish and Game Commission designated the longfin smelt as a candidate for potential listing under the California ESA. On June 26, 2009, the California Fish and Game Commission ruled to list the status of longfin smelt as threatened under the California ESA.

A6.2 SPECIES DISTRIBUTION AND STATUS

A6.2.1 Range and Status

Populations of longfin smelt occur along the Pacific Coast of North America, from Hinchinbrook Island, Prince William Sound, Alaska to the San Francisco estuary (Lee et al. 1980). Although individual longfin smelt have been caught in Monterey Bay (Moyle 2002), there is no evidence of a spawning population south of the Golden Gate. The Bay-Delta population is the southernmost, and also the largest, spawning population in California (see Figure A-6a).

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Figure A-6a. Longfin Smelt Range in California

Small and perhaps ephemeral longfin smelt spawning populations have been documented or suspected to exist in Humboldt Bay, the Eel River estuary, the Klamath River estuary, the Eel River drainage, and the Russian River (Moyle 2002, Pinnix et al. 2004).

Longfin smelt seasonally inhabit the entire Bay-Delta estuary, typically in the lower Sacramento River downstream of Rio Vista and the lower San Joaquin River downstream of Medford Island, Suisun Bay, San Pablo Bay, and San Francisco Bay including South San Francisco Bay (see Figure A-6b). During non-spawning periods, individuals are most often concentrated in Suisun, San Pablo and north San Francisco bays (Baxter 1999, Moyle 2002). The species is also common in nearshore coastal marine waters outside the Golden Gate Bridge in late summer and fall (Baxter 1999, Sakuma, pers. comm. 2003). Longfin smelt are periodically caught in nearshore ocean surveys (City of San Francisco, unpublished data, Sakuma pers. comm.), suggesting that some individuals emigrate from or immigrate into the estuary.

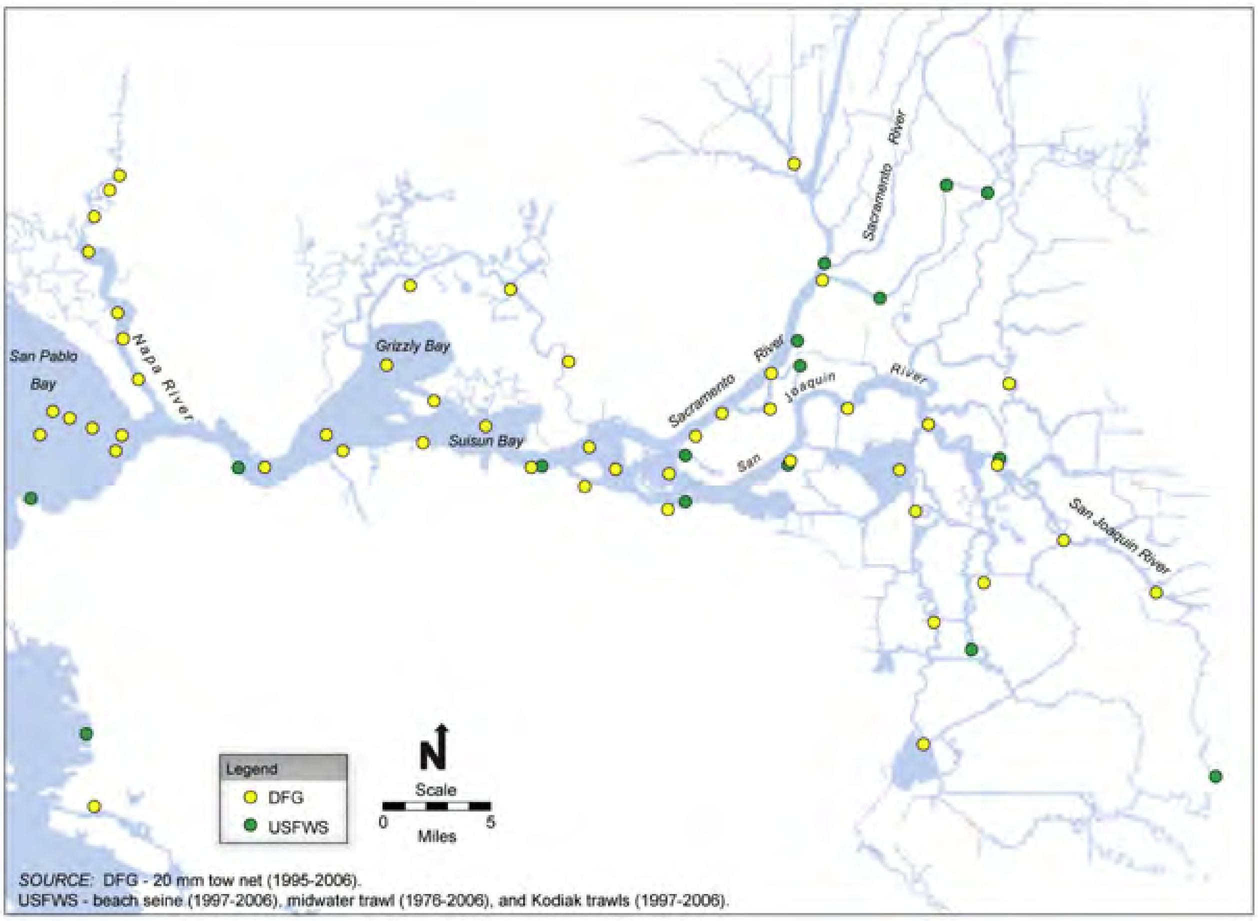


Figure A-6b. Historical Sampling Locations Where Longfin Smelt Have Been Captured Since 1976

Longfin smelt abundance within the Bay-Delta estuary has been highly variable as reflected in the DFG fall midwater trawl surveys and Bay study surveys (see Figure A-6c). The DFG fall midwater trawl samples approximately 100 locations throughout the Bay-Delta system during the period from September through December each year. The survey has been conducted since 1967 and is considered to represent the best long-term record of the index of longfin smelt abundance in the Bay-Delta estuary. Additional information on trends in abundance of longfin smelt inhabiting the estuary is available from the DFG Bay fishery surveys that have sampled monthly since 1980 at a wide range of locations using both an otter trawl and midwater trawl. Since the fall midwater trawl surveys and Bay fishery surveys show similar trends in abundance of longfin smelt (Hieb et al. 2005), the following description of trends in the status of longfin smelt is based on results of the long-term DFG fall midwater trawl surveys.

Indices of longfin smelt abundance (see Figure A-6c) are characterized by high variability among years. Abundance indices were greatest in 1967 and 1969 followed by a second peak in abundance in 1980 and 1982. High abundance indices have generally been associated with years when spring Delta outflow has been high. Abundance indices have typically been low in years when Delta outflow in the spring is low, such as the drought conditions that occurred in 1976 and 1977 and during the early 1990s drought. The trends in longfin abundance also show a general pattern of declining abundance over the 1967 through 2009 survey period. In recent years, longfin smelt abundance was greatest in 1995 followed by a general decline in abundance between 1998 and 2009. The abundance index based on the DFG fall midwater trawl survey conducted in 2007 was the lowest on record over the 1967 to 2009 survey period. Fall midwater trawl abundance indices suggest that abundance of longfin smelt within the Bay-Delta estuary has declined by over 95 percent since the survey began.

Correlations between longfin smelt abundance indices and various environmental parameters suggest that freshwater outflow from the Delta during the longfin smelt larval and early juvenile period (January-June) has a strong influence on longfin smelt abundance (see Figure A-6d) (Moyle 2002).

Although there was a four-fold decline in longfin smelt abundance after the 1987 invasion of the overbite clam, there was no change in the slope of the relationship between freshwater outflow and longfin smelt abundance (see Figure A-6d) Kimmerer 2002a, Sommer et al. 2007). Furthermore, although Delta outflow conditions were relatively high in 2003, 2005, and 2006, reflecting wet and above normal hydrologic conditions, longfin smelt abundance did not increase (as would be expected based on the 1987 to 2000 relationship; Sommer et al. 2007). There appears to be yet a further reduction in the height of the abundance-flow relationship since 2001, although the slope of the relationship remains unchanged (see Figure A-6d). This finding suggests that an additional factor or factors may now be limiting the Bay-Delta population response. When longfin smelt abundance is low, it becomes more difficult to accurately assess their geographic distribution and abundance.

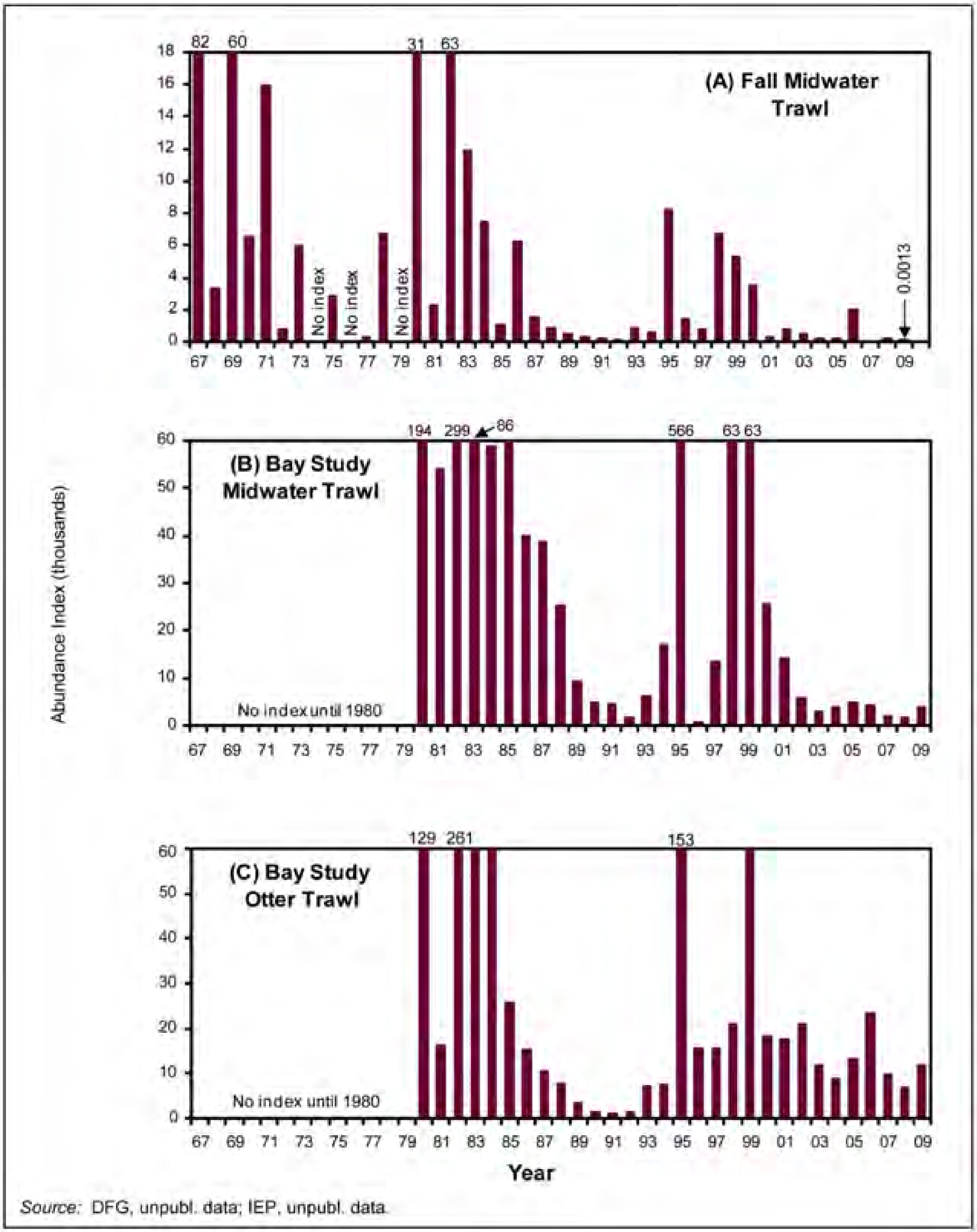


Figure A-6c. Annual Abundance Indices of Longfin Smelt from 1967-2009 in (A) Fall Midwater Trawl, (B) Bay Study Midwater Trawl, and (C) Bay Study Otter Trawl

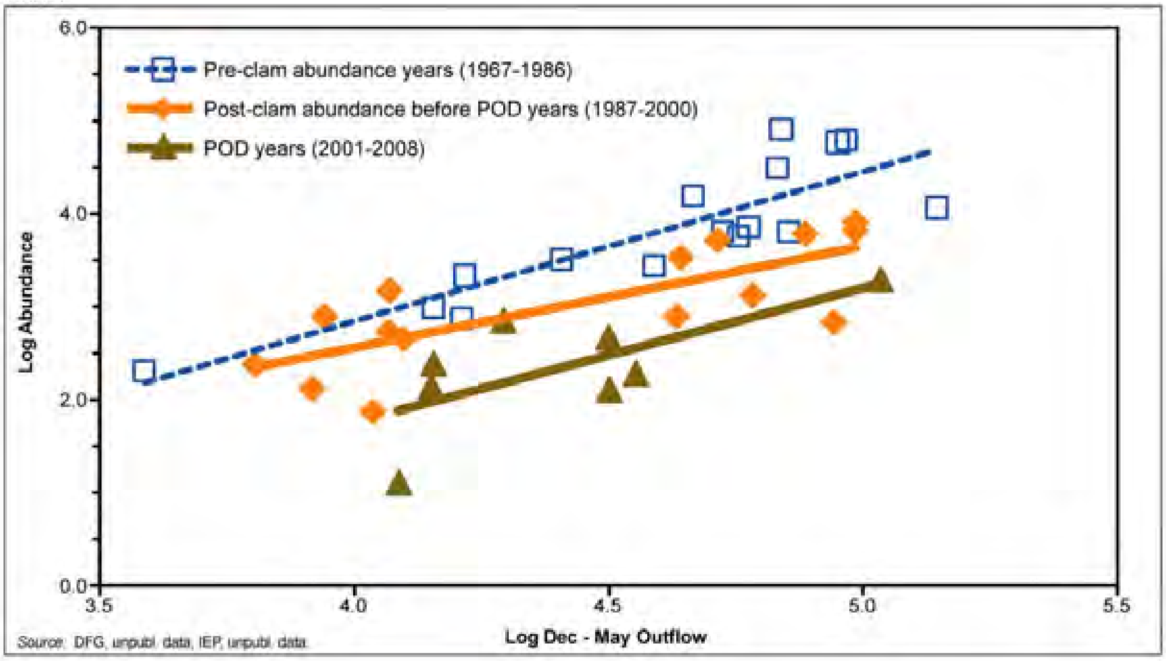


Figure A-6d. Longfin Smelt Abundance ($\log_{10}$) from DFG Fall Midwater Trawl Survey as a Function of Mean Delta Outflow from December through May ($\log_{10}$)

Longfin smelt migration patterns and geographic distribution patterns within the Bay-Delta estuary have remained the same throughout the period of record (1967-present, fall midwater trawl; 1980-present, Bay Study trawls). Results of fishery surveys suggest that the geographic distribution of pre-spawning adult longfin smelt in the winter and early spring does not vary substantially in response to seasonal and inter-annual variation in inflows to the Delta. It has been hypothesized that the pre-spawning longfin smelt distribution is determined by staging and foraging prior to spawning and associations with suitable habitat conditions for spawning. The geographic distribution of larval and early juvenile lifestages of longfin smelt may be influenced by freshwater inflows to the Delta during the late winter and spring, possibly influencing larval planktonic transport rates from the upstream spawning habitat to the downstream estuarine portions of the Delta. In addition, when Delta inflows are high the location of the low salinity zone is further west (downstream) and larval and early juvenile delta smelt are frequently observed further downstream within Suisun Bay.

No spawning habitats have been specifically identified for longfin smelt, but based on the collection of larvae, most spawning is believed to take place in the Sacramento River near or downstream of Rio Vista, and downstream of Medford Island on the San Joaquin River (Wang 1986). Historically, spawning longfin smelt were also common in Suisun Marsh; in recent years, very few adult, spawning-age longfin smelt have been collected in Suisun Marsh (DFG, unpubl. data). Larval longfin smelt have been found concentrated off the mouth of Coyote Creek, indicating that spawning can take place in tributaries of South San Francisco Bay during periods when freshwater runoff and Delta outflow are high, such as conditions that occurred in 1982 and

1983 (Baxter 1999). Collection of small larvae in the Interagency Ecological Program (IEP) 20 mm tow net surveys suggests spawning regularly occurs in the Napa River.

Larval longfin smelt are typically collected in the region of the estuary extending from the western Delta into San Pablo Bay, but their distribution shifts upstream or downstream in response to Delta outflow (Baxter 1999, Dege and Brown 2004). In years when winter-spring Delta outflow is low, few larvae are transported to San Pablo Bay. In years when winter-spring Delta outflow is high, few larvae remain in the western Delta, but are abundant in San Pablo Bay and may reach northern San Francisco Bay (Baxter 1999, Dege and Brown 2004). Longfin smelt larvae are distributed broadly into all open water habitats and into marsh sloughs (Baxter 1999, Meng and Matern 2001).

The initial distribution of young juveniles correlates positively with that of larvae, both vertically within the water column and geographically. During their first year, juveniles disperse broadly downstream, eventually inhabiting Suisun, San Pablo, and Central and South San Francisco bays and moving into near shore coastal marine habitats in most years (see Figure A-6e) (Baxter 1999, Dege and Brown 2004, Hieb and Baxter 1993, Moyle 2002). Juveniles move from offshore shoals into channels during summer and fall (Rosenfield and Baxter 2007).

Longfin smelt in their second year of life (age 1) are typically distributed from the western Delta through South San Francisco Bay during January through March. Their distribution then moves toward the Central San Francisco Bay, such that by August and September few, if any, are collected outside of Central San Francisco Bay (Baxter 1999). During the summer longfin smelt are also common in nearshore coastal waters (City of San Francisco unpubl. data, Sakuma pers. comm.). As longfin smelt begin to mature in the fall, they re-inhabit the entire estuary and begin migrating upstream toward freshwater (Baxter 1999, Rosenfield and Baxter 2007).

A6.2.2 Distribution and Status in the Plan Area

Longfin smelt occur primarily in the lower Sacramento River (downstream of Rio Vista), lower San Joaquin River, and western Delta and Suisun Bay within the Plan Area (see Figure A-6a). Longfin smelt occur in relatively low abundance in the south Delta as reflected in results of DFG fishery sampling and fish salvage monitoring at the State Water Project (SWP) and Central Valley Project (CVP) export facilities. The typical distribution of juvenile and adult longfin smelt (brackish water and coastal marine waters of San Pablo and San Francisco bays) is downstream of the Plan Area.

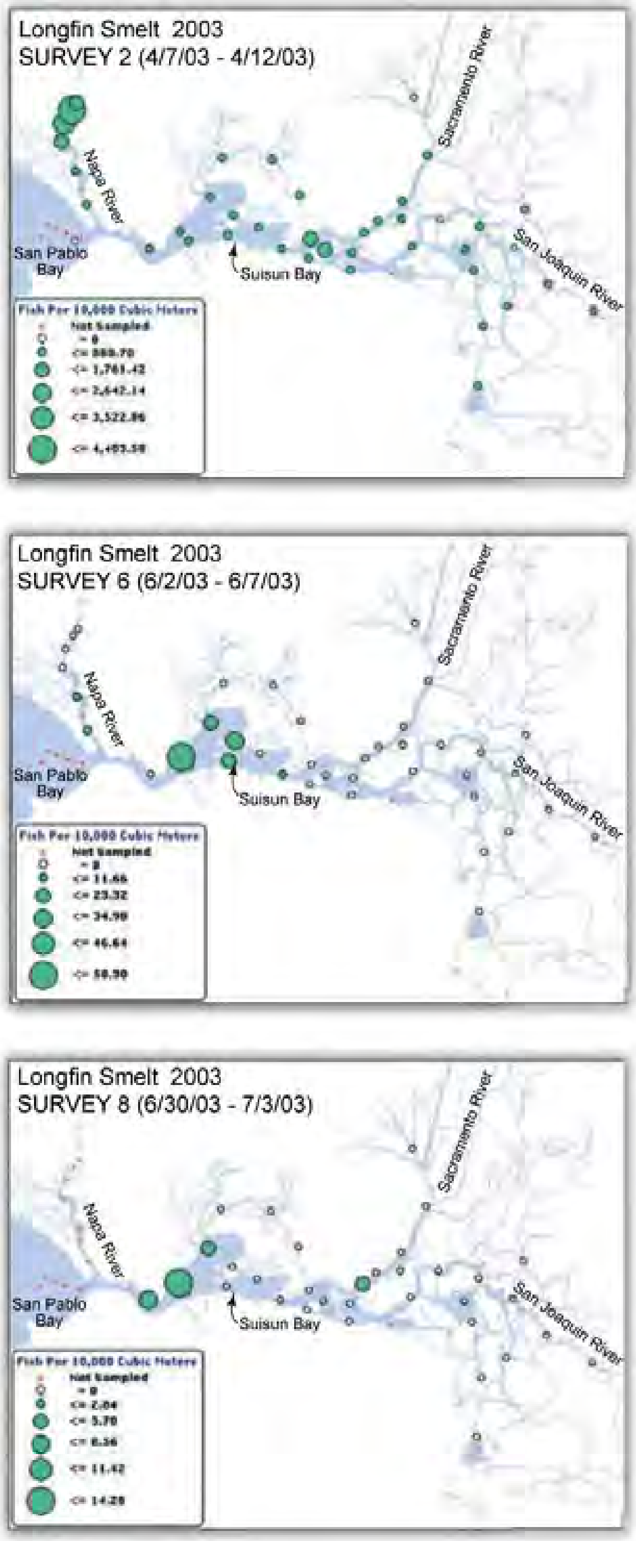
A6.3 Habitat Requirements and Special Considerations

Longfin smelt inhabiting the Bay-Delta estuary are thought to spawn in freshwater or slightly brackish water over sandy or gravel substrates at temperatures ranging from 7 to 14.5 °C (44.6 to 58.1 °F) (Moyle 2002).

Early April

Early June

Early July



Source: CDFG 2003, 20 mm Longfin smelt survey. This annual survey monitors post-larval and juvenile longfin smelt distribution and relative abundance every two weeks during spring and early summer throughout their historical spring range using a 1600 μm egg and larval net. For more information see http://www.delta.dfg.ca.gov/data/20mm/description.asp

Figure A-6e. Example of Distribution of Post-Larval and Juvenile Longfin Smelt in Spring-Summer of a Representative Above Normal Water Year

Other populations of longfin smelt inhabiting West Coast waters are present in coastal estuaries or may complete their entire life cycle in freshwater (Dryfoos 1965, Moulton 1974), indicating that there is no lower limit to salinity tolerance for any life stage. Collections of larval and juvenile longfin smelt smaller than 50 mm fork length (FL) within the Bay-Delta showed that 90 percent of the individuals inhabited areas with salinities lower than 18 parts per thousand (ppt) (Baxter 1999). Healthy individuals 20 mm FL and larger have been captured in salinities of 32 ppt (ocean water) and along the open coast, suggesting that high salinity may be limiting the geographic distribution for only a small portion of their lifecycle, if at all (Baxter, unpubl. data).

Spawning in the Bay-Delta estuary occurs immediately before, and for several months after, the coldest water temperatures of the year (Baxter 1999, Orsi 1999). Movement patterns based on catches in DFG fishery sampling suggest that longfin smelt actively avoid water temperatures greater than 22 °C (72 °F) (see Figure A-6d). Longfin smelt do not occupy areas with temperatures greater than 22 °C (72 °F) in combination with salinities greater than 26 ppt. These conditions occur between August and September almost annually in South San Francisco Bay and periodically in shallower portions of San Pablo Bay. Spawning is thought to occur in freshwater over sand, gravel, rocks, or aquatic vegetation (Wang 1991).

The effect of turbidity on longfin smelt geographic distribution or habitat preferences is unknown. However, longfin smelt larvae hatch coincident with annual peak Delta outflows, which typically coincide with high turbidity. Also, larval and older life stages of longfin smelt possess a well developed olfactory system. The development of the olfactory system at an early lifestage suggests its use in food acquisition (S. Foott, pers. comm.).

A6.4 LIFE HISTORY

An unknown fraction of the longfin smelt population migrates to the marine environment during both their first and second years of life; some may remain in the marine environment from their first year until they return to the estuary to spawn near the end of their second year (rarely their third). It is unknown whether marine residence is necessary for proper egg development, but the extremely limited number of age1 smelt captured upstream of Central San Francisco Bay during fall suggests that salinity or, more likely, higher temperatures may be a factor affecting the seasonal distribution of smelt within the estuary.

Upon hatching from adhesive eggs (primarily January-April), buoyant longfin smelt larvae rise toward the surface and are transported downstream by surface currents resulting from both river flow and tidal mixing of fresh and marine waters. Flow rates are positively related to downstream transport of the planktonic larvae (Hieb and Baxter 1993, Baxter 1999, Dege and Brown 2004). Larval longfin smelt remain in the upper part of the water column until they reach 10 to 15 mm, after which they move to the middle and bottom parts of the water column (Hieb and Baxter 1993, Bennett et al. 2002, Moyle 2002).

Larval and small juvenile longfin smelt feed on copepods and other small crustaceans (Moyle 2002). In Suisun Bay, at low salinities, the non-native copepods, *Pseudodiaptomus* and *Acanthocyclops,* dominate the diet of small juvenile smelt in summer (Hobbs et al. 2006). Mysid shrimp become important in the diets of larger juvenile and adult longfin smelt (Moyle 2002, Feyrer et al. 2003, Rosenfield and Baxter 2007). Since the decline of *Neomysis* following the invasion of the overbite clam in the late 1980s, subadult and adult longfin smelt have fed on a broader variety of organisms, but mysids remain their primary food item (Moyle 2002, Feyrer et al. 2003). In fall 2006, a high outflow year, longfin smelt fed predominantly on the introduced mysid, *Acanthomysis*, but consumed other mysids, as well as the copepod *Pseudodiaptomus* and amphipod, *Corophium* (DFG, unpubl. data).

During their first year, juvenile longfin smelt disperse broadly downstream, eventually inhabiting Suisun, San Pablo, and Central and South San Francisco bays, as well as nearshore coastal marine habitat in most years (Hieb and Baxter 1993, Baxter 1999, Moyle 2002, Dege and Brown 2004). Juveniles move from offshore shoals into channels during the summer and fall (Rosenfield and Baxter 2007). This movement may be a response to increasing water temperatures (greater than 20 °C [68 °F]), as does the late summer emigration from South San Francisco Bay (Baxter 1999).

A6.5 THREATS AND STRESSORS

Reduced spawning habitat. A primary mechanism responsible for the reduction in spawning habitat for longfin smelt has been the reclamation, channelization, and riprapping of historical freshwater intertidal and shallow subtidal wetlands. Furthermore, reductions of winter and spring Delta outflows over the past several decades as a result of water exports, reservoir storage, and upstream diversions have repositioned the low salinity region of the estuary (X2 location) farther upstream, possibly forcing spawning adult longfin smelt to migrate farther upstream to reach suitable spawning habitat.

Reduced access to rearing habitat. Access to suitable rearing habitat, which is centered in the low salinity zone (Dege and Brown 2004), has likely declined as a result of reductions in Delta outflow over the past 40 years. Reduced access to rearing habitat can result from low net downstream flows slowing the transport of planktonic larval longfin smelt downstream towards suitable rearing habitat in the western Delta and Suisun Bay. The documented correlation between the abundance of longfin smelt in the FMWT and the location of X2 in the winter and spring months (Dec-May; Kimmerer 2002, Kimmerer et al. 2009) is hypothesized to relate to the transport of larval longfin smelt out of the Delta to rearing habitats downstream.

The low salinity zone, when positioned over shallow shoal areas in Suisun Bay in response to high Delta outflows, is thought to be highly productive (Moyle et al. 1992, Bennett et al. 2002). When located upstream, the low salinity zone is confined to the deep river channels, is smaller in total surface area, contains very few shoal areas, may have swifter, more turbulent water currents, and may lack high zooplankton productivity. Hobbs et al. (2006) found evidence that the health and survival of longfin smelt were greater in habitats associated with shallow water. Furthermore, as the distribution of longfin smelt shifts upstream, individuals may become more vulnerable to entrainment by the SWP and CVP export facilities and other diversions within the interior of the Delta.

The Suisun Marsh Salinity Control Gates function to decrease salinity in managed wetlands of Suisun Marsh to support crops that attract game birds for the many duck clubs located throughout the marsh. When in operation, generally from October through May, the control gates near Collinsville divert up to 2,500 cubic feet per second (cfs) of freshwater from upstream flows into the marsh. Because the minimum outflow standard during fall months is 5,000 cfs, a significant proportion of total Delta outflow (up to 50 percent) does not flow through the eastern Suisun Bay region. This diversion has resulted in a measurable increase in salinity in eastern Suisun Bay, which may correspond to a decrease in low salinity habitat for longfin smelt (Fullerton 2007).

Reduced food availability. Reduced food availability for longfin smelt can result from at least seven impact mechanisms.

First, the presence of non-native species has reduced the abundance of food available to longfin smelt. Efficient filter feeding and high abundance of the overbite clam have dramatically reduced phytoplankton and zooplankton abundance in Suisun Bay, the western Delta, and Suisun Marsh since its introduction in the mid 1980s (Kimmerer and Orsi 1996). The Asian clam has also reduced phytoplankton abundance in the Delta, which likely reduced zooplankton abundance (Jassby et al. 2002, Thompson 2007). Other non-native zooplanktivores that may compete for limited available food resources with longfin smelt include threadfin shad, inland silversides, and wakasagi.

Second, much of the floodplain habitat in the Delta and tributary rivers has been eliminated by levees and reclamation. As a result of levee construction, flood control, and increased reservoir storage the frequency of inundation on floodplains that still exist has been reduced (Resources Agency 2007). Floodplains are highly productive due to their shallow, warm, low-velocity water (Sommer et al. 2001a, b) and input of organic material and nutrients from the terrestrial community (Booth et al. 2006). Floodplains are a key source of nutrients and organic material for the Bay-Delta estuary (Sommer et al. 2001a, Harrell and Sommer 2003).

Third, levee construction, island reclamation, and channelization within the Delta have resulted in a substantial reduction in intertidal and shallow-water subtidal wetland/emergent marshes and open water habitat throughout the Delta. Historically, Delta wetlands and shallow-water habitat was expansive and provided large areas of estuarine and freshwater habitat that was highly productive. The significant reduction in tidal and shallow-water subtidal habitat, and an associated reduction in emergent vegetation, nutrient cycling, and the production of phytoplankton, zooplankton, macroinvertebrates, and other aquatic organisms that provide food resources for delta smelt, have been identified as a major factor affecting habitat conditions within for Delta species, such as longfin smelt.

Fourth, SWP and CVP exports and the over 2,200 in-Delta agricultural diversions (Herren and Kawasaki 2001) export zooplankton, nutrients, and organic material that would otherwise support the base of the food web in the Delta, thus reducing food availability for the longfin smelt (Jassby and Cloern 2000, Resources Agency 2007).

Fifth, hydraulic residence time in the Delta has declined as a result of increased channelization and passage of Sacramento River water through the Delta Cross Channel into the central and southern Delta to meet water quality standards and supplies for in-Delta exports. The decreased hydraulic residence time reduces the time available for bacteria to use nutrients and organic carbon and for production of phytoplankton and zooplankton that provide food for longfin smelt and other aquatic species (Jassby et al. 2002, Kimmerer 2002a, 2004, Resources Agency 2007).

Sixth, exposure of phytoplankton and zooplankton to toxics (e.g., pesticides, herbicides) that enter the Delta from point and non-point sources may contribute to the observed low abundance of zooplankton prey species for longfin smelt and other species inhabiting the Bay-Delta (Weston et al. 2004, Luoma 2007, Werner 2007). Although direct impacts of toxics on longfin smelt have not been extensively studied, the indirect effect of toxics on reducing zooplankton and phytoplankton abundance is thought to result in reduced availability of food resources to longfin smelt (Johnson et al. 2010, Werner et al. in press).

Seventh, in addition to the discharge of toxic contaminants, municipal wastewater treatment plants, particularly the Sacramento Regional County Sanitation District's Wastewater Treatment Plant, discharge high loads of ammonia directly into the Sacramento River in the North Delta (Jassby 2008). High concentrations of ammonium, the ionized form of ammonia, may inhibit phytoplankton production in the Sacramento and San Joaquin rivers, as has been found downstream in the Suisun, San Pablo and Central bays (Wilkerson et al 2006, Dugdale et al. 2007), which could result in reduced food production for longfin smelt. Additional research is ongoing to determine if and to what extent, ammonia/um may affect phytoplankton production.

Non-native species. The effect of non-native predators, such as inland silversides, largemouth bass, striped bass, and other fish on the longfin smelt population is largely unknown, but may be important (Bennett and Moyle 1996, Moyle 2002). The establishment of the highly invasive and fast growing aquatic plants, such as the Brazilian waterweed and water hyacinth, has provided habitat for non-native predatory fish, such as centrarchids and striped bass, although no population level effects on longfin smelt have been detected or quantified (Nobriga et al. 2005). These aquatic plants may have had other potentially detrimental impacts to longfin smelt, including competition with native vegetation and reducing dissolved oxygen concentrations and turbidity within their immediate vicinity (Grimaldo and Hymanson 1999, Brown and Michniuk 2007, Feyrer et al. 2007).

The overbite clam has caused dramatic changes to the composition and abundance of phytoplankton and zooplankton communities in the aquatic food web since its introduction into the Bay-Delta estuary (Kimmerer and Orsi 1996). Kimmerer (2002a) asserted that these changes likely reduced food availability for a large assemblage of organisms, leading to reduced recruitment success of longfin smelt and a four-fold reduction in the abundance of longfin smelt (Rosenfield and Baxter 2007).

Reduced turbidity. The observed change in Bay-Delta turbidity has the potential, in combination with other factors, such as non-native species, to fundamentally alter the trophic dynamics of the estuary for species such as longfin smelt. Based on the similarities in life history, seasonal and geographic distribution, pelagic foraging and diet, it has been hypothesized that longfin smelt may have a similar relationship to turbidity as that observed for delta smelt (S. Foot unpubl. data, R. Baxter pers. comm.). Enlarged olfactory organs in longfin smelt suggest that they are well adapted to high turbidity conditions during foraging. As a result, longfin smelt may lose their competitive advantage in foraging to other zooplanktivores when turbidity is low.

Turbidity has decreased over the past several decades in the Delta as a result of a variety of factors (Kimmerer 2004, Wright and Shoellhamer 2004, Feyrer et al. 2007, Fullerton 2007). First, upstream sediment inputs have been reduced due to a range of anthropogenic actions (Jassby et al. 2002, Kimmerer 2004), including depletion of erodible sediments from hydraulic mining in the 1800s, river bank protection, trapping of sediments by dams and reservoirs, levee construction that reduced flood plain inundation and channel meanders, and changes in land use (Wright and Shoellhamer 2004). Wright and Shoellhamer (2004) estimated that the yield of suspended sediments from the Sacramento River declined by approximately one half from 1957 to 2001.

Second, the distribution and abundance of non-native aquatic plant species, particularly *Egeria* and water hyacinth, has increased dramatically over the past 20 years (Nobriga et al. 2005, Brown and Michniuk 2007). Both plants can reduce turbidity by reducing water velocity and trapping fine suspended sediments (Grimaldo and Hymanson 1999, Jassby et al. 2002, Nestor et al. 2003, Hobbs et al. 2006).

Third, the high filtering efficiency of the overbite clam has dramatically reduced phytoplankton and zooplankton abundance in the western Delta and Suisun Bay since its introduction (Kimmerer and Orsi 1996, Jassby et al. 2002, Kimmerer 2002b, 2004). The reduction in phytoplankton in the water column may contribute to increased water clarity and reduced turbidity in the Delta.

Fourth, hydraulic residence in the Delta has declined as a result of increased channelization and the movement of water from the Sacramento River into the interior Delta channels to improve water quality and provide increased supplies to in-Delta exports. SWP and CVP export operations have also directly resulted in changes in the hydrodynamics within Delta channels such as Old and Middle rivers which affect hydraulic residence time. Reduced hydraulic residence time reduces the ability of phytoplankton and bacteria to incorporate nutrients and carbon (Jassby et al. 2002, Kimmerer 2002a, 2004, Resources Agency 2007). This reduction in phytoplankton and zooplankton production contributes directly to reduced turbidity within the Bay-Delta estuary.

Reduced food quality. The zooplankton community inhabiting the Bay-Delta estuary has changed multiple times in response to multiple introductions of non-native species. These changes in the zooplankton species composition have affected the quality of food resources available to longfin smelt because some of the non-native species do not appear to be as suitable of a food resource as the native species (Resources Agency 2007, Sommer 2007). For example, the non-native copepod *Limnoithona* (Orsi and Ohtsuka 1999) is described as lower quality prey for longfin smelt because they are small and have sufficient swimming ability to avoid capture (Orsi and Ohtsuka 1999, B. Herbold pers. comm.). As a result, foraging efficiency of longfin smelt may have decreased (Resources Agency 2007). A decrease in foraging efficiency and/or the availability of suitable prey for various life stages of longfin smelt may have resulted in reduced growth, survival, and reproductive success contributing to reduced population abundance.

Entrainment. The effect of entrainment on the population dynamics and abundance of longfin smelt remains largely unquantified. Because longfin smelt tend to be mostly estuarine, they likely spend most of their life (approximately 1.5 years) downstream of the influences of the SWP/CVP facilities (see Figure A-6e). However, entrainment during winter months when spawners move upstream may be higher and particularly detrimental to the population because it results in mortality of not only pre-spawning and spawning adults, but also their potential progeny. Guerin et al (2008, in review) found significant correlations for longfin smelt as reported earlier for delta smelt between SWP winter salvage of adult smelt and subsequent fall mid-water trawl (FMWT) index of smelt with 1 and 2 year lags over the past 12 years. More recent work shows that SWP winter salvage of adult smelt normalized to the prior FMWT correlates strongly with subsequent FMWT for delta smelt over a longer record. These relationships do not establish causality, but they are an indicator that winter salvage at the SWP may be a factor to be considered.

The relationship between Delta outflow during the late winter and spring and the DFG fall midwater trawl longfin smelt index (see Figure A-6d) may be partially explained by entrainment vulnerability relative to the geographic distribution of the longfin smelt population. In high outflow years, salvage rates are lower, suggesting that longfin smelt may not be vulnerable to the SWP and CVP exports when the population is located farther west in Suisun Bay and further downstream.

There are over 2,200 small agricultural diversions in the Delta (Herren and Kawasaki 2001). Although these diversions generally take water near the bottom, the intakes may entrain water near the surface at low tide; therefore, the vulnerability of a pelagic species such as juvenile and adult longfin smelt may be reduced. Planktonic larval longfin smelt may have a greater vulnerability to entrainment into diversions than older life stages that have greater swimming ability and may inhabit areas further offshore and in the upper portions of the water column. It has been hypothesized that, although juvenile and adult longfin smelt may avoid entertainment at unscreened water diversions, planktonic longfin smelt larvae are expected to be distributed within the water column and have weak swimming performance and, therefore, may be vulnerable to entrainment losses in larger numbers than suggested by results of investigations of juvenile and adult smelt. Many agricultural diversions are located within longfin smelt spawning and larval rearing habitat. The impact of entrainment mortality at these diversions on the longfin smelt population abundance has not been quantified.

Power plants in Antioch and Pittsburg have the ability to entrain large numbers of longfin smelt, particularly because longfin smelt tend to be located near these facilities for most of the year (Matica and Sommer 2005, C. Hanson unpubl. data). However, use of cooling water is currently low with the retirement of older units. According to recent regulations by the State Water Resources Control Board, units at these two plants must be equipped with a closed cycle cooling system by 2017 that eliminates fish entrainment.

Exposure to toxins. Exposure of longfin smelt to toxic substances can result from point and non-point sources associated with agricultural, urban, and industrial land uses. Longfin smelt can potentially be exposed to these toxic materials, including pesticides, herbicides, endocrine disrupting compounds, and metals, during their period of residence within the Bay-Delta. There are no known studies that directly link mortality of longfin smelt with exposure to toxic chemicals within the Bay-Delta estuary (S. Foott unpubl. data, R. Baxter pers. comm., Resources Agency 2007). However, longfin smelt spawn during winter months when non-point runoff of pesticides tends to be the greatest. The pesticide diazinon is known to reduce growth and increase spinal deformities in Sacramento splittail (Teh et al. 2004), but effects of diazinon on longfin smelt have not been investigated. Reports during January 1997 indicated that flooding along the Feather River dispersed fuel and agricultural chemicals into the water column during a period when longfin smelt larvae were hatching in high numbers; the subsequent 1997 year class was low given the high winter outflow, although a direct cause and effect linkage with exposure to toxics was not documented. Kuivila and Moon (2004) sampled pesticide concentrations within the Delta and west to Chipps Island for 3 years (1998-2000) during April-June. Their water samples contained multiple pesticides, but at individual concentrations well below lethal 96-hr LC50 concentrations for fishes. In 1999 and 2000, sizable, but uncalculated fractions of the longfin smelt population overlapped their pesticide sampling area (see http://www.delta.dfg.ca.gov/data/20mm/CPUE_map.asp), although no known direct link between chemical concentration and larval mortality was established.

The short life span (less than 3 years) and location of their food source in the food web (zooplankton are primary consumers) reduce the ability of toxic chemicals to bioaccumulate in the tissue of longfin smelt (Moyle 2002). Their location in the water column may further reduce the probability of some toxic impacts by those chemicals that are sequestered quickly by sediments (i.e., pyrethroids; B. Herbold pers. comm). Additional research is needed to investigate the potential risk of exposure to toxic chemicals at concentrations and exposure durations typical of Bay-Delta conditions on various life stages of longfin smelt. To date, no formal risk assessment has been performed on the potential lethal and sublethal effects of toxics to longfin smelt population dynamics, although investigations of the toxicity of contaminants to larval delta smelt (Werner unpubl. data, as cited in Baxter et al. 2008) are being undertaken as part of the Interagency Ecological Program's studies of pelagic organism decline.

Ammonia discharged from municipal wastewater treatment plants may contribute to localized toxicity in longfin smelt. Werner et al. (2008) found that water samples near the Sacramento Regional County Sanitation District's wastewater treatment plant effluent reduced 4-day survival of larval delta smelt in 2006, but did not affect survival even after 7 days in 2007. Furthermore, there were two instances of significant larval delta smelt mortality from POD bioassays collected from the Sacramento River in June and July 2007 that had relatively low turbidity and salinity and moderate levels of ammonia (Werner unpubl. data, as cited in Baxter et al. 2008). Exposure to ammonia may have similar effects on longfin smelt. The form and toxicity of ammonia/um changes based on pH and it has been hypothesized that changes in pH of the Delta receiving waters may change in response to algal growth, discharges from managed wetlands and duck clubs, and agricultural return flows that result in ammonia toxicity. These potential water quality interactions and the effects of discharging ammonia from a number of wastewater treatment plants located throughout the Sacramento and San Joaquin rivers, Delta, Suisun Bay and Suisun Marsh on the health and survival of delta smelt and other aquatic species are under investigation.

Consistent evidence of direct toxicity of contaminants to smelt within the Delta is lacking (Werner et al. 2008); however, there is growing evidence that toxics may have indirect effects on longfin smelt. For example, invertebrate prey of longfin smelt are affected by toxics (Weston et al. 2004, Luoma 2007, Werner 2007), reducing food availability of longfin smelt. Additionally, the nitrate uptake by and production of phytoplankton, the base of the food web that supports longfin smelt, may be inhibited by ammonia concentrations in the North Delta as has been demonstrated for phytoplankton in San Francisco and San Pablo bays (Dugdale et al. 2007). There is also evidence that toxics may cause sublethal impacts to longfin smelt that make them more vulnerable to other sources of mortality (Werner 2007). Most, if not all, pyrethroids are potent neurotoxicants (Bradbury and Coats 1989, Shafer and Meyer 2004) and have immunosuppressive effects (Madsen et al. 1996, Clifford et al. 2005). In addition, these compounds and their breakdown products can act as endocrine disrupting compounds by disrupting hormone-related functions (Go et al. 1999, Tyler et al. 2000, Perry et al. 2006, Sun et al. 2007). Esfenvalerate, a common pyrethroid insecticide, has been shown to increase the susceptibility of juvenile fall-run Chinook salmon to infectious hematopoietic necrosis virus (Clifford et al. 2005), reduce swimming ability, and increase susceptibility to predation in larval fathead minnows (Floyd et al. 2008). In delta smelt, exposure to environmentally relevant pyrethroid concentrations resulted in significant swimming abnormalities, which were strongly linked with downregulation of genes involved in neuromuscular activity (Connon et al. 2009).

Exposure to copper contamination can also result in significant sublethal effects on Delta fish species, with implications for their vulnerability to other stressors. Environmentally relevant copper concentrations are shown to result in significant immunosuppressive effects (Hetrick et al. 1979) and impair olfactory function and eliminate the predator avoidance response in fish (Sandahl et al. 2006; Werner et al. in press). Swimming abnormalities have been observed after exposure to copper concentrations as low as 0.25 of the chemical's LC50 values (Little and Finger 1990; Oros and Werner 2005). Dissolved copper causes acute toxicity to the calanoid copepod, *Eurytemora affinis,* in the north and south Delta (Teh 2009) and impairs the sensory function of juvenile salmonids (Hecht et al. 2007), specifically related to predator avoidance behavior. Moreover, specific concentrations of dissolved copper correspond to sublethal endpoints such as primary production and salmonid growth (Hecht et al. 2007). Longfin smelt may be affected in a similar manner. Additionally, negative synergistic effects have been documented such that the presence of copper in combination with ammonia is more toxic to aquatic organisms than either toxicant individually (Herbert and Vandyke 1964).

Predation. Predation by introduced predators, such as inland silversides, striped bass, and centrarchids, has been identified as a potential stressor on smelt populations (Sommer et al. 2007, Rosenfield 2010), but the importance of predation for longfin smelt abundance is thought to be low (Nobriga and Feyrer 2008, Rosenfield 2010). Information regarding the impact of predation on longfin smelt is limited; however, inland silversides are believed to prey on larval longfin smelt, and predation by striped bass adults likely results in mortality for the juvenile and adult lifestages (Rosenfield 2010). Larval longfin smelt are not strong swimmers, and are thus particularly vulnerable to predation (Wang 1986). Various factors such as turbidity, outflows, and exposure to contaminants are likely to influence the susceptibility of longfin smelt to predation (Rosenfield 2010).

Predation has been implicated as an important factor affecting production of juvenile longfin smelt, in part due to the correspondence between freshwater flows, the volume of turbid habitat, and the young-of-year class size for longfin smelt (Rosenfield 2010). The coincidence of the increase in inland silverside abundance and decline in longfin smelt abundance also provides evidence of the potential importance of predation as a stressor to longfin smelt. However, increases in predation are not believed to be responsible for the most recent decline in the longfin smelt population. Although striped bass are likely to be major predators of longfin smelt, their populations have declined substantially in recent years and any impact they have on longfin smelt populations is also expected to have declined (Rosenfield 2010). In addition, inland silversides are predatory, but they prefer shallow-water habitats where juvenile and sub-adult longfin smelt are rare. Consequently, their impact as predators of juvenile longfin smelt is likely limited (Rosenfield 2010).

Elevated water temperature. Temperature affects the metabolic requirements and physiological processes of longfin smelt. Beyond a certain threshold, temperature increases are expected to cause increases in longfin smelt mortality. The temperature limitations and sublethal impacts of temperature variation on longfin smelt are unknown. Given the northerly distribution of longfin smelt and their probable derivation from a marine ancestor, it is possible that longfin smelt distribution and abundance in the Estuary are limited by high temperatures, particularly during summer months. Rosenfield and Baxter (2007) noted several aspects of their distribution patterns that would be consistent with temperature limitation. Temperatures below the longfin smelt minimum temperature threshold are not likely to occur in this estuary.

Low dissolved oxygen. In order to respire, longfin smelt require sufficient dissolved oxygen concentrations. Below a certain threshold, longfin smelt mortality would be expected to increase rapidly with decreasing dissolved oxygen levels (or increased time of exposure to low dissolved oxygen levels). No studies on the dissolved oxygen requirements of longfin smelt are available. Given the species' range (and limited historical exposure to high temperature/low dissolved oxygen conditions) and distribution within this ecosystem, this fish may be expected to have fairly high requirements for dissolved oxygen concentrations. For example, longfin smelt requirements for dissolved oxygen are expected to equal or exceed those of Delta smelt because the latter species specializes in the warmer habitats with lower dissolved oxygen. Given their pelagic distribution, regular exposure to low dissolved oxygen conditions is unlikely. Low dissolved oxygen conditions may limit longfin smelt use of the lower San Joaquin as DO levels are frequently extremely low in that area.

A6.6 RELEVANT CONSERVATION EFFORTS

The CALFED Multi-Species Conservation Strategy (CALFED 2000) designates longfin smelt as an "R" species and states that the goal is to "achieve recovery objectives identified for longfin smelt in the recovery plan for the Sacramento/San Joaquin Delta native fishes" (USFWS 1996). However, no conservation efforts in the recovery plan specifically target longfin smelt; all are referenced to delta smelt.

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) was formed to guide the implementation of CALFED Ecosystem Restoration Plan elements within the Delta (DFG 2007b). The DRERIP team has created a suite of ecosystem and species conceptual models, including longfin smelt that document existing scientific knowledge of Delta ecosystems. The DRERIP Team has used these conceptual models to assess the suitability of actions proposed in the Ecosystem Restoration Plan for implementation. DRERIP conceptual models have been used in the analysis of proposed BDCP conservation measures. Additional enhancement and protective actions are also being identified as part of mitigation programs for various projects, biological opinions, and regional conservation planning efforts.

Modifications in the seasonal timing of SWP and CVP export operations on the longfin smelt population are currently being evaluated.

The Environmental Water Account (EWA) is intended to contribute to the protection, restoration, and recovery needs of fish, including longfin smelt, while still providing water supply reliability. However, analysis of the biological response of longfin smelt and other fish species to EWA actions in the past have failed to demonstrate significant protection or benefits to the overall populations of longfin smelt and other fish species.

In January 2005, the Interagency Ecological Program established a new Pelagic Organism Decline (POD) work team to investigate the causes of the recently observed rapid decline in populations of pelagic organisms, including longfin smelt, in the upper San Francisco Bay estuary (Baxter et al. 2008). Since that time, numerous studies have been conducted to determine the cause of the POD. Based on results of these studies and relevant studies undertaken by others, the work team has developed conceptual models to further the understanding POD. The Resources Agency prepared a Pelagic Fish Action Plan in March 2007 to address POD (Resources Agency 2007). The action plan identifies 17 actions that are being implemented or that are under active evaluation to help stabilize the Delta ecosystem and improve conditions for pelagic fish.

A6.7 RECOVERY GOALS

Longfin smelt is included in the 1996 Sacramento-San Joaquin Delta Native Fishes Recovery Plan, which also includes the delta smelt, Sacramento splittail, green sturgeon, Sacramento perch, and three races of Chinook salmon. The USFWS has the responsibility to review and update the recovery plan for these species. To accomplish this task, the USFWS has formed the Delta Native Fishes Recovery Team to assist in the preparation of this updated recovery plan. An updated recovery plan is expected to be completed in the near future.

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A6.8.3 Personal Communications

Keith Sakuma (Fishery Biologist, National Marine Fisheries Service) email to Randall Baxter (Fishery Biologist, California Department of Fish and Game) providing a print out of Osmerid catches 1980-1993 from NOAA May-June trawling in the Gulf of the Farallones. September 23, 2003.

Scott Foott (Pathologist, US Fish and Wildlife Service, Fish Pathology Lab, Anderson, California) phone call to Randall Baxter (Fishery Biologist, California Department of Fish and Game) describing histopathological examinations of larval and juvenile longfin smelt. December 2006.

Bruce Herbold (Fisheries Biologist, EPA) email to Rick Wilder about potential effects of pyrethroids on delta smelt. June 22, 2007.

Randy Baxter (Fishery Biologist, California Department of Fish and Game) phone conversation with Rick Wilder and Pete Rawlings about turbidity effects to longfin smelt. July 7, 2007.

APPENDIX A7. SACRAMENTO SPLITTAIL (*POGONICHTHYS MACROLEPIDOTUS*)

A7.1 LEGAL STATUS

The Sacramento splittail was listed as threatened under the federal Endangered Species Act (ESA) on February 8, 1999 (64 FR 5963). This ruling was challenged by two lawsuits (San Luis & Delta-Mendota Water Authority v. Anne Badgley et al. and State Water Contractors et al. v. Michael Spear et al.). On June 23, 2000, the Federal Eastern District Court of California found the ruling to be unlawful and on September 22 of that same year remanded the determination back to the U.S Fish and Wildlife Serviuce (USFWS) for re-evaluation of their original listing decision. Upon further evaluation, splittail was removed from the ESA on September 22, 2003 (68 FR 55139). On August 13, 2009, the Center for Biological Diversity (2009) challenged the 2003 decision to remove splittail from the ESA. However, on October 7, 2010, the USFWS found that listing of splittail was not warranted (75 FR 62070).

The splittail is designated as a species of special concern by the California Department of Fish and Game (DFG).

A7.2 SPECIES DISTRIBUTION AND STATUS

A7.2.1 Range and Status

The Sacramento splittail is endemic to the San Francisco Estuary and watershed. Splittail regularly inhabit the Sacramento River upstream to the Red Bluff Diversion Dam at river mile (rm) 243 and the San Joaquin River upstream to the mouth of Mud Slough at rm 125 (plus an additional 10.5 miles into Mud Slough) (see Figure A-7a). Splittail also inhabit the Napa and Petaluma River drainages (upper documented range: rm 18 and 17, respectively) and marshes. Splittail inhabiting these drainages have been found to be genetically distinct from splittail inhabiting the Sacramento and San Joaquin rivers (Baerwald et al. 2007). Splittail from the Petaluma River exhibited a higher degree of differentiation from the Sacramento-San Joaquin population than did Napa River splittail, suggesting high salinities in San Pablo Bay and Carquinez Strait isolated these populations to differing degrees from the larger Sacramento-San Joaquin population. Spawning occurs in the Petaluma and Napa rivers, but spawning locations within these rivers remain unknown (Moyle et al. 2004, Feyrer et al. 2005). No populations of splittail exist outside of the Central Valley rivers and the Bay-Delta estuary. Splittail range and selected observations in the lower portions of Sacramento River and tributaries include: the American River to rm 12, in the Feather River to rm 58 and from just below the Thermalito Afterbay outlet (B. Oppenheim pers. comm., A. Seesholtz pers. comm.), and in Butte Creek/ Sutter Bypass to vicinity of Colusa State Park.

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Figure A-7a. Sacramento Splittail Inland Range in California

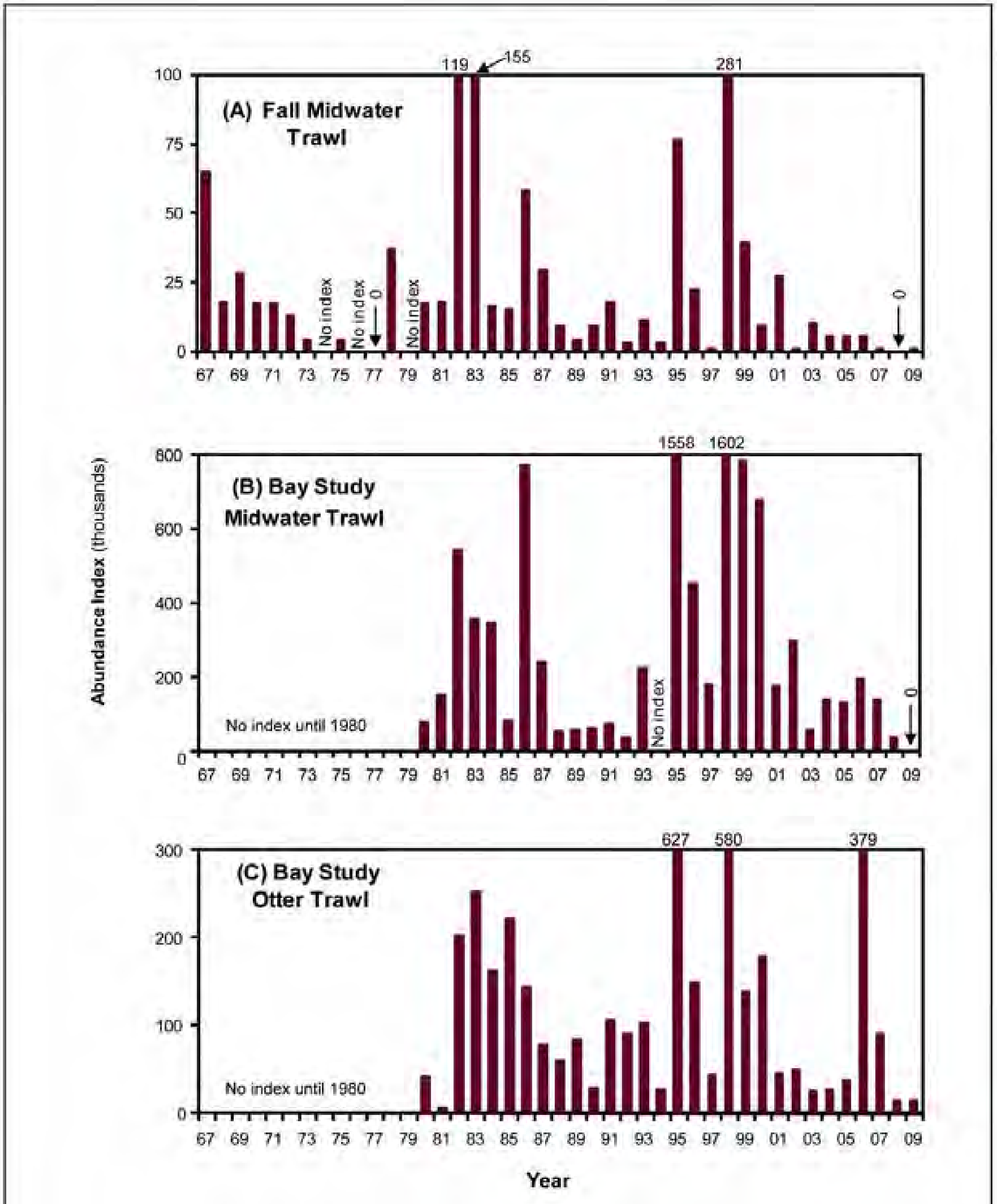
Long-term beach seine sampling data for age 0 splittail (less than or equal to 50 mm fork length) in the Sacramento River spanning 32 years (1976-2008) indicates that the farthest location upstream where juvenile splittail have been collected was 144 to 184 miles upstream of the confluence of the Sacramento and San Joaquin rivers (USFWS, unpublished data). The consistency in the upstream range of juvenile splittail found in these long-term studies supports a finding that there has been no decrease in distribution during this period (Feyrer et al. 2005).

Splittail range in other rivers includes:

- San Joaquin River – into Salt Slough (rm 135; Moyle 2002) and Mud Slough at the highway 140 bridge (R. Tibstra, pers. comm.);
- Cosumnes River – just above the confluence with the Mokelumne River (Crain et al. 2004);
- Mokelumne River – observed above Woodbridge Diversion Dam to rm 60;
- Stanislaus River – no confirmed sightings, but, based on observations from other tributaries, splittail probably inhabit low gradient portions of the lower river;
- Tuolumne River – rm 17 (Legion Park, Modesto, T. Ford pers. comm.) and several annually at rm 5 during 1999-2002 (T. Heyne, pers. comm.); and
- Merced River – rm 13 several annually 1999-2001 (1 mile upstream of Hagaman Park, M. Horvath pers. comm.; T. Heyne pers. comm.).

Near Mud and Salt Sloughs, splittail can access historical valley floodplains and apparently use them for spawning in wet years (e.g., 1995 and 1998; Baxter 1999, Moyle et al. 2004). Splittail occasionally extend their range farther southward into central and southern San Francisco Bays using freshwater and low salinity habitats created during high outflow years (DFG unpubl. data; Moyle et al. 2004). After high outflow years in the early 1980s and mid-1990s, splittail were captured in the estuary of Coyote Creek, South San Francisco Bay (M. Stevenson, pers. comm.). There is no recent information on the status or persistence of these south Bay populations.

The abundance of juvenile splittail (young-of-the-year) is highly variable from one year to the next and positively correlated with hydrologic conditions within the rivers and Delta during the late-winter and spring spawning period and the magnitude and duration of floodplain inundation (Sommer et al. 1997). Because splittail are a long-lived species (5 to 7 years; Moyle 2002), the abundance of juveniles in a given year may not be a good predictor of adult splittail abundance. Results of DFG fall midwater trawl surveys indicate a marked decline in overall splittail abundance and consistently low population levels since 2002 (see Figure A-7b). In addition, Bay study indices were extremely low.



Source: DFG, unpubl. data; IEP, unpubl. data.

Figure A-7b. Annual Abundance Indices of Splittail from 1967-2009 in (A) Fall Midwater Trawl, (B) Bay Study Midwater Trawl, and (C) Bay Study Otter Trawl

A7.2.2 Distribution and Status in the Plan Area

Adult splittail spawn within the mainstem rivers and major tributaries to the Delta upstream of the Plan Area. Adult splittail spawn in the Plan Area on inundated floodplains of the Yolo Bypass and Cosumnes River. Collection of larvae and young juveniles indicates that inundation of terrestrial habitat within the levees of the San Joaquin River also provides suitable spawning habitat (Moyle et al. 2004). Larvae and young juveniles begin their migration downstream through the Delta with rising water temperatures during the spring; such migrations often occur in late-April, May, or even June of high flow years (Moyle et al. 2004). In low flow years, juvenile splittail are most abundant in the northern and western regions of the Delta; in high flow years, their distribution is more even throughout the Delta (Sommer et al. 1997). Most late stage juveniles and non-reproductive adults inhabit moderately shallow (less than 4 m) brackish and freshwater tidal sloughs and shoals, such as those found in Suisun Marsh and the margins of the lower Sacramento River (Moyle et al. 2004, Feyrer et al. 2005). Figure A-7c indicates the geographic distribution of splittail over the past 34 years throughout the Delta region and Figure A-7d indicates seasonal variation in the abundance of post-larval and juvenile splittail throughout their range.

No population level estimates currently exist for Sacramento splittail. However, because much of the overall distribution of splittail occurs in the Plan Area, population status and trends in the Plan Area are expected to be very similar to overall population status and trends.

A7.3 Habitat Requirements and Special Considerations

Spawning and Early Rearing. Splittail spawning is known to take place from February to July in freshwater on inundated floodplains in the Yolo and Sutter Bypasses and along the Cosumnes River (Sommer et al. 1997, 2001, 2002, Crain et al. 2004, Moyle et al. 2004). Limited collections of ripe adults and early stage larvae indicate splittail spawn in shallow water (less than 2 m deep) over flooded vegetated habitat (cockle burr, other annual terrestrial vegetation, and perennial vegetation like willow) with a detectable water flow (Moyle et al. 2004). Turbidity is typically high under these conditions, but decreases rapidly as flows diminish. On floodplains, complex topography slows water velocities, creating eddies, and increasing hydraulic residence time. Increased hydraulic residence time promotes phytoplankton and zooplankton production on seasonally inundated floodplains. Copepods are an important first food for larval splittail (Kurth and Nobriga 2001). Floodplain inundation initiates egg development of an aquatic fly (chironomids) that, as late stage larva or pupa, is an important food of late stage larval splittail (Kurth and Nobriga 2001). Relatively warm temperatures and an abundance of food allow young splittail to grow and develop rapidly on floodplains so that they are physically prepared to leave floodplains when water levels recede. Increased water temperatures and reduced water levels may cue floodplain emigration of juvenile splittail. Many of these ecosystem benefits are dependent upon the frequency, duration, and timing of the floodplain inundation.

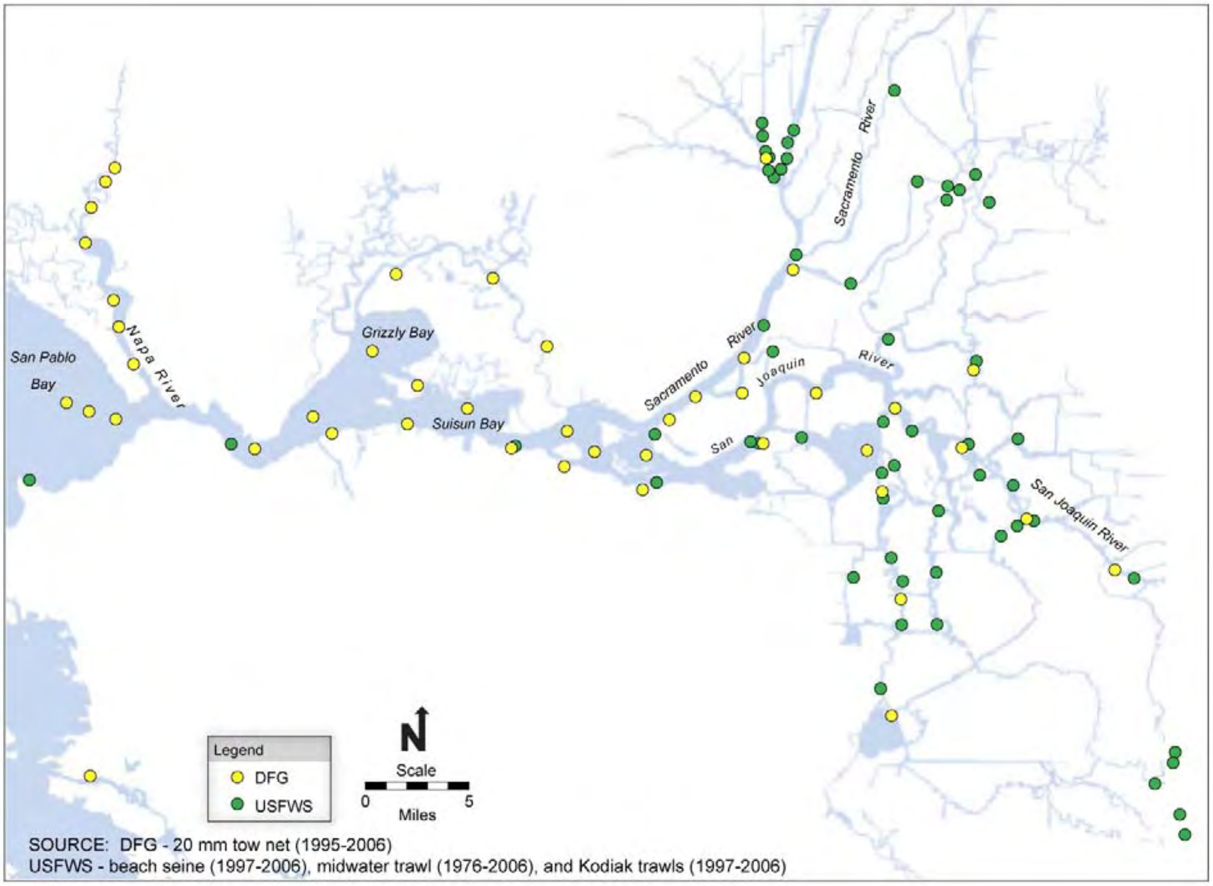
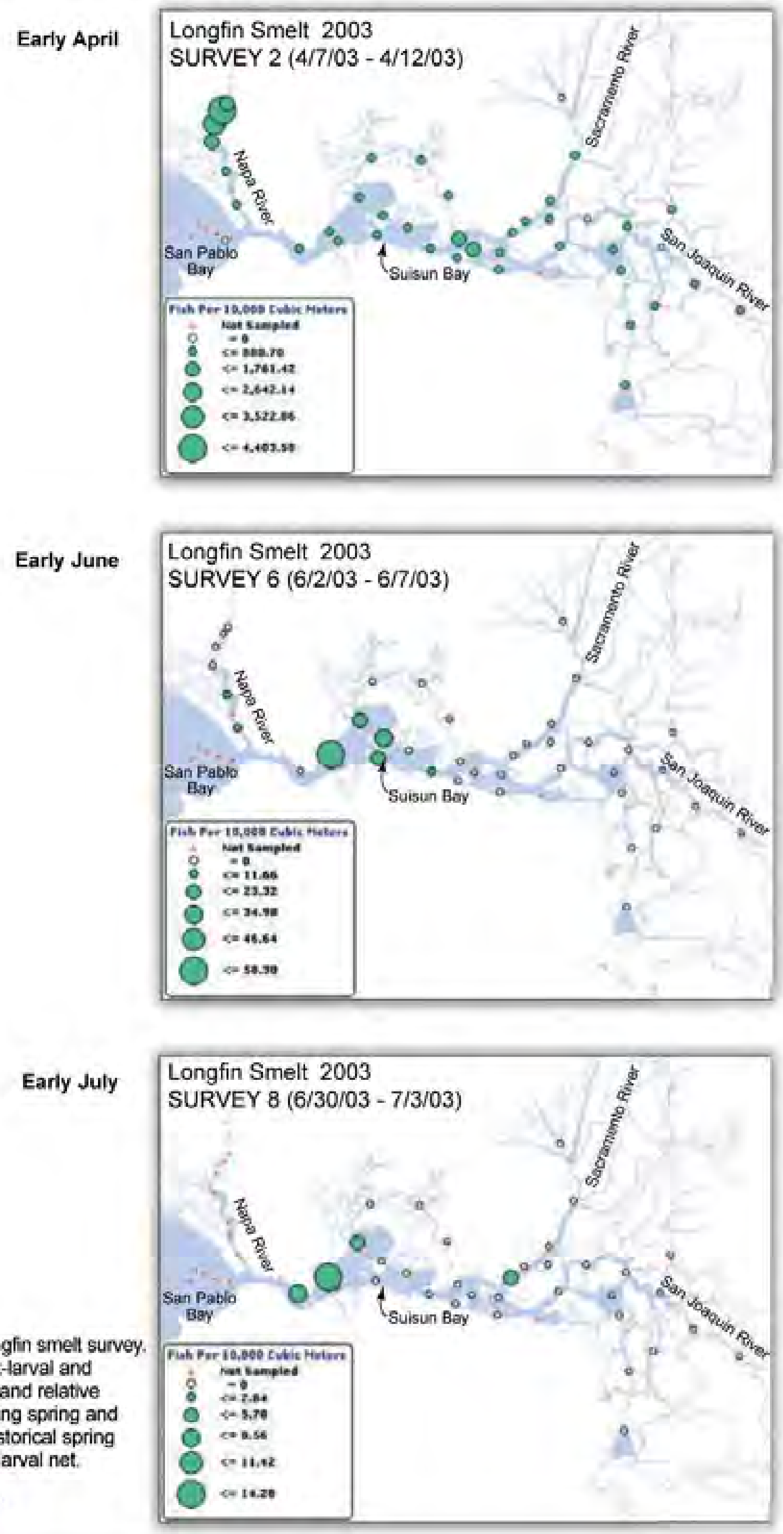


Figure A-7c. Historical Sampling Locations where Splittail have been Captured Since 1976

When floodplain inundation does not occur in the Yolo or Sutter Bypasses, adult splittail migrate farther upstream to suitable habitat along channel margins or flood terraces; spawning in such locations occurs in all water year types (Feyrer et al. 2005). Although evidence from DFG fishery surveys demonstrates that splittail spawn in all years, spawning success, as reflected in juvenile abundance, is typically greatest in wet years.

Juveniles and Adults. Although some larval and juvenile splittail are swept off floodplains and downstream by flood currents (Baxter et al. 1996), many splittail larvae and juveniles remain in riparian or annual vegetation along shallow edges on floodplains as long as water temperatures remain cool (Sommer et al. 2002, Moyle et al. 2004). Juvenile and subadult splittail commonly inhabit regions of the estuary characterized by salinities of 10 to 18 parts per thousand (ppt) (Meng and Moyle 1995; Sommer et al. 1997). Salinity tolerance increases with size (and age) such that adult splittail can survive salinities up to 29 ppt for brief periods of time (Young and Cech 1996). Splittail inhabit a broad range of temperatures, 5 to 24°C (41 to 75.2 °F) depending upon season, and acclimated fish can tolerate 29 to 33°C (84.2 to 91.4 °F) for short periods (Young and Cech 1996).



Source: CDFG 2003, 20 mm Longfin smelt survey. This annual survey monitors post-larval and juvenile longfin smelt distribution and relative abundance every two weeks during spring and early summer throughout their historical spring range using a 1600 µm egg and larval net. For more information see http://www.delta.dfg.ca.gov/data/20mm/description.asp

Figure A-7d. Example of Distribution of Post-Larval and Juvenile Longfin Smelt in Spring-Summer of a Representative Above Normal Water Year

Complementing their temperature and salinity tolerances, splittail of all sizes can tolerate low dissolved oxygen levels (less than 1 mg O_2 L^{-1}, Moyle et al. 2004), making them well suited to slow moving sections of sloughs and rivers. In Suisun Marsh during summer, splittail commonly inhabit areas with salinities of 6 to 10 ppt and temperatures of 15 to 23 °C (59 to 73.4 °F; Meng and Moyle 1995). Juveniles are most abundant in shallow (less than 2 m), turbid water with a current, and are often m) with incoming tide to feed. Napa and Petaluma River stocks may possess a higher salinity tolerance than the Central Valley stock (Baerwald et al. 2007).

Two early life history strategies occur in juvenile splittail produced in the Sacramento River system: the dominant strategy is characterized by juveniles migrating downstream in late spring and early summer to the Delta, Suisun Bay, and Suisun Marsh; a less well studied strategy is to remain upstream through the summer into the next fall or spring and migrate downstream as a subadult (Baxter 1999, Moyle et al. 2004). This latter strategy occurs in Butte Creek and the mainstem Sacramento River. As water recedes further, juveniles remaining in upstream riverine habitats and congregate in large eddies for feeding (R. Baxter, unpubl.data).

Channel margin and backwater habitats can be critical to the survival of young-of-year (YOY) splittail, as well as the population as a whole (Moyle et al. 2004, Feyrer et al. 2005). Such habitats provide refugia from predatory fishes and feeding sites as fish grow in upstream regions before and during downstream migration. Many backwater habitats are associated with the complex topography of remnant riparian habitats and are ephemerally created in response to increases in river stage (water surface elevation); others are synthetic creations such as cut channels, boat ramps, or agricultural pump intakes. This contrasts with major floodplain inundation typically associated with large splittail year classes (Meng and Moyle 1995, Baxter et al. 1996, Sommer et al. 1997), which may require an 8 to 10 m increase in river stage (typically associated with flood flow events). In the Sacramento River, levees constrain river meander from rm 194 at Chico Landing downstream to Collinsville (rm 0) and restrict the riparian zone accessible via the river channel.

Levee configuration differs through three reaches downstream of Chico Landing and has important implications in terms of splittail spawning and rearing habitat: (1) the river reach from Chico Landing to Colusa (rm 144) is characterized by setback levees enclosing remnant floodplain (flood terraces) and a narrowly meandering river channel; (2) the reach from Colusa to Verona (rm 80) is tightly leveed and contains fewer and much narrower flood terraces, many of which are actively eroding and targeted for rip-rap; and (3) the reach from Verona to Collinsville (rm 0) is also tightly leveed and contains extensive, narrow flood terraces between Verona and Sacramento, but is almost completely rip-rapped from Sacramento to Collinsville (Feyrer et al. 2005).

Maintaining and increasing this seasonally inundated floodplain habitat suitable for splittail spawning and juvenile rearing throughout the species range has been identified as a factor that will help maintain successful reproduction and increase juvenile abundance and genetic diversity during prolonged drought events and avoid a genetic “bottleneck.”

A7.4 LIFE HISTORY

Phenology. Adult splittail begin a gradual upstream migration towards spawning areas sometime between late November and late January. The relationship between migrations and river flows is poorly understood, but it is likely that splittail have a positive behavioral response to increases in flows. Feeding in flooded riparian areas in the weeks just prior to spawning may be important for later success of spawning and for post-spawning survival. Not all splittail make significant movements prior to spawning, as indicated by evidence of spawning in Suisun Marsh (Meng and Matern 2001) and the Petaluma River. The upstream movement of splittail is closely linked with flow events during February-April that inundate floodplains and riparian areas (Garman and Baxter 1999, Harrell and Sommer 2003). Seasonal inundation of shallow floodplains provides both spawning and foraging habitat for splittail (Caywood 1974, Daniels and Moyle 1983, Baxter et al. 1996, Sommer et al. 1997). Evidence of splittail spawning on floodplains has been found on both the San Joaquin and Sacramento rivers. In the San Joaquin River drainage, spawning has apparently taken place in wet years in the region where the San Joaquin River is joined by the Tuolumne and Merced rivers (T. Ford, pers. comm.). Spawning has also been documented on flooded areas along the lower Cosumnes River (Crain et al. 2004). Spawning may take place elsewhere in the Delta (e.g., on mid-channel islands) but it has not been documented. In the Sacramento River drainage, the most important spawning areas appear to be the Yolo and Sutter Bypasses, which are extensively flooded during wet years (Sommer et al. 1997, 2001). However, some spawning takes place every year along the river edges and backwaters created by small increases in flow.

In the eastern Delta, the floodplain along the lower Cosumnes River appears to be important as spawning habitat. Ripe splittail have been observed in areas flooded by levee breaches, in association with cool temperatures (less than 15 °C [59 °F]), turbid water, and flooded terrestrial vegetation (P. Moyle, unpubl. data).

Life Cycle. Splittail spawning occurs between late February and early July (Wang 1986). Fecundity is highly variable; females lay between 5,000 to 100,000 eggs. Egg incubation lasts for 3 to 7 days depending on water temperature (Moyle 2002). Newly hatched larvae are typically 6.5 to 8 mm (fork length) (Wang 1986). Larvae remain in shallow weedy areas near spawning areas for 10 to 14 days (Meng and Moyle 1995). When juveniles reach a length of approximately 29 mm (fork length), they move into deeper habitats (Sommer et al. 2002). Splittail grow to a typical length of 110 mm (standard length) during their first year, 170 mm during their second year, 250 mm during their third year, and 35 mm/year during remaining years (Moyle 2002). Maturity is typically reached at the end of their second year (Daniels and Moyle 1983).

Diet. The diet of splittail larvae up to 15 mm in length is dominated by zooplankton, primarily cladocerans with some copepods, chironomids, and rotifers present in small amounts; chironomids become important after splittail reach 15 mm in length (Kurth and Nobriga 2001, Moyle 2002). For age 1+ splittail, detritus is the dominant item found in fish collected from the estuary; various macroinvertebrates, including amphipods, clams, and mysid shrimp, are the most common non-detrital items (Caywood 1974, Daniels and Moyle 1983, Feyrer et al. 2003). During upstream migration to spawning areas, adult splittail captured near inundated shorelines along the Sacramento River were found to contain oligochaetes (earth worms) as well as smaller amounts of dipterans and cladocerans (Caywood 1974).

A7.5 THREATS AND STRESSORS

The following have been identified as important threats and stressors to Sacramento splittail (not in order of priority).

Reduced juvenile/adult rearing habitat. Reclamation of Delta islands and wetlands during the 19th and early 20th centuries removed or degraded large areas of high quality juvenile/adult rearing habitat. This habitat consisted of shallow, low velocity areas throughout the Delta, and particularly in the western Delta and Suisun Marsh (Moyle et al. 2004). In the 1960s and 1970s, the U.S. Army Corps of Engineers (USACE) increased downstream water conveyance and reinforced levees by clearing and rip-rapping levees along the lower Sacramento River. These actions further reduced or eliminated suitable rearing habitat for splittail from the city of Sacramento downstream by removing large areas of shallow channel margins. Current efforts are under way to improve flood protection for communities along much of the lower Sacramento River and several other valley rivers. Actions being proposed and conducted include removal of trees and riparian vegetation and armoring with riprap. USACE's current policy is for removal of all large trees and brush from levees to improve detection of weak points and potential levee failures.

Reduced spawning/larval rearing habitat. Reclamation and levee construction along the majority of Delta waterways and upstream riverine habitats has degraded or eliminated large areas of seasonally inundated floodplains that once served as spawning and larval rearing habitat for splittail. Although some spawning occurs on shallow margins of the main channels every year, floodplains are highly productive and, when inundated, are used more heavily by splittail than channel margin habitat for spawning and larval rearing.

Changes in river stage resulting from upstream diversions and reservoir storage has not been well studied, but, during low and moderate runoff years, water management may affect access of splittail to floodplains and their ability to emigrate successfully after spawning and early rearing (Moyle et al. 2004). Reservoir operations are designed to reduce peak flows during winter and spring months that historically would have resulted in seasonal inundation of floodplains.

Reduced food. There are multiple mechanisms that may cause reductions in food supplies for juvenile and adult splittail, including competition with non-native species and reductions in primary and secondary productivity (Jassby et al. 2002, Resources Agency 2007). The overbite clam is a highly efficient filter feeder that has reduced zooplankton populations in the Delta and Suisun Bay (Kimmerer and Orsi 1996). Zooplankton, particularly mysid shrimp, were the principal component of the splittail diet prior to the invasion of the estuary by the overbite clam, and the introduction of the clam has reduced the availability of mysids to splittail (Feyrer et al. 2003). However, the effect of the overbite clam on food availability to splittail is mixed because splittail also consume the clams (Feyrer et al. 2003).

Reductions in productivity within the estuary have been attributed to changes in hydrology associated with upstream reservoir operations, in-Delta water diversions, and reduced hydraulic residence time in the Delta. Upstream reservoir operations have reduced seasonal variability in Delta and river hydrology, resulting in fewer and shorter high flow events and, therefore, reduced frequency and duration of floodplain inundation (Sommer et al. 1997, 2002, Meng and Matern 2001, Feyrer et al. 2005, 2006). Floodplains are highly productive and are a source of large amounts of organic carbon (Schemel et al. 1996, Sommer et al. 2001, Schemel et al. 2004, Lehman et al. 2008).

The State Water Project (SWP) and Central Valley Project (CVP) export facilities and the over 2,200 in-Delta agricultural diversions (Herren and Kawasaki 2001) export nutrients, organic material, phytoplankton, and zooplankton from the Delta that would otherwise support the base of the food web (Jassby et al. 2002, Resources Agency 2007).

Reductions in hydraulic residence time in the central Delta have resulted, in part, from the need to maintain high water quality in the Delta for agricultural uses and SWP/CVP exports. Higher quality water from the Sacramento River is conveyed southward through the Delta via the Delta Cross Channel, creating a hydraulic barrier against salt water that may otherwise enter the Delta from the west. As a result, water movement has increased and hydraulic residence time has declined in the central Delta. Reduced hydrologic residence time is thought to reduce productivity in the Delta because nutrients and organics are transported downstream and out of the Delta before stimulating phytoplankton or zooplankton production (Jassby et al. 2002, Kimmerer 2002a,b, Resources Agency 2007). Increased hydraulic residence time allows more opportunity for bacterial activity and phytoplankton and zooplankton production.

Exposure to toxins. Although there is strong support from laboratory studies that toxics can be lethal to splittail (Teh et al. 2002, 2004a,b, 2005), there is little information about the chronic or acute toxicity of contaminants within the Delta (e.g., Greenfield et al. 2008). The longevity of splittail relative to most other covered fish species (5 to 7 years, Moyle 2002) enables their tissue to bioaccumulate toxicants to higher concentrations than these other species. This makes splittail particularly vulnerable to heavy metals, such as mercury, and other fat-soluble chemicals. Perhaps the greatest concern among the impacts of contaminants on splittail relates to selenium. Tissues of splittail collected in Suisun Bay had sufficiently high selenium concentrations to potentially cause physiological impacts, in particular reproductive abnormalities (Stewart et al. 2004). Adult splittail feed on the overbite clam, which bioaccumulates and transfers selenium in high concentrations (Luoma and Presser 2000). With the decline of the mysid shrimp, *Neomysis,* in the estuary, juvenile and adult splittail have increased foraging on benthic macroinvertebrates such as clams (Feyrer et al. 2003). Teh et al. (2004b) found that young splittail that were fed a diet high in selenium grew significantly slower and had higher liver and muscle selenium concentrations after nine months of testing.

Kuivila and Moon (2004) documented dissolved pesticides in the Sacramento-San Joaquin Delta during April-June (1998-2000) when young, growing splittail were migrating into the Delta and estuary. The use of pyrethroid pesticides has increased substantially in the Central Valley since the early 1990s (Oros and Werner 2005). Though relatively non-toxic to mammals, these chemicals are highly toxic to aquatic organisms, including fishes. Also, pesticide use on row crops (including rice) commonly grown in the Yolo and Sutter Bypasses and their proclivity to adhere to sediment particles suspended in water and deposited on the bottom provide a dietary pathway to splittail ingestion along with detritus during feeding (see Diet section above) (Werner 2007). Exposure to pesticides and other chemical contaminants may occur while splittail forage on inundated floodplains or in the estuary after the pesticides have entered Delta channels through agricultural drainage and have been transported to and settled in the Delta.

Non-native species. Splittail have persisted in the estuary through numerous invasions of non-native fish and invertebrates. Some, such as the invasion of the mysid shrimp, *Acanthomysis*, may have been beneficial to splittail, as the native mysid, *Neomysis*, was already on a steep decline in abundance. Both mysid species are eaten by splittail. The invasive overbite clam also became a food item, but with potential detrimental effects, such as bioaccumulation of selenium and reduction in overall phytoplankton and zooplankton abundance (see above).

Major non-native predatory fish introduced into the Bay-Delta estuary, such as striped bass and largemouth bass, have resided in the Delta for over a century (Dill and Cordone 1997), and splittail have persisted. However, reduced turbidity in the Delta combined with increased habitat for non-native predatory species provided by Brazilian waterweed and water hyacinth has enhanced both largemouth bass abundance and their ability to visually forage, thus increasing predation risk to splittail (Toft et al. 2003, Brown and Michniuk 2006).

A major concern is the potential invasion of the Delta by the highly predatory northern pike. The pike, recently present in Lake Davis on the Feather River, is currently the target of a major eradication effort (DFG 2007a). If eradication fails and pike escape downstream to the Delta, they would likely to become abundant in many of the same habitats as splittail (Moyle 2002).

Entrainment. Splittail are salvaged year-round in the SWP and CVP fish salvage facilities, with the greatest occurrence during May-July. The majority of splittail observed in fish salvage monitoring are early juveniles. Although juvenile splittail are collected in SWP and CVP fish salvage, there is no evidence that juvenile entrainment mortality has a significant population level effect on splittail (Sommer et al. 1997). Splittail salvage rates at the SWP and CVP facilities are high when splittail populations are at high levels. Young-of-the-year splittail have critical swimming velocities that are similar to water velocities occurring at the SWP and CVP diversions and are entrained at these facilities (Young and Cech 1996). Because salvage rates are high when splittail abundance is high, the effect of entrainment at the SWP and CVP export facilities on the overall population of splittail is not expected to be great. However, prolonged drought and subsequent reduction in adult splittail abundance could eventually cause a proportionally large effect on the population, particularly if the geographic distribution of the splittail population were to occur near the export facilities (Sommer et al. 1997).

Increases in export rates during the winter and total water exports from the south Delta have been associated with increased salvage of a wide variety of upper estuary fishes since 2000 (Herbold et al. 2005). The majority of splittail salvage at the SWP and CVP export facilities is composed of age 0 fish in May-July during years with high outflows that persist into the March-April splittail spawning period (Sommer et al. 1997). For example, splittail salvage increased substantially in both 2005 and 2006, corresponding to high levels of juvenile production within the system, reaching a record high of over 5 million fish at the CVP Tracy Fish Collection Facility (Gartz 2007).

There are no studies that quantitatively examine splittail mortality during the SWP or CVP fish salvage process, but it is thought to be high. Mortality to young splittail may occur as a result of overcrowding within transport tanks and predation at release locations within the Delta. Furthermore, adults that are salvaged are returned to an area downstream of the export facilities, which is expected to increase the energy expenditure needed to reach their upstream spawning sites and could reduce their ability to spawn successfully (Moyle et al. 2004).

In addition to SWP and CVP export facilities, there are over 2200 small water diversions within the Plan Area, the majority of which are unscreened (Herren and Kawasaki 2001). Results of surveys at unscreened diversions (Nobriga et al. 2004) have shown that a variety of fish species (e.g., threadfin shad, silversides, striped bass, etc.), primarily larval and juvenile lifestages, are vulnerable to entrainment. Based on results of this and similar studies conducted on unscreened diversions, it has been hypothesized that early juvenile splittail would be vulnerable to entrainment from these smaller diversions. The available information, however, is insufficient to fully assess the potential magnitude of the entrainment risk, how the risk varies among areas and seasonally, and the cumulative effect of entrainment losses on the population dynamics of splittail. Water velocities at these relatively small agricultural pumps and siphons are low enough that larger fish are able to avoid entrainment. No comprehensive quantitative estimates have been developed for the level of potential entrainment mortality that may occur as a result of diversions from the rivers and Delta.

Power plants within the Plan Area have the ability to entrain large numbers of fish. However, use of cooling water is currently low with the retirement of older units. Furthermore, recent State Water Resources Control Board (SWRCB) regulations require that units at these plants be equipped with a closed cycle cooling system by 2017.

Harvest. The legal fishery for splittail is thought to be substantial, despite poor documentation (Moyle et al. 2004). Subadult and adult splittail are harvested by recreational anglers for consumption, as well as for use as bait by striped bass anglers. There is no evidence that splittail are affected at a population level by the fishery, but there is insufficient evidence to conclude this with confidence.

A7.6 RELEVANT CONSERVATION EFFORTS

The Ecosystem Restoration Program (ERP) (CALFED 2000) lists splittail as “r,” contribute to recovery, and includes the following prescription to achieve the species goal:

> *Species recovery objectives will be achieved when 2 of the following 3 criteria are met in at least 4 of every 5 years for a 15 year period: 1) the fall mid-water trawl survey numbers must be 19 or greater for 7 of 15 years. 2) Suisun Marsh catch per trawl must be 3.8 or greater and the catch of young-of-year must exceed 3.1 per trawl for 3 of 15 years, and 3) Bay Study otter trawls must be 18 or greater AND catch of young-of-year must exceed 14 for 3 out of 15 years.*

The CALFED ERP has funded the Yolo Bypass Watershed Restoration Strategy. The purpose of this project is to develop a local implementation strategy for a broad landscape level of restoration and rehabilitation for the Yolo Bypass, which should have direct benefits to splittail.

The ERP has also funded a feasibility study for flood protection and ecosystem restoration at Hamilton City. The feasibility study identified constructing an 11 km (6.8 mile) setback levee with varying heights. To accomplish ecosystem restoration within the project area, the majority of the existing “J” levee would be removed to reconnect the river to the floodplain, allowing overbank flooding and increasing capacity in the Sacramento River. Native vegetation would be restored on all project lands waterside of the new setback levee. Existing orchards in the proposed restoration areas would be removed and native vegetation planted. The native vegetation would be riparian species, scrub, oak savannah, and grassland species.

Connectivity to and restoration of floodplain habitat were achieved along the Cosumnes River through breaching of levees on the Cosumnes River Preserve during the 1990s (Booth et al. 2006). The Cosumnes River Preserve is managed by a coalition of state, federal, and non-profit organizations, such as The Nature Conservancy California. The Cosumnes River floodplain is now thought to be used for spawning by splittail (Crain et al. 2004, Moyle et al. 2004).

There are several conservation activities planned to improve shallow subtidal habitat in the Delta that should provide benefit to splittail. The CALFED ERP Suisun Marsh Land Acquisition and Tidal Marsh Restoration project will restore 500 acres within the Suisun Marsh to tidal wetland. The Suisun Marsh/North San Francisco Bay Ecological Zone Biological Restoration and Monitoring project will restore, maintain, and monitor the biology of at least three major eastern San Pablo Bay and southern Suisun Bay areas within a single CALFED-defined ecological zone (Suisun Bay/North San Francisco Bay), and compare and improve these restoration efforts through an integrated monitoring program. Construction in Ponds 3, 4, and 5 in the Napa-Sonoma Marsh will restore three commercial salt ponds along the Napa River that are expected to provide habitat benefits for splittail and other aquatic species. Restoration of Pond 3 will provide tidal habitat, whereas restoration actions in Ponds 4 and 5 will reduce salinity in preparation for tidal habitat restoration. The overall goal of this project is to restore tidal influence and re-create natural/historic elevations/topography, soil conditions, and plant communities throughout the entire elevational range to restore tidal marsh habitat.

Using ERP funds**,** construction of the Sutter Mutual Water Company Tisdale positive barrier fish screen and pumping plant has been completed. This diversion is located 45 miles north of Sacramento on the Sacramento River and will eliminate entrainment losses while maintaining Sutter Mutual Water Company's diversions.

Construction is ongoing for the Reclamation District 108 Poundstone Intake Consolidation and Positive Barrier Fish Screen Project in Colusa County. This project will construct an 81 foot long positive barrier fish screen at the entrance to a new water diversion site on the Sacramento River (rm 110.5) in Colusa County. The new diversion will consolidate and allow removal of three existing unscreened diversions. Other projects (e.g., Reclamation District 1004 intake screens, RD 108 Wilkins Slough Positive Barrier Fish Screen) have been constructed on the Sacramento River to reduce entrainment of splittail and other fish.

A new integrated monitoring and outreach program to evaluate fish contamination issues has recently been funded by ERP. This project will monitor mercury levels in sport fish and biosentinel indicators for three years throughout the watershed. The monitoring will evaluate spatio-temporal variability and gather information needed for management decisions.

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) was formed to guide the implementation of CALFED ERP elements within the Delta (DFG 2007b). The DRERIP team has created a suite of ecosystem and species conceptual models, including splittail, that document existing scientific knowledge of Delta ecosystems. The DRERIP Team has used these conceptual models to assess the suitability of actions proposed in the Ecosystem Restoration Plan for implementation. DRERIP conceptual models were used in the analysis of proposed BDCP habitat restoration actions.

The Sacramento River Conservation Area Forum, DWR, USFWS, DFG, the Department of Parks and Recreation, the Wildlife Conservation Board, nonprofit organizations such as the Nature Conservancy and the Sacramento River Partners, and many other stakeholders conduct conservation and restoration activities in the middle and upper reaches of the Sacramento River. The Sacramento River Conservation Area Forum developed guidelines for all stakeholders to follow in directing their restoration and conservation actions. These guidelines "ensure that riparian habitat management along the river addresses the dynamics of the riparian ecosystem and the reality of the local agricultural economy." Sacramento River Conservation Area Forum goals include preserving remaining riparian habitat and reestablishing a continuous riparian ecosystem along the river. Restoration activities generally fall into one of two categories:

- Actions aimed to protect and maintain existing healthy habitat and natural processes; or
- Actions aimed to restore and recover lost habitat and disrupted processes.

The Sacramento River Conservation Area Forum recommends preserving existing riparian habitat and reestablishing a continuous band of riparian vegetation along the river. Most conservation actions to date embrace this goal and were initiated to offset habitat fragmentation as a significant threat to declining fish and wildlife populations. The most flood-prone land parcels with less productive soils and more rapid bank erosion have been bought from willing sellers and restored first.

On December 10, 2009, the California Fish and Game Commission adopted DFG's proposal to establish fishing regulations on splittail in an effort to reduce the potential effects of harvest on the splittail population. Effective March 1, 2010, there is a year-round two fish daily bag and possession limit.

A7.7 Recovery Goals

Although splittail is not listed, it is included in the USFWS 1996 Sacramento-San Joaquin Delta Native Fishes Recovery Plan, which also includes the delta smelt, longfin smelt, green sturgeon, Sacramento perch, and three races of Chinook salmon (USFWS 1996). The USFWS has the responsibility to review and update the recovery plan for these species. To accomplish this task, the Service has formed a new Delta Native Fishes Recovery Team to assist in the preparation of this updated plan. An updated recovery plan from USFWS is expected to be completed soon.

A7.8 References

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A7.8.3 Personal Communications

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Heyne, Tim (Biologist, DFG) email to Randall Baxter (DFG) documenting splittail counts from the Tuolumne (rm 5) and Merced (rm 13) rotary screw traps 1999-2003. October 3, 2003.

Horvath, Mike (Fish and Wildlife Technician, DFG) email to Randall Baxter (DFG) describing the catch in a screw trap of a gravid female splittail the previous day. April 16, 1999,

Oppenheim, Bruce (Biologist, NMFS) email report to Randall Baxter (DFG) of a fresh angler killed adult splittail thrown up on a river bank just below the Thermalito outlet. September 15, 2003.

Seesholtz , Alicia (Environmental Scientist, DWR) phone conversation with Rick Wilder about fish use of the Feather River. September 20, 2007

Stevenson, Marty (Biologist/Consultant, Kinetic Laborary for South Bay Dischargers) to Randall Baxter (DFG) describing juvenile splittail collected in Coyote Creek and adjacent, Guadalupe Slough in 1983 and 1984. May 16, 1997.

Tibstra, Robert (Biologist, DFG) email to Randall Baxter (DFG) describing splittail collected electrofishing at 3 sites: in the San Joaquin River upstream of the Merced River confluence and downstream of the Mud Slough confluence (RKM 191); in the SJR upstream of the Mud Sl. confluence, 100m downstream of the highway 140 bridge (RKM 201); and in Mud Slough (north) downstream of the discharge of the San Luis Drain at hwy 140 bridge. November 15, 2002.

APPENDIX A8. WHITE STURGEON (*ACIPENSER TRANSMONTANUS*)

A8.1 LEGAL STATUS

The white sturgeon is not listed under the Federal or California Endangered Species Acts (ESA).

A8.2 SPECIES DISTRIBUTION AND STATUS

A8.2.1 Range and Status

White sturgeon inhabit three major drainages on the west coast of North America including the California Central Valley, Columbia (Washington), and Fraser River (British Columbia) systems. In California, white sturgeon are most abundant in the Sacramento River and San Francisco Bay-Delta estuary (Figure A-8a) (Moyle 2002). White sturgeon have been reported from the San Joaquin River system, particularly in wet years (DFG 2002, Beamesderfer et al. 2004).

Historical spawning range of white sturgeon extended upstream of Shasta Dam before its construction in the 1940s (Figure A-8a). It is thought that white sturgeon also spawned farther upstream on the San Joaquin River before major water diversions existed (Moyle 2002).

In the Central Valley, white sturgeon populations have declined from an estimated 144,000 adults in 1994 to 10,000 adults in 2005 (Bland 2006). The number of adults fluctuates annually and appears to be the result of highly variable juvenile production; the population is dominated by a few strong year classes associated with high spring outflows (Moyle 2002).

A8.2.2 Distribution and Status in the Plan Area

The Delta and Suisun Bay serve as a migratory corridor, feeding area, and juvenile rearing area for white sturgeon. White sturgeon move from coastal marine waters into the Delta and lower Sacramento River during the late fall and winter. Larval and juvenile white sturgeon inhabit the lower reaches of the Sacramento and San Joaquin rivers and the Delta (Stevens and Miller 1970). Adult white sturgeon have also been documented in the Yolo Bypass (Webber et al. 2007; M. Marshall, pers. comm.).

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Figure A-8a. White Sturgeon Inland Range in California

A8.3 HABITAT REQUIREMENTS AND SPECIAL CONSIDERATIONS

As anadromous fish, sturgeon inhabit riverine, estuarine, and marine habitats at various life stages during their long life. White sturgeon spawn preferably in the Sacramento River in the reach between the Red Bluff Diversion Dam (RBDD) and Jelly's Ferry Bridge (River Mile [rm] 267) in areas characterized by swift currents and deep pools with gravel (USFWS 1995, Schaffter 1997, DFG 2002, Moyle 2002). Habitats for migration of white sturgeon are downstream of spawning areas and include the mainstem Sacramento River, Delta, and San Francisco Bay estuary. These corridors allow the upstream passage of adults and the downstream emigration of juveniles. It has been hypothesized that migratory habitat conditions are affected by a variety of factors that may include the presence of barriers and impediments to passage (e.g., dams, gates such as the RBDD gates). Rearing habitat condition and function may be affected by annual and seasonal variation in flow and water temperatures.

A8.4 LIFE HISTORY

White sturgeon spend most of their lives in brackish portions of the estuary, although a small number of individuals move extensively in the ocean (Moyle 2002, Surface Water Resources, Inc. 2004, Welch et al. 2006). Individuals tend to concentrate in deeper areas of the estuary with soft mud and sand substrate (Pacific States Marine Fisheries Council 1996, Moyle 2002). Individuals can live over 100 years and can grow to over 19.7 feet (6 m), but sturgeon greater than 27 years old and over 6.6 feet (2 m) are rare (Moyle 2002).

Male white sturgeon reach sexual maturity at 10 to 12 years old and females reach sexual maturity at 12 to 16 years old (Moyle 2002). Maturation is thought to be a function of both photoperiod and temperature (Birstein et al. 1997). White sturgeon can spawn multiple times throughout their life. Males are believed to spawn every 1 to 2 years, whereas females spawn every 2 to 4 years (Moyle 2002). Females can produce 100,000 to several million eggs (PSMFC 1996), although typical females will produce approximately 200,000 eggs (Moyle 2002). Spawning typically occurs between February and June when temperatures are 46 to 66 °F (8 to 19 °C; Moyle 2002). Maximum spawning occurs at 58 °F (14.4 °C) in the Sacramento River (Kohlhorst 1976). It is thought that adults broadcast spawn in the water column in areas with swift current. Fertilized eggs sink and attach to the gravel bottom, where they hatch. Eggs hatch after four days at 61 °F (16 °C; Beer 1981), but may take up to 2 weeks at lower water temperatures (PSMFC 1996).

Spawning success varies from year to year. Newly hatched larvae are 7.5 to 19.5 mm in length (Kohlhorst 1976) and generally remain in the gravel for 7 to 10 days before emergence into the water column (Moyle 2002). Newly emerged larvae are pelagic for approximately seven to 10 days until their yolk-sac is absorbed, at which time they begin actively feeding on amphipods and other small benthic macroinvertebrates (Wang 1986). Juvenile white sturgeon feed primarily on algae, aquatic insects, small clams, fish eggs, and crustaceans, but their diet becomes more varied with age (Wang 1986, PSMFC 1996, Moyle 2002). Since the invasion by the overbite clam in the western Delta and Suisun Bay during the late 1980s, the clam has become a major component of the diet of juvenile and adult white sturgeon.

A8.5 THREATS AND STRESSORS

The following have been identified as important threats and stressors to white sturgeon inhabiting the Bay-Delta estuary (without priority).

Harvest. As long-lived, late maturing fish, white sturgeon are particularly susceptible to threats from overfishing (Musick 1999). White sturgeon are a popular game species within the Bay-Delta estuary and Sacramento River and support commercial fisheries within estuaries in Oregon and Washington. White sturgeon are also vulnerable to illegal (poaching) harvest. Catches of white sturgeon occur during all years, with the greatest catches typically occurring in wet years. The California Fish and Game Commission has recently adopted more restrictive sport fishing regulations designed to reduce the effects of angler harvest on white sturgeon inhabiting the Bay-Delta estuary.

Due to limits imposed on the sport fishery by DFG (2007a), only white sturgeon between 46 and 66 inches may be retained by sport fisherman with a daily bag limit of one fish in possession. Current regulations, initially implemented by DFG in 2007, require that anglers carry an annual sturgeon report card that limits annual harvest of white sturgeon to three fish per year. DFG (2002) indicates high sturgeon vulnerability to the fishery in areas where sturgeon are concentrated, such as the region between the Delta and San Pablo Bay in late winter and the upper Sacramento River during the spawning migration. In addition, the trophy status of white sturgeon and the consequent incentive for retaining oversized (greater than 66 inches [167.6 cm]) fish is another impetus for active enforcement of sturgeon angling regulations (DFG 2002).

Poaching (illegal harvest) of white sturgeon is known to occur in the Sacramento River, particularly in areas where sturgeon have been stranded (e.g., Fremont Weir) (M. Marshall, pers. comm.), as well as throughout the Bay-Delta estuary. Poaching rates in the estuary, Sacramento River, San Joaquin River and Feather River are unknown.

Furthermore, the effects of legal and illegal harvest on the population dynamics and abundance of white sturgeon within the Bay-Delta estuary are largely unknown. The small population of white sturgeon inhabiting the San Joaquin River experiences heavy fishing pressure, particularly from illegal fishing (U.S. Fish and Wildlife Service [USFWS] 1995). In addition, areas just downstream of Thermalito Afterbay Outlet, Cox's Spillway, and several barriers impeding sturgeon migration on the Feather River, may be areas of high adult mortality from high fishing effort and poaching. Poaching of white sturgeon females for roe has increased over the past 10 years despite increased enforcement efforts by DFG (L. Schwall, pers. comm.). This type of poaching is particularly detrimental to the white sturgeon population because it targets the oldest and largest adults with the highest fecundity, which affects both current and future stocks.

Reduced spawning habitat. Access to historical spawning habitat has been reduced by construction of barriers to upstream migration that block or impede access to spawning and juvenile rearing habitat. Major dams include Keswick Dam on the Sacramento River and Oroville Dam on the Feather River (Lindley et al. 2004, National Marine Fisheries Service [NMFS] 2005). White sturgeon adults have been observed periodically in the Feather River (USFWS 1995, Beamesderfer et al. 2004). Habitat modeling by Mora (2006) suggests there is suitable habitat for sturgeon in the upstream reaches of the Feather River that have been blocked by Oroville Dam. This modeling also suggests that suitable conditions are present in the San Joaquin River upstream of Friant Dam, and in the tributaries such as Stanislaus, Tuolumne, and Merced rivers upstream to their respective dams.

Other potential migration barriers include structures such as the RBDD, Sacramento Deep Water Ship Channel locks, Sutter Bypass, and Delta Cross Channel Gates on the Sacramento River, and Shanghai Bench and Sunset Pumps on the Feather River (70 FR 17386). The RBDD is an important migration barrier for sturgeon on the Sacramento River (USFWS 1995). Adult sturgeon can migrate past the RBDD when gates are raised between mid-September and mid-May to allow passage of winter-run Chinook salmon. However, tagging studies by Heublein et al. (2006) found that, when the gates were closed, a substantial portion of tagged adult green sturgeon failed to use the fish ladders at the dam and were, therefore, unable to access upstream spawning habitats. The same behavioral response may be true for white sturgeon. A set of locks at the end of the Sacramento River Deep Water Ship Channel at the connection with Sacramento River “blocks the migration of all fish from the deep water ship channel back to the Sacramento River” (California Department of Water Resources [DWR] 2005).

The Fremont Weir is located at the upstream end of the Yolo Bypass, a 40 mile (64 km) long basin that functions as a flood control facility on the Sacramento River. When the Yolo Bypass is inundated by flood water, white sturgeon are attracted into the Bypass and become trapped behind Fremont Weir, which acts as a barrier and impediment to upstream migration (DWR 2005). Sturgeon that are trapped by the weir are then subject to heavy legal and illegal fishing pressure, or become stranded behind the flashboards when the flows recede (M. Marshall, pers. comm.). Sturgeon can also be attracted to small pulse flows and trapped during the descending hydrograph (Harrell and Sommer 2003). Methods to reduce stranding and increase passage have been investigated by DWR and DFG (J. Navicky, pers. comm.).

It has been hypothesized that white sturgeon use the same migratory routes as Chinook salmon. Tagging studies have been designed and initiated to track sturgeon movement and migration patterns (P. Klimley, pers. comm.). Delta Cross Channel gate closures occur during the winter and early spring months (February through May) during sturgeon migration. The seasonal closure of the Delta Cross Channel gates is required by the State Water Resources Control Board D-1641 as a measure designed to improve the survival of downstream migrating juvenile Chinook salmon. Upstream migrating adult Chinook salmon are known to use the Delta Cross Channel as a migratory pathway when the gates are open (Hallock et al. 1970). When the gates are open, Sacramento River water flows into the central Delta providing migration cues. It is likely that attraction to flows passing into the central Delta from the Sacramento River cause migration delays and straying of white sturgeon, as it does to Chinook salmon (CALFED Science Program 2001, McLaughlin and McLain 2004). Gate closures completely block juvenile and adult sturgeon migration.

Exact white sturgeon spawning locations in Feather River are unknown; however, based on angler catches, most spawning is believed to occur downstream of Thermalito Afterbay and upstream of Cox's Spillway, just downstream of Gridley Bridge. Potential physical barriers to upstream migration include the rock dam associated with Sutter Extension Water District's sunrise pumps, shallow water caused by a head cut at Shanghai Bend, and several shallow riffles between the confluence of Honcut Creek upstream to the Thermalito Afterbay Outlet (USFWS 1995). These structures are likely to present barriers or impediments during low flow periods that block and or delay upstream sturgeon migration to spawning habitat.

Exposure to toxins. Water quality in the Sacramento and San Joaquin rivers and the Delta is influenced by a variety of point and non-point source pollutants from urban, industrial, and agricultural land uses. Runoff from residential, agricultural, and industrial areas introduces pesticides, oil, grease, heavy metals, other organics, and nutrients that contaminate drainage waters and deteriorate the quality of aquatic habitats necessary for white sturgeon survival (NMFS 1996, California Regional Water Quality Control Board-Central Valley Region 1998). Organic contaminants from agricultural returns, urban and agricultural runoff from storm events, and high concentrations of trace elements, such as boron, selenium, and molybdenum, have been identified as factors that decrease sturgeon early life-stage survival, causing abnormal development and high mortality in yolk-sac fry sturgeon at concentrations of only a few parts per billion (USFWS 1995, California Regional Water Quality Control Board 2004). Principal sources of organic contamination in the Sacramento River are rice field discharges from Butte Slough, Reclamation District 108, Colusa Basin Drain, Sacramento Slough, and Jack Slough (USFWS 1995). In recent years, changes have been made in the composition of herbicides and pesticides used on agricultural crops in an effort to reduce potential toxicity to aquatic and terrestrial species. Modifications have also been made to water system operations and discharges related to agricultural wastewater discharges (e.g., agricultural drainage water system lock-up and holding prior to discharge) and municipal wastewater treatment and discharges. Concerns remain, however, regarding the toxicity to sturgeon of contaminants that adsorb to sediments, such as pyrethroids, and other chemicals including selenium and mercury.

The extent to which toxic pollution has affected the population of white sturgeon is unknown. Sturgeon are a long-lived species that feed on invertebrates, such as clams and shrimp, and are vulnerable to the effects of toxicant bioaccumulation on the health and condition of sub-adult and adult sturgeon and their reproductive success within the estuary. However, sturgeon do not readily concentrate lipid-soluble toxins such as polychlorinated biphenyls (PCBs). Greenfield et al. (2003) found that dichlorodiphenyltrichloroethane (DDT) and chlordane concentrations in white sturgeon tissues have declined since the 1980s while selenium concentrations have remained elevated. High levels of selenium can also be found in some white sturgeon prey

(Johns and Luoma 1988, White et al. 1988), including Corbula (Urquhart and Regalado 1991), as well as in sturgeon muscle, liver, and eggs (White et al. 1987, 1988, 1989, Kroll and Doroshov 1991, Urquhart and Regalado 1991). Doroshov et al. (2007) found selenium incorporation into the plasma vitellogenin and egg yolk proteins after exposing gravid females to a selenium enriched diet. The accumulation of selenium in egg yolk to a level greater than or equal to 15 µg g-1 resulted in severe deformities and mortalities of newly hatched larvae, and the amount of selenium measured in the ovaries of recently caught wild white sturgeon has approached or exceeded these levels (Doroshov et al. 2007). Early life history stages are especially sensitive to contaminant uptake, and Kruse and Scarnecchia (2002) showed moderately increased mortality rates of white sturgeon embryos to concentrations of trace metals and other contaminants found in the Kootenai River environment. The effects on the different life history stages of white sturgeon of contaminants, other than selenium, at concentrations found in the San Francisco Bay Estuary are unknown, as are any additive or synergistic effects of multiple contaminants.

Water quality in the San Joaquin River has degraded significantly since the late 1940s (California Regional Water Quality Control Board 2004). Discharges of agricultural return flows and other point and non-point discharges have resulted in increased loading of various water quality constituents to the river and subsequently the Delta. In an effort to improve water quality, habitat, and reduce stressors on fish species such as sturgeon, water quality monitoring and management programs have been implemented on the San Joaquin River and its tributaries to reduce the loading of salt, selenium, and other water quality contaminants.

Acidic water discharges from Iron Mountain Mine, located adjacent to the upper Sacramento River, have been identified as a factor affecting the survival of fish downstream of Keswick Dam and storage limitations and limited availability of dilution flows cause high levels of downstream copper, cadmium, and zinc (Environmental Protection Agency [EPA] 2007). The EPA's Agency's Iron Mountain Mine remediation has removed toxic metals in acidic mine drainage from the Spring Creek Watershed with a state-of-the-art lime neutralization plant. Contaminant loading into the Sacramento River from Iron Mountain Mine has shown measurable reductions since the early 1990s.

Since the invasion of the overbite clam and its rapid increase in abundance within Suisun Bay, the diet of white sturgeon has shifted such that the clam is now the main component of their diet (State Water Resource Control Board 1999). The overbite clam, due to its high filtration efficiency, accumulates selenium in high concentrations and loses it slowly (Luoma and Presser 2000, Linville et al. 2002, Doroshov et al. 2007). As a result, concentrations of selenium in white sturgeon have been observed at greater than threshold levels at which toxic effects have been observed in other fish species (Lemly 2002). Dietary selenium in high concentrations can adversely affect white sturgeon survival, activity, and growth (Tashjian et al. 2006).

Reduced rearing habitat. Historical reclamation of wetlands and islands has reduced and degraded suitable in- and off-channel rearing habitat for white sturgeon. Furthermore, the channelization and hardening of levees with riprap has reduced in- and off-channel intertidal and subtidal rearing habitat as well as seasonal inundation of floodplains. The resulting changes to river hydraulics, riparian cover, and geomorphology affect important ecoystem functions (Sweeney et al. 2004). Because juvenile and adult white sturgeon feed primarily on benthic organisms such as clams and shrimp, habitat related impacts of reclamation, channelization, and riprapping would be expected to contribute to ecosystem related impacts, such as changes in the availability of food source and altered predator densities. The impacts of channelization and riprapping are thought to affect larval, post-larval, juvenile, and adult stages of sturgeon, as these life stages are dependent on the freshwater and estuarine food webs within the rivers and Bay-Delta estuary.

Increased water temperature. While juvenile and adult white sturgeon are tolerant of higher temperatures, although they appear to show signs of stress at temperatures at and above 68 °F (20 °C) (Cech et al. 1984, Geist et al. 2005). Exposure to water temperatures greater than 63 °F (17.2 °C) has also been shown to increase sturgeon egg and larval mortality (Pacific States Marine Fisheries Commission 1992).

Water temperatures in the upper Sacramento River near the RBDD historically occurred within optimum ranges for sturgeon reproduction; however, temperatures downstream, especially later in the spawning season, were reported to be frequently above 63 °F (17.2 °C; USFWS 1995). Concern regarding exposure to high temperatures in the Sacramento River during the February to June period has been reduced in recent years as temperatures in the upper Sacramento River are actively managed for Sacramento River winter-run Chinook salmon. The Shasta temperature control device, which was installed at Shasta Dam in 1997, cold water pool management within Lake Shasta, and management to maintain higher reservoir storage have all contributed to improving cool water temperature conditions within the upper Sacramento River where white sturgeon spawning and juvenile rearing are thought to occur.

Water temperatures in the lower Feather River may be inadequate for sturgeon spawning and egg incubation as the result of releases of warmed water from Thermalito Afterbay (Surface Water Resources, Inc. 2003). The warmed water may be one reason that neither green nor white sturgeon are found in the river in low-flow years (DFG 2002). Exposure to elevated water temperatures within the Feather River downstream of Thermalito Afterbay is expected to be a factor affecting habitat quality and availability for sturgeon spawning and juvenile rearing on the lower Feather River (DFG 2002).

Reduced flow on the San Joaquin River resulting from dam and diversion operations and agricultural return flows contribute to seasonally elevated water temperatures in the mainstem San Joaquin River, particularly during late summer and fall. Although these effects are difficult to measure, water temperatures in the lower San Joaquin River continually exceed preferred temperatures for sturgeon migration and development during spring months. Temperatures at Stevenson on the San Joaquin River near the Merced River confluence as recorded on May 31 (spawning typically occurs February-June) between 2000 and 2004 ranged from 77 to 82 °F (25 to 27.8 °C; California Data Exchange Center 2007). Juvenile sturgeon are also exposed to increased water temperatures in the Delta during the late spring and summer, as a result in part of the loss of riparian shading, and by thermal inputs from municipal, industrial, and agricultural discharges. Seasonally elevated water temperature on the San Joaquin River and within the Delta has been identified as a factor affecting habitat quality and availability for sturgeon migration, spawning, and juvenile rearing.

Non-native species. White sturgeon have been impacted, both positively and negatively, by the introduction of non-native species into the Bay-Delta estuary. Changes in the species composition of fish and macroinvertebrates have altered trophic interactions and dynamics for juvenile and adult white sturgeon. Many of the recent introductions of invertebrates have greatly affected the benthic fauna in the Delta and Suisun Bay and non-native species such as the overbite clam and Asian clam are now a major component of the diet of white sturgeon (DFG 2002). The overbite clam and other introduced clams are benthic filter feeders that can accumulate various toxic substances , such as selenium, mercury, and other compounds, in their tissue. Sturgeon, which are long-lived species, may bioaccumulate these toxics by foraging on these clams, which may adversely impact the health and survival of sub-adult and adult sturgeon and their reproduction (Doroshov et al. 2007).

DFG (2002) reviewed many of the recent non-native invasive species introductions and the potential consequences to white sturgeon. The most notable species responsible for altering the trophic system of the Sacramento-San Joaquin Delta and Suisun Bay include overbite and Asian clams, and the Chinese mitten crabs. Sturgeon regularly consume both clam species, which is of particular concern because of the high bioaccumulation rates of these clams (Doroshov et al. 2007). Although Chinese mitten crabs may be eaten by adult white sturgeon, it is possible they prey upon sturgeon eggs. The Chinese mitten crab population within the Bay-Delta system has undergone a substantial decline since 2002 and currently occurs in very low abundance (Hieb, pers. comm. 2008) and, therefore, may currently not be a major factor affecting white sturgeon.

Introductions of non-native invasive plant species such as water hyacinth and Brazilian waterweed have altered habitat within the Delta and Suisun Bay and have affected local assemblages of fish within the Bay-Delta estuary (Nobriga et al. 2005). Nobriga et al. (2005) found significant differences in water clarity and fish communities in those areas where submerged aquatic vegetation (SAV) was abundant when compared to open water habitats where SAV was not abundant. The occurrence of dense concentrations of SAV has been hypothesized to result in a number of potential effects on aquatic habitat including raising temperatures, reducing turbidity and dissolved oxygen levels, and inhibiting access to shallow water habitat by fish intolerable to these conditions. The presence of non-native centrarchid species is strongly associated with the occurrence of Brazilian waterweed (Brown and Michniuk 2007). Brazilian waterweed forms thick “walls” along the margins of channels and shallow water habitat in the Delta. This growth may prevent juvenile sturgeon from accessing shallow water habitat along channel edges. Water hyacinth creates dense floating mats that can impede river flows and alter the aquatic environment beneath mats. By reducing water velocities near plants, these species reduce turbidity in the water column, potentially exposing sturgeon to higher predation risk.

Dissolved oxygen levels beneath the mats often drop below suitable levels for fish due to the increased amount of decaying vegetative matter produced from the overlying mat and diel respiration by aquatic plants. Like Brazilian waterweed, water hyacinth is often associated with the margins of the Delta waterways in its initial colonization, but can eventually cover the entire channel if conditions permit. High levels of infestation by non-native aquatic plants may produce barriers to white sturgeon movement within the Delta, although there is no evidence that this occurs.

Dredging. Hydraulic dredging is a common practice in the navigational channels within San Francisco, San Pablo, and Suisun bays, the Delta, and the Sacramento and San Joaquin rivers to allow commercial and recreational vessel traffic. White sturgeon are at risk of entrainment from dredging, with young-of-the-year fish at greatest risk (Boysen and Hoover 2009).. Studies by Buell (1992) reported approximately 2,000 sturgeon entrained in the removal of one million tons of sand from the bottom of the Columbia River at depths of 60 to 80 feet (18 to 24 m). In addition, dredging operations can result in the resuspension of toxics such as ammonia, hydrogen sulfide, and copper as a result of both dredging and dredge spoil disposal, and alter channel bathymetry and current patterns (NMFS 2006).

Reduced turbidity. Turbidity levels in the Delta have decreased over the past few decades (Jassby et al. 2002). This reduction may have had detrimental effects to white sturgeon. Gadomski and Parsley (2005) found that larval white sturgon predation by prickly sculpin was greater with reduced turbidity. However, larval sturgeon are found close to spawning locations generally upstream of the Delta, where turbidity is already lower than the Delta.

The relationship between turbidity and the vulnerablity of various life stages of white sturgeon to predation has not been established within the Delta. As discussed above, the dense colonization of local areas within the Delta by SAV such as the Brazilian waterweed (*Egeria densa*) has been shown to be associated with increased water clarity (e.g., resuting from trapping and settlement of suspended sediments). Increased water clarity may contribute to increased vulnerablity of sturgeon to predation. Juvenile white sturgeon are expected to be less vulnerable to predation than other estuarine fish due to their scutes and protective armoring. In addition, the large size of sub-adult and adult white sturgeon further reduces their vulnerablity to predation. As a result of these factors, the potential increase in vulnerability to predation due to localized reductions in turbidity is expected to be minor relative to other covered fish species.

Stranding. White sturgeon that are attracted to high flows when the Yolo Bypass is inundated by flood waters from the Sacramento River will move onto the floodplain and eventually concentrate behind Fremont Weir, where they are blocked from further upstream migration (DWR 2005). As Bypass flows recede, these sturgeon become stranded behind the weir (Harrell and Sommer 2003) and are then subject to both legal and illegal harvest (M. Marshall, pers. comm.). Methods to reduce stranding and increase sturgeon passage are have been previously developed (J. Navicky, pers. comm.) but have been stalled (Z. Matica, pers. comm.).

Entrainment. There is little evidence that the overall population of white sturgeon is influenced by entrainment. Adults are not likely to be entrained due to their large size and benthic habits. Larval sturgeon are more susceptible to entrainment from water diversion facilities as a result of their migratory behavior within the water column and reduced swimming perfomance capability. Herren and Kawasaki (2001) documented 431 water diversions located on the Sacramento River between Sacramento and Shasta Dam. In the Feather River, there are eight diversions greater than 10 cubic feet per second (cfs) and approximately 60 small diversions between 1 to 10 cfs between the Thermalito Afterbay outlet and the confluence with the Sacramento River (USFWS 1995). White sturgeon have been reported in low numbers in fish salvage at both the SWP and CVP export facilities. White sturgeon observed in fish salvage have predominantly been juvenile and sub-adult life stages. Occasionally, adult white sturgeon have been observed impinged on the trash racks at the CVP intake; it has been hypothesized that these large adults were in weakened conditions or had previously died from stresses associated with spawning, angler mortality, or other causes before being impinged at the export intake. Given the large number of diversions, it is possible that larval white sturgeon are vulnerable to entrainment at these diversions; however, actual entrainment mortality and potential effects on the abundance and population dynamics of white sturgeon are unknown.

A8.6 RELEVANT CONSERVATION EFFORTS

The Central Valley Project Improvement Act's Anadromous Fish Restoration Program (AFRP) have a goal of supporting efforts that lead to doubling the natural production of anadromous fish in the Central Valley at a sustainable, long-term basis, at levels not less than twice the average abundance reported during the period of 1967 to 1991. Though most efforts of the AFRP have focused on Chinook salmon as a result of their listing history and status, sturgeon may receive some unknown incidental amount of benefit from these restoration efforts. For example, the acquisition of water for flow enhancement on tributaries to the Sacramento River, spawning gravel augmentation, fish screening for the protection of Chinook salmon and Central Valley steelhead, or riparian revegetation and instream restoration projects would likely have ancillary benefits to sturgeon.

Many beneficial actions have originated and been funded by the CALFED program including such projects as floodplain and instream restoration, riparian habitat protection, fish screening and passage projects, research regarding non-native invasive species and contaminants, restoration methods, watershed stewardship, education, and outreach programs. Prior Federal Register notices have reviewed the details of Central Valley Project Improvement Act (CVPIA) and CALFED programs and potential benefits for anadromous fish, particularly Chinook salmon and Central Valley steelhead (69 FR 33102). Projects potentially benefiting sturgeon primarily consist of fish screen evaluation and construction projects, restoration evaluation and enhancement activities, contamination studies, and dissolved oxygen investigations related to the San Joaquin River Deep Water Ship Channel.

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) was formed to guide the implementation of CALFED Ecosystem Restoration Plan elements within the Delta (DFG 2007b). The DRERIP team has created a suite of ecosystem and species conceptual models, including white sturgeon, that document existing scientific knowledge of Delta ecosystems. The DRERIP Team has used these conceptual models to assess the suitability of actions proposed in the Ecosystem Restoration Plan for implementation. DRERIP conceptual models were used in the analysis of proposed BDCP conservation measures.

New sport fishing regulations adopted over the past several years specifically to protect and reduce harvest of sturgeon and increased law enforcement are expected to further reduce illegal fishing practices, and reduce the effects of harvest of white sturgeon by recreational anglers, throughout the range of the species.

A8.7 RECOVERY GOALS

No recovery plan has been prepared for white sturgeon because the species is not listed under the California or Federal ESA.

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APPENDIX A9. NORTH AMERICAN GREEN STURGEON *(ACIPENSER MEDIROSTRIS)*

A9.1 LEGAL STATUS

The North American green sturgeon is composed of two Distinct Population Segments (DPS): the northern DPS, which includes all populations in the Eel River and northward; and the southern DPS, which includes all populations south of the Eel River. Only the southern DPS is found in the Plan Area of the Bay Delta Conservation Plan (BDCP).

After a status review was completed in 2002 (Adams et al. 2002), the National Marine Fisheries Service (NMFS) determined that the southern DPS of the North American green sturgeon did not warrant listing as threatened or endangered but should be identified as a Species of Concern. The "not warranted" determination was challenged on April 7, 2003. The National Marine Fisheries Service (NMFS) updated their status review on February 22, 2005, and determined that the southern DPS should be listed as threatened under the Federal Endangered Species Act (Biological Review Team 2005). NMFS published a final rule on April 7, 2006 that listed the southern DPS as threatened, which took effect on June 6, 2006 (71 FR 17757). Included in the listing are the spawning population in the Sacramento River and fish living in the Sacramento River, the Sacramento-San Joaquin Delta, and the San Francisco Estuary.

California Department of Fish and Game has identified green sturgeon as a Species of Special Concern (California Department of Fish and Game [DFG] 2003).

A9.2 SPECIES DISTRIBUTION AND STATUS

A9.2.1 Range and Status

Green sturgeon range from Ensenada, Mexico to the Bering Sea, Alaska (Colway and Stevenson 2007, Moyle 2002). Green sturgeon are currently known to spawn in two California basins: the Sacramento and Klamath rivers. These reproducing populations are genetically distinct and occupy the Southern and Northern DPS, respectively (Adams et al. 2002, Israel et al. 2004). Adult populations in the less-altered Klamath and Rogue rivers are fairly constant with a few hundred spawning adults typically being harvested annually by tribal fisheries. In the Sacramento River, the green sturgeon population is believed to have declined over the last two decades with less than 50 spawning green sturgeon being sighted annually in the best spawning habitat (Richard Corwin, Bureau of Reclamation, pers. comm.). In the Umpqua, Feather, Yuba, and Eel rivers green sturgeon sightings are extremely limited and spawning has not been recently recorded. In the San Joaquin and South Fork Trinity rivers, the green sturgeon population appears extirpated (see Figure A-9a).

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Figure A-9a. Green Sturgeon Inland Range in California

Green sturgeon have been recorded in the Feather River (Beamesderfer et al. 2004), and may spawn there during high flow years (DFG 2002), although no indication of spawning has been documented despite intensive sampling efforts (Niggemyer and Duster 2003). No juvenile green sturgeon have been documented in the San Joaquin River, although Moyle (2002) suggests that reproduction may have taken place in the San Joaquin River because adults have been captured at Santa Clara Shoal and Brannan Island. Additionally, two unidentified juvenile sturgeon have been caught on the Mokelumne River, a tributary to the San Joaquin River (J. Smith, pers. comm.).

Green sturgeon are anadromous and pass through the San Francisco Bay to the ocean where they primarily move northward and commingle with other sturgeon populations, spending much of their lives in the ocean or in Oregon and Washington estuaries (DFG 2002; Kelly et al. 2007). Subadult and adult green sturgeon are thought to potentially migrate thousands of miles along the coasts of northern California and the Pacific Northwest. Relatively large concentrations of sturgeon occur in the Columbia River estuary, Willapa Bay, and Grays Harbor, with smaller aggregations in the San Francisco estuary (Emmett et al. 1991, Moyle et al. 1992, Israel 2006).

Although NMFS indicates that absolute population abundance of green sturgeon is currently not determinable (74 FR 52,300), some information on the population abundance of the southern DPS of North American green sturgeon is available, and is described in NMFS status reviews (Adams et al. 2002, 2007, NMFS 2005). Musick et al. (2000) noted that the abundance of North American green sturgeon populations has declined by 88 percent throughout much of its range. DFG (2002) estimated that green sturgeon abundance within the Bay-Delta estuary ranged from 175 to more than 8,000 adults between 1954 and 2001 with an annual average of 1,509 adults. Fish monitoring efforts at Red Bluff Diversion Dam (RBDD) and the Glenn-Colusa Irrigation District pumping facility on the upper Sacramento River have recorded between zero and 2,068 juvenile North American green sturgeon per year (Adams et al. 2002). Catches of sub-adult and adult North American green sturgeon by the Interagency Ecological Program (IEP) between 1996 and 2004 ranged from one to 212 green sturgeon per year, with the highest catch in 2001 (Samantha Vu, pers. comm.). Because these fish were primarily captured in San Pablo Bay, where both northern and southern DPSs exist, the proportion of fish captured in IEP sampling from the southern DPS is unknown.

Green sturgeon are long-lived (up to 60 to 70 years) and late maturing (sexual maturity is reached at approximately 15 to 20 years) (Moyle 2002). They have a low fecundity rate (59,000 to 242,000 eggs per female) relative to white sturgeon (180,000 to 590,000 eggs per female) and spawn only periodically (Doroshov 1983, Moyle 2002, Van Eenennaam et al. 2006). These characteristics make them particularly susceptible to habitat degradation and overharvest (Musick 1999). With only one population in the Central Valley, the viability of the southern DPS is vulnerable to changes in the environment and catastrophic events through a lack of spatial geographic diversity. As a result of low abundance, the population has limited genetic diversity, which decreases the ability of individuals in the green sturgeon population to withstand environmental variation.

A9.2.2 Distribution and Status in the Plan Area

The Delta serves as a migratory corridor, feeding area, and juvenile rearing habitat for North American green sturgeon in the southern DPS. Adults migrate upstream primarily through the western edge of the Delta into the lower Sacramento River between March and June (Adams et al. 2002). Green sturgeon spawning is thought to occur primarily in the upper reaches of the Sacramento River, although some spawning may also occur in tributaries. Larvae and post-larvae are present in the lower Sacramento and North Delta between May and October, primarily in June and July (DFG 2002). Juvenile green sturgeon have been captured in the Delta during all months of the year (Borthwick et al. 1999, DFG 2002, BDAT 2007). Adult green sturgeon have been documented in the Yolo Bypass (M. Marshall, pers. comm.) and rear in Suisun Bay and marsh.

A9.3 Habitat Requirements and Special Considerations

On October 9, 2009, NMFS (74 FR 52,300) designated critical habitat for the green sturgeon Southern DPS throughout most of its occupied range, including: coastal marine waters from Monterey Bay to the Washington/Canada border; coastal bays and estuaries in California, Oregon, and Washington; and fresh water rivers in the Central Valley, California. The essential physical and biological habitat features identified for the Southern DPS include prey resources (benthic invertebrates and small fish), water quality, water flow (particularly in freshwater rivers), water depth, substrate types (i.e., appropriate spawning substrates within freshwater rivers), sediment quality, and migratory corridors (see Figure A-9b). Proposed inland critical habitat in the Sacramento and San Joaquin River basins includes the Sacramento River downstream of Keswick Dam, the Feather River downstream of Oroville Dam, and the Yuba River downstream of Daguerre Dam; portions of Sutter and Yolo Bypasses; the legal Delta, excluding Five Mile Slough, Seven Mile Slough, Snodgrass Slough, Tom Paine Slough and Trapper Slough; and San Francisco, San Pablo, and Suisun bays.

As anadromous fish, North American green sturgeon rely on riverine, estuarine, and marine habitats during their long life. Freshwater habitat of green sturgeon of the southern DPS varies in function, depending on location within the Sacramento River watershed. Spawning areas currently are limited to accessible reaches of the Sacramento River upstream of Hamilton City and downstream of Keswick Dam (see Figure A-9a) (DFG 2002). Preferred spawning habitats are thought to contain large cobble in deep and cool pools with turbulent water (DFG 2002, Moyle 2002, Adams et al. 2002). Sufficient flows are needed to sufficiently oxygenate and limit disease and fungal infection of recently laid eggs (Deng et al. 2002; Parsley et al. 2002). Within the Sacramento River, spawning appears to be triggered by large increases in water flow during spawning (Brown 2007). However, within the Rogue River, Erickson et al. (2002) found that green sturgeon were most often found at depths greater than 5 m with low or no currents during summer and fall months.

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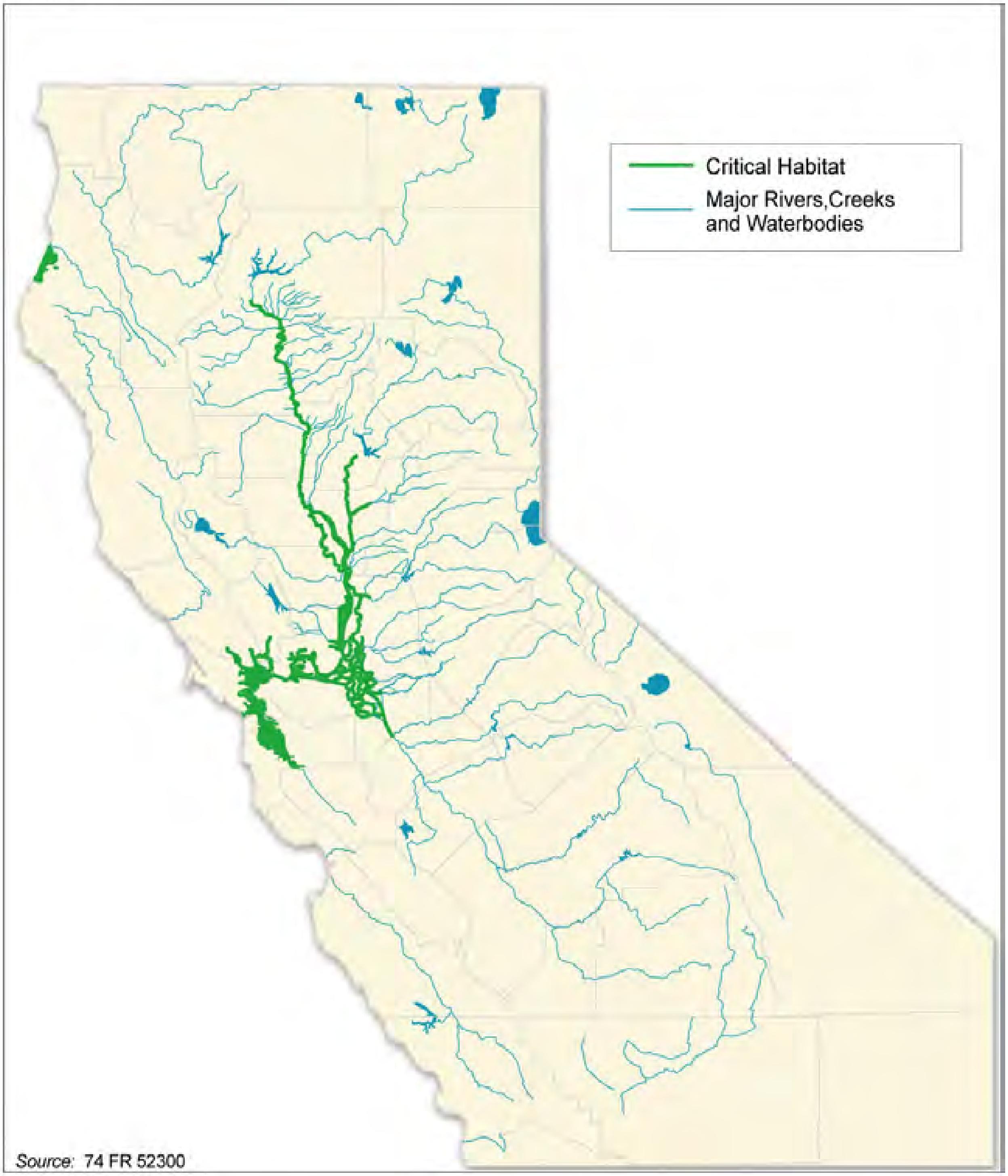

Figure A-9b. Green Sturgeon Inland Critical Habitat in California

In addition, acoustic tagging studies by Erickson et al. (2002) indicate that adult green sturgeon hold for as long as six months in deep (greater than 5 m), low gradient reaches or off-channel sloughs or coves of the river during summer months when water temperatures were between 15 and 23 °C (59 and 73.5 °F). When ambient temperatures in the river dropped in fall and early winter (less than 10 °C [50 °F]) and flows increased, fish moved downstream and into the ocean. Water temperatures in spawning and egg incubation areas are critical; temperatures greater than 19 °C (66.2 °F) are lethal to green sturgeon embryos (Cech et al. 2000, Mayfield and Cech 2004, Van Eenennaam et al. 2005, Allen et al. 2006).

Habitats for migration are downstream of spawning areas and include the mainstem Sacramento River, Delta, and San Francisco Bay estuary. These corridors allow the upstream passage of adults and the downstream emigration of juveniles (NMFS 2006a). Migratory habitat conditions are strongly affected by the presence of barriers and impediments to migration (e.g., dams), unscreened or poorly screened diversions, and degraded water quality. Heublein et al. (2009) found two different patterns of "spawning migration" and out-migration for green sturgeon in the Sacramento River. Results of this study found six individuals potentially spawned, over-summered and moved out of the river with the first fall flow event, nine individuals promptly moved out of the Sacramento River before September 1. While some green sturgeon appeared to be impeded on their upstream movement by closure of the RBDD in mid-May, at least five individuals passed under the dam gates during their downstream migration. Both spawning areas and migratory corridors comprise rearing habitat for juvenile green sturgeon, which feed and grow up to three years in freshwater. Stomach contents from adult and juvenile green sturgeon captured in the Delta point to the importance of habitat that supports shrimp, mollusks, amphipods, and small fish (Radtke 1966, Houston 1988, Moyle et al. 1992). Rearing habitat condition and function may be affected by variation in annual and seasonal flow and water temperatures (NMFS 2006a).

Nearshore marine habitats must provide adequate food resources, suitable water quality conditions, and natural cover for juvenile green sturgeon to successfully forage and grow to adulthood. Offshore marine habitats are also important for supporting growth and maturation of sub-adult green sturgeon.

A9.4 LIFE HISTORY

There is relatively little known about the North American green sturgeon, particularly for those that spawn in the Sacramento River (the Nature Conservancy et al. 2008). Adult North American green sturgeon are believed to spawn every 3 to 5 years, but can spawn as frequently as every 2 years (Lindley and Moser pers. comm., as cited in NMFS 2005) and reach sexual maturity at an age of 15 to 20 years. Adult green sturgeon begin their upstream spawning migrations into the San Francisco Bay in March, reach Knights Landing during April, and spawn between March and July (Heublein et al. 2006). Based on the distribution of sturgeon eggs, larvae, and juveniles in the Sacramento River, DFG (2002) concluded that green sturgeon spawn in late spring and early summer upstream of Hamilton City, and possibly to Keswick Dam.

Peak spawning is believed to occur between April and June (Table A-9a). Adult female green sturgeon produce between 59,000-242,000 eggs, depending on body size, with a mean egg diameter of 4.3 mm (Moyle et al. 1992, Van Eenennaam et al. 2006).

Table A-9a. Temporal Occurrence of (a) Adult, (b) Larval and Post-larval, (c) Juvenile, and (d) Coastal Migrants of the Southern DPS of North American Green Sturgeon. Locations are specific to the Central Valley of California. Darker shades indicate months of greatest relative abundance.

(a) Adult (≥13 years old for females and ≥9 years old for males)

Location	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
[1,2,3]Upper Sac River			Medium	Medium/High	High	High	Medium	Medium	Medium	Medium	Medium	
[4,8]SF Bay Estuary			Medium	Medium	Medium	Medium	Medium	Medium	Medium			

(b) Larval and post-larval (≤10 months old)

Location	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
[5]RBDD, Sac River					Medium	High	High	Medium				
[5]GCID, Sac River					Medium	High	High	Medium	Low	Low		

(c) Juvenile (> 10 months old and ≤3 years old)

Location	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
[6]South Delta*	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
[6]Sac-SJ Delta	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
[5]Suisun Bay	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium

(d) Coastal migrant (3 to 13 years old for females and 3 to 9 years old for males)

Location	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
[3,7]Pacific Coast	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low

Relative Abundance: High (darkest) = High; Medium (dark grey) = Medium; Low (light grey) = Low

* Fish Facility salvage operations
RBDD – Red Bluff Diversion Dam
GCID – Glenn-Colusa Irrigation District facility
Sources: [1]USFWS 2002, [2]Moyle et al. 1992, [3]Adams et al. 2002 and NMFS 2005, [4]Kelly et al. 2007, [5]DFG 2002, [6]BDAT, fall midwater trawl green sturgeon captures from 1969 to 2003, [7]Nakamoto et al. 1995, [8]Heublein et al. 2006

Newly hatched green sturgeon are approximately 12.5 to 14.5 mm in length. Green sturgeon are strongly oriented to the river bottom and exhibit nocturnal activity patterns (Cech et al. 2000). After six days, the larvae exhibit nocturnal swim-up activity (Deng et al. 2002) and nocturnal downstream migrational movements (Kynard et al. 2005). Juvenile green sturgeon continue to exhibit nocturnal behavior beyond the metamorphosis from larval to juvenile stages. After approximately 10 days, larvae begin feeding and growing rapidly, and young green sturgeon appear to rear for the first one to two months in the Sacramento River between Keswick Dam and Hamilton City (DFG 2002). Length measurements estimate juveniles to be two weeks old (24 to 34 mm fork length) when they are captured at RBDD (DFG 2002, USFWS 2002), and three weeks old when captured further downstream at the Glenn-Colusa facility (DFG, unpubl. data, Van Eenennaam et al. 2001). Growth is rapid as juveniles reach up to 30 cm the first year and over 60 cm in the first 2 to 3 years (Nakamoto et al. 1995).

Juveniles appear to spend 1 to 4 years in freshwater and estuarine habitats before they enter the ocean (Nakamoto et al. 1995). According to Heublein (2006), all adults leave the Sacramento River prior to September. Lindley (2006) found frequent large-scale migrations of green sturgeon along the Pacific coast. Kelly et al. (2007) reported that green sturgeon enter the San Francisco estuary during the spring and remain until fall. Juvenile and adult green sturgeon enter coastal marine waters after making significant long-distance migrations with distinct directionality thought to be related to resource availability.

Little is known about juvenile and adult green sturgeon feeding and diet within the ocean. On entering the highly productive ocean environment, green sturgeon grow at a rate of approximately 7 cm per year until they reach maturity. Male green sturgeon mature at an earlier age and are smaller than females (Van Eenennaam et al. 2006). Green sturgeon spend 3-13 years in the ocean before returning to freshwater to spawn.

A9.5 THREATS AND STRESSORS

The following have been identified as important threats and stressors to the southern DPS of green sturgeon (without priority).

Reduced spawning habitat. Access to historical spawning habitat has been reduced by construction of migration barriers, such as major dams, that block or impede access to the spawning habitat. Major dams include Keswick Dam on the Sacramento River and Oroville Dam on the Feather River (Lindley et al. 2004, NMFS 2005). The Feather River is likely to have supported significant spawning habitat for the green sturgeon population in the Central Valley before dam construction (see Figure A-9a) (DFG 2002). Green sturgeon adults have been observed periodically in the lower Feather River (USFWS 1995, Beamesderfer et al. 2004). Results of habitat modeling by Mora (2006) suggest there is potential habitat on the Feather River upstream of Oroville Dam that would have been suitable for sturgeon spawning and rearing prior to construction of the dam. This modeling also suggests sufficient conditions are present in the San Joaquin River to Friant Dam, and in the tributaries such as Stanislaus, Tuolumne, and Merced rivers upstream to their respective dams, although it is unknown whether green sturgeon ever inhabited the San Joaquin River or its tributaries (Beamesderfer et al. 2004).

NMFS (2006a) reports several potential migration barriers, including structures such as the RBDD, Sacramento Deep Water Ship Channel locks, Sutter Bypass, and Delta Cross Channel gates on the Sacramento River, and Shanghai Bench and Sunset Pumps on the Feather River (). In the Central Valley, approximately 4.6 percent of the total river kilometers have spawning habitat characteristics similar to where Northern DPS green sturgeon spawn, with only 12 percent of this habitat is currently occupied by sturgeon (Neuman et al. 2007). Of the 88 percent that is unoccupied (approx. 4000 km), 44.2 percent is currently inaccessible due to dams Neuman et al. (2007).

The RBDD has been identified as a major barrier and impediment to sturgeon migration on the Sacramento River (USFWS 1995). Adult sturgeon can migrate past RBDD when gates are raised between mid-September and mid-May to allow passage for winter-run Chinook salmon. However, tagging studies by Heublein (2006) found that, when the gates were closed, a substantial portion of tagged adult green sturgeon failed to use fish ladders at the dam and were, therefore, unable to access upstream spawning habitats. A set of locks at the end of the Sacramento River Deep Water Ship Channel at the connection with the Sacramento River "blocks the migration of all fish from the deep water ship channel back to the Sacramento River" (DWR 2005).

The Fremont Weir is located at the upstream end of the Yolo Bypass, a 40 mile (64 km) long basin that functions as a flood control project on the Sacramento River. Green sturgeon are attracted by high floodwater flows into the Yolo Bypass basin and then concentrate behind Fremont Weir, which they cannot effectively pass (DWR 2005). Green sturgeon that concentrate behind the weir are subject to heavy illegal fishing pressure or become stranded behind the flashboards when high flood flows recede (M. Marshall, pers. comm.). Sturgeon can also be attracted to small pulse flows and trapped during the descending hydrograph (Harrell and Sommer 2003). Methods to reduce stranding and increase passage have been investigated by the California Department of Water Resources (DWR) and DFG (DWR 2007, J. Navicky, pers. comm.).

It is thought that adult and juvenile green sturgeon use the same migratory routes as Chinook salmon. Delta Cross Channel gate closures occur during the winter and early spring months sturgeon migration period (February through May) as required by State Water Resources Control Board (SWRCB) D-1641. Upstream migrating adult Chinook salmon are known to use the Delta Cross Channel as a migratory pathway when the gates are open (Hallock et al. 1970). When the gates are open, Sacramento River water flows into the central Delta and the Mokelumne and San Joaquin rivers providing migration cues. It is possible that attraction to water passing from the Sacramento River into the interior Delta causes delays and straying of green sturgeon, as it does to Chinook salmon (CALFED Science Program 2001, McLaughlin and McLain 2004). The Delta Cross Channel completely blocks juvenile and adult sturgeon migration to and from the interior Delta when the gates are closed.

Exposure to toxins. Exposure of green sturgeon to toxics has been identified as a factor that can lower reproductive success, decrease early life stage survival, and cause abnormal development, even at low concentrations (USFWS 1995, Environmental Protection Information Center et al. 2001, Klimley 2002). Water discharges containing metals from Iron Mountain Mine, located adjacent to the Sacramento River, have been identified as a factor affecting survival of sturgeon downstream of Keswick Dam and storage limitations and limited availability of dilution flows cause downstream copper and zinc levels to exceed salmonid tolerances. Treatment processes and improved drainage management in recent years have reduced the toxicity of runoff from Iron Mountain Mine to acceptable levels. Although the impact of trace elements on green sturgeon reproduction is not completely understood, negative impacts similar to those of salmonids are suspected.

Green sturgeon consume overbite and Asian clams, which are known to bioaccumulate selenium rapidly and lose selenium slowly (Linville et al. 2002, Doroshov 2006). Selenium is transferred to the egg yolk where it can cause mortality of larvae. Although chronic and acute exposure to toxics has been identified as a factor adversely affecting various lifestages of green sturgeon, the severity, frequency, geographic locations, and population level consequences of exposure to toxics have not been quantified (Linville et al. 2002, Doroshov 2006). However, Linville (2006) observed larvae to have increased skeletal deformities and mortality associated with maternal effects of selenium exposure, while smaller quantities (about 20mg/kg) decreased feeding efficiency and larger quantities (greater than 20mg/kg) reduced growth rates after four weeks (Lee et al. 2008a).

Methylmercury is another toxic substance that could potentially affect sturgeon development and survival. Between 2002 and 2006, sediment concentrations of methylmercury was highest in the Central Bay, while shallower parts of San Pablo Bay and Suisun Bay also contained levels greater than 0.2 parts per billion (ppb) (San Francisco Estuary Institute [SFEI] 2007). The amount of methylmercury resulting in the death of juvenile green sturgeon lies between 20 to 40mg/kg, with greater consumption increasing mortality significantly (Lee et al. 2008b).

Harvest. As a long-lived, late maturing fish with relatively low fecundity and periodic spawning, the green sturgeon is particularly susceptible to threats from overfishing (Musick 1999). Commercial harvest for green sturgeon occurs primarily along the Oregon and Washington coasts and within their coastal estuaries, with almost all catch being entirely in bycatch of three fisheries: white sturgeon commercial and sport fisheries, Klamath Tribal salmon gill-net fisheries, and coastal groundfish fisheries trawl fisheries (Adams et al. 2007). Total captures of green sturgeon in the Columbia River Estuary in commercial fisheries between 1985 and 2003 ranged from 46 fish per year to 6,000 (Adams et al. 2007). However, a high proportion of green sturgeon present in the Columbia River, Willapa Bay, and Grays Harbor (as high as 80 percent in the Columbia River) may be from the southern DPS (DFG 2002, Israel 2006).

Green sturgeon are also vulnerable to recreational sport fishing with the Bay-Delta estuary and Sacramento River, as well as other estuaries located in Oregon and Washington. Green sturgeon are primarily captured incidentally in California by sport fishermen targeting the more desirable white sturgeon, particularly in San Pablo and Suisun bays (Emmett et al. 1991).

Since the listing of the southern DPS of green sturgeon, new federal and state regulations, including the June 2, 2010 NMFS take prohibition (75 FR 30714), mandate that no green sturgeon can be taken or possessed in California (DFG 2007a). If green sturgeon are caught incidentally and released while fishing for white sturgeon, it must be reported to DFG. The level of hooking mortality that results following release of green sturgeon by anglers is unknown. Sport fishing captures have declined through time; however, it is not known whether this is a result of reduced abundance, changed fishing regulations, or other factors. DFG (2002) indicates that sturgeon are highly vulnerable to the fishery in areas where sturgeon are concentrated, such as the Delta and Suisun and San Pablo Bays in late winter and the upper Sacramento River during spawning migration. Because many sturgeon in the Columbia River, Willapa Bay, and Grays Harbor are likely from the southern DPS, additional harvest closures in these areas would likely benefit the southern DPS.

Poaching (illegal harvest) of sturgeon is known to occur in the Sacramento River, particularly in areas where sturgeon have been stranded (e.g., Fremont Weir) (M. Marshall, pers. comm.), as well as throughout the Bay-Delta (L. Schwall, pers. comm.). Catches of sturgeon are thought to occur during all years, especially during wet years. The small population of green sturgeon inhabiting the San Joaquin River experiences heavy fishing pressure, particularly from illegal fishing (U.S. Fish and Wildlife Service [USFWS] 1995). Areas just downstream of Thermalito Afterbay outlet, Cox's Spillway, and several barriers impeding migration on the Feather River may be areas of high adult mortality from increased fishing effort and poaching. Poaching rates in the rivers and estuary and the impact of poaching on green sturgeon abundance and population dynamics are unknown.

Reduced rearing habitat. Historical reclamation of wetlands and islands have reduced and degraded the availability of suitable in- and off-channel rearing habitat for green sturgeon. Further, channelization and hardening of levees with riprap has reduced in- and off-channel intertidal and subtidal rearing habitat. The resulting changes to river hydraulics, riparian cover, seasonal floodplain inundation, and geomorphology affect important ecoystem functions (Sweeney et al. 2004). The impacts of channelization and riprapping are thought to affect larval, post-larval, juvenile, and adult stages of sturgeon, as these life stages are dependent on the food web in freshwater and low salinity regions of the Bay-Delta.

Increased water temperature. Exposure to water temperatures greater than 63 ºF (17.2 °F) can increase mortality of sturgeon eggs and larvae (Pacific States Marine Fisheries Commission 1992) and temperatures above 69 °F (20.6 °C) are lethal to embryos (Cech et al. 2000). Temperatures near the RBDD on the Sacramento River historically occur within optimum ranges for sturgeon reproduction; however, temperatures downstream, especially later in the spawning season, were reported to be frequently above 63 °F (17.2 °F; USFWS 1995). High temperatures in the Sacramento River during the February to June period no longer appear to be a major concern for green sturgeon spawning, egg incubation, and juvenile rearing, as temperatures in the upper Sacramento River are actively managed for Sacramento River winter-run Chinook salmon. The Shasta temperature control device, installed at Shasta Dam in 1997, in combination with improved cold water pool management and storage within Lake Shasta, have resulted in improved cool water stream conditions within the upper Sacramento River.

Water temperatures in the Feather River may be inadequate for spawning and egg incubation as the result of releases of warmed water from Thermalito Afterbay (Surface Water Resources, Inc. 2003). Warmed water may be one reason why neither green nor white sturgeon are found in the river during low flow years (DFG 2002). It is not expected that water temperatures will become more favorable in the near future and this temperature problem will continue to be a factor affecting habitat quality for green sturgeon on the lower Feather River (DFG 2002).

The lack of flow in the San Joaquin River from dam and diversion operations and agricultural return flows contribute to higher temperatures in the mainstem San Joaquin River, offering less water to keep temperatures cool for sturgeon, particularly during late summer and fall. Though these effects are difficult to measure, temperatures in the lower San Joaquin River continually exceed preferred temperatures for sturgeon migration and development during spring months. Temperatures at Stevenson on the San Joaquin River near the Merced River confluence recorded on May 31 (spawning typically occurs during April-June; see Table A-9a) between 2000 and 2004 ranged from 77 to 82 °F (25 to 27.8 °C; California Data Exchange Center 2007). Juvenile sturgeon are also exposed to increased water temperatures in the Delta during the late spring and summer due to the loss of riparian shading and by thermal inputs from municipal, industrial, and agricultural discharges.

Non-native species. Green sturgeon have been impacted, both positively and negatively, by non-native species introductions through changes in trophic dynamics within the Delta and Suisun Bay. Many of the recent introductions of invertebrates have greatly affected the benthic fauna in the Delta and Suisun Bay. DFG (2002) reviewed many of the recent non-native invasive species introductions and the potential consequences to green sturgeon. The most notable species responsible for altering the trophic system of the Sacramento-San Joaquin Delta include the overbite clam and the Chinese mitten crab. Sturgeon regularly consume overbite and Asian clams, which is of particular concern because of the high bioaccumulation rates of these clams (Doroshov 2006). Although Chinese mitten crabs may be eaten by adult green sturgeon, it is possible they prey upon sturgeon eggs. However, the Chinese mitten crab population within the Bay-Delta system has undergone a substantial decline since 2002 and currently occurs in very low abundance (K. Hieb, pers. comm.) and, therefore, has not been a major factor affecting green sturgeon during this period.

Introductions of non-native invasive plant species such as water hyacinth and Brazilian waterweed have altered habitat and have affected local assemblages of fish within the Bay-Delta estuary (Nobriga et al. 2005). Nobriga et al. (2005) found significant differences in water clarity and fish communities in those areas where submerged aquatic vegetation (SAV) was abundant when compared to open water habitats where SAV was not abundant. The occurrence of dense concentrations of SAV has been hypothesized to result in a number of potential effects on aquatic habitat including raising temperatures, reducing turbidity and dissolved oxygen levels, and inhibiting access to shallow water habitat by fish that cannot tolerate these conditions. The presence of non-native centrarchid species is strongly associated with the occurrence of Brazilian waterweed (Brown and Michniuk 2007). Brazilian waterweed forms thick “walls” along the margins of channels in the Delta. This growth is thought to prevent juvenile sturgeon from accessing shallow water habitat along channel edges. Water hyacinth creates dense floating mats that can impede river flows and alter the aquatic environment beneath the mats. By reducing water velocities near plants, these species reduce turbidity in the water column, potentially exposing young sturgeon to higher predation risk. Several investigators (Abrahams and Kattenfeld 1997, Utne-Palm 2002; cited in Nobriga and Feyrer 2007) observed that various lifestages of estuarine fish may use turbidity as a form of cover from predators. High densities of SAV have been observed to trap suspended sediments and reduce local water velocities resulting in reduced turbidity and increased water clarity associated with SAV. Although there is no direct evidence of a relationship between turbidity and vulnerability of species such as juvenile green sturgeon to predation mortality, Nobriga et al. (2005) found that an inverse relationship between SAV and water clarity, as well as an increase in the occurrence of several predatory fish species in association with SAV within the estuary, which potentially may increase the vulnerability of juvenile sturgeon to predation mortality.

Dissolved oxygen levels beneath mats of aquatic vegetation often drop below suitable levels for fish possibly due to the increased amount of decaying vegetative matter produced from the overlying mat as well as diel respiration by aquatic plants. Like Brazilian waterweed, water hyacinth is often associated with the margins of Delta waterways in its initial colonization, but can eventually cover the entire channel if conditions permit. This level of infestation may produce barriers to green sturgeon migration and access to rearing and foraging habitat within the Delta, although there is no evidence that this occurs.

Dredging. Hydraulic dredging is a common practice in the Sacramento and San Joaquin rivers, navigation channels within the Delta, and Suisun, San Pablo, and San Francisco bays to allow commercial and recreational vessel traffic. Such dredging operations pose risks to bottom oriented fish such as green sturgeon. Studies by Buell (1992) reported approximately 2,000 sturgeon entrained in the removal of one million tons of sand from the bottom of the Columbia River at depths of 60 to 80 feet (18 to 24 m). In addition, dredging operations can decrease the abundance of locally available prey species, and contribute to resuspension of toxics such as ammonia, hydrogen sulfide, and copper during dredging and dredge spoil disposal, and alter bathymetry and water movement patterns (NMFS 2006b).

Reduction in turbidity. Turbidity levels in the Delta have been reduced over the past few decades (Jassby et al. 2002). This reduction may have had detrimental effects to green sturgeon. Although little is known about the effects of reduced turbidity on green sturgeon, Gadomski and Parsley (2005) have found that larval white sturgon predation by prickly sculpin was greater in water with lower turbidity. Because green and white sturgeon larvae may have similar behavior and morphology, this effect likely applies to green sturgeon, as well. However, larval sturgeon are found close to spawning locations generally upstream of the Delta, where turbidity is already lower than the Delta.

Entrainment. Larval sturgeon are susceptible to entrainment from non-project water diversion facilities as a result of their migratory behavior and habitat selection within the rivers and Bay-Delta estuary. The overall impact of entrainment of fish populations is typically unknown (Moyle and Israel 2005), however there is enough descriptive information to predict where green sturgeon may be entrained. Herren and Kawasaki (2001) documented 431 non-project diversions located on the Sacramento River between Sacramento and Shasta Dam. Entrainment information regarding larval and post-larval individuals of the green sturgeon is unreliable because entrainment at these diversions has not been monitored and field identification of green sturgeon larvae is difficult. USFWS staff are working on identification techniques and are optimistic that green sturgeon greater than 40 mm can be identified in the field (Poytress 2006). Sturgeon collected at the Glenn-Colusa Irrigation District diversion located on the upper Sacramento River are not identified to species, but are assumed to primarily consist of green sturgeon because white sturgeon are known to spawn primarily downstream (Schaffter 1997). Although screens at the Glenn-Colusa Irrigation District diversion satisfy both the NMFS and DFG screening criteria for salmonids, the effectiveness of these criteria is unknown for sturgeon. Low numbers of green sturgeon have also been identified and entrained at the Red Bluff Research Pumping Plant (Borthwick et al. 1999).

In the Feather River, there are 8 large diversions greater than 10 cfs and approximately 60 small diversions between 1 and 10 cfs between the Thermalito Afterbay outlet and the confluence with the Sacramento River (USFWS 1995). Based on potential entrainment problems of green sturgeon elsewhere in the Central Valley and the presence of multiple screened and unscreened diversions on the Feather River, it is thought that operation of unscreened water diversions on the Feather River are a possible threat to juvenile green sturgeon.

Presumably, as green sturgeon juveniles grow, they become less susceptible to entrainment as their swimming ability and capacity to escape diversions improves. The majority of North American green sturgeon captured in the Bay-Delta are between 200 and 500 mm in length (DFG 2002). Herren and Kawasaki (2001) inventoried water diversions in the Delta finding a total of 2,209 diversions of various types; only 0.7 percent of which were screened. The majority of these diversions were between 12 and 24 inches in diameter. The vulnerability of juvenile green sturgeon to entrainment at these unscreened diversions is largely unknown. Results of limited entrainment studies at diversions within the Delta suggest that larger juvenile green sturgeon have a lower risk of entrainment mortality. The largest diversions within the Delta are the State Water Project (SWP) and Central Valley Project (CVP) export facilities, located in the southern Delta, where a low number of juvenile green sturgeon have been recorded as part of fish salvage monitoring (DFG 2002). The average number of green sturgeon taken per year at the SWP Skinner Fish Facility was 87 individuals between 1981 and 2000, and 20 individuals from 2001 through 2007 (M. Donnellan, unpublished data). At the CVP Tracy Fish Collection Facility, green sturgeon counts averaged 246 individuals per year between 1981 and 2000, and 53 individuals per year between 2001 and 2007 (M. Donnellan, unpublished data). This reduction in salvage is consistent with a significant reduction in white sturgeon take at the salvage facilities within the same time periods (NMFS 2005).

Stranding. Green sturgeon that are attracted by high flows in the Yolo Bypass move onto the floodplain and eventually concentrate behind Fremont Weir, where they are blocked from further upstream migration (DWR 2005). As the Bypass recedes, these sturgeon become stranded behind the flashboards of the weir and can be subjected to heavy illegal fishing pressure (M. Marshall, USFWS, pers. comm.). Sturgeon can also be attracted to small pulse flows and trapped during the descending hydrograph (Harrell and Sommer 2003). Methods to reduce stranding and increase passage have been investigated (J. Navicky, pers. comm.).

A9.6 Relevant Conservation Efforts

The Central Valley Project Improvement Act's Anadromous Fish Restoration Program has a goal of supporting efforts that lead to doubling the natural production of anadromous fish in the Central Valley at a sustainable, long-term basis, at levels not less than twice the average levels attained during the period of 1967 to 1991. Although most efforts of the Anadromous Fish Restoration Program have focused on Chinook salmon as a result of their listing history and status, sturgeon may receive some unknown amount of incidental benefit from these restoration efforts. For example, the acquisition of water for flow enhancement on tributaries to the Sacramento River, fish screening for the protection of Chinook salmon and Central Valley steelhead, spawning gravel augmentation, or riparian revegetation and instream restoration projects would likely have some ancillary benefits to sturgeon. The Anadromous Fish Restoration Program has also invested in a green sturgeon research project that has helped improve our understanding of the life history requirements and temporal patterns of the southern DPS of North American green sturgeon.

Many beneficial actions have originated from and been been funded by the CALFED program including such projects as floodplain and instream restoration, riparian habitat protection, fish screening and passage projects, research on non-native invasive species and contaminants, restoration methods, watershed stewardship, and education and outreach programs. Prior Federal Register notices have reviewed the details of the Central Valley Project Improvement Act (CVPIA) and CALFED programs and potential benefits for anadromous fish, particularly Chinook salmon and Central Valley steelhead (69 FR 33102). Projects potentially benefiting sturgeon primarily consist of fish screen evaluation and construction projects, restoration evaluation and enhancement activities, and contaminant studies. Two evaluation projects specifically addressed green sturgeon while the remaining projects primarily address listed salmonids and fishes of the area in general. The new information developed through these research investigations will be used to enhance the understanding of the risk factors affecting population dynamics and recovery, thereby improving the ability to develop effective management measures.

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) was formed to guide the implementation of CALFED Ecosystem Restoration Plan elements within the Delta (DFG 2007b). The DRERIP team has created a suite of ecosystem and species conceptual models, including green sturgeon, that document existing scientific knowledge of Delta ecosystems. The DRERIP team is in the process of using these conceptual models to assess the suitability of actions proposed in the Ecosystem Restoration Plan for implementation. DRERIP conceptual models have been used in the analysis of proposed BDCP conservation measures.

In response to passage impediment concerns to green sturgeon and other migratory species, operations of the RBDD have been modified since its construction in 1964 to reduce the "gates-in" period. In 2009, U.S. Bureau of Reclamation received funding for the Fish Passage Improvement Project at the RBDD to build a pumping facility to provide reliable water supply for high-valued crops in Tehama, Glenn, Colusa, and northern Yolo counties while providing year-round unimpeded fish passage. This project, which is expected to be completed in late 2012, will eliminate passage issues for sturgeon and other migratory species.

The combination of increased law enforcement and new sport fishing regulations adopted over the past several years specifically to protect sturgeon and reduce their harvest is expected further reduce illegal fishing practices as well as the effects of incidental harvest of green sturgeon by recreational anglers throughout the range of the species. Mitigation under the Delta Fish Agreement has increased the number of wardens enforcing harvest regulations for steelhead and other fish in the Bay-Delta and upstream tributaries by creating the Delta Bay Enhanced Enforcement Program (DBEEP).

A9.7 Recovery Goals

On November 12, 2009, NMFS announced its intent to develop a recovery plan for the Southern DPS of North American green sturgeon (*Acipenser medirostris*) and has requested information from the public (74 FR 58245). This plan has not yet been developed.

A9.8 References

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APPENDIX A10. PACIFIC LAMPREY (*ENTOSPHENUS TRIDENTATUS*)

A10.1 LEGAL STATUS

The Pacific lamprey is not listed under the California or federal Endangered Species Acts (ESA).

A broad group of West Coast conservation organizations petitioned the U.S. Fish and Wildlife Service (USFWS) on January 27, 2003 to list Pacific lamprey, along with three other lamprey species on the West Coast, as threatened or endangered Klamath-Siskiyou Wildlands Center 2003). However, the petition was declined in a 90-day finding on December 27, 2004, citing insufficient evidence that listing was warranted (69 FR 77158).

A10.2 SPECIES DISTRIBUTION AND STATUS

A10.2.1 Range and Status

The Pacific lamprey is the most widely distributed lamprey species on the west coast of the United States. The species occurs from Hokkaido Island, Japan (Morrow 1980) along the Pacific Rim to Rio Santo Domingo, Baja California, Mexico (Ruiz-Campos and Gonzalez-Guzman 1996). A single individual was caught in 1889 offshore of Clarion Island, Revillagigedo Islands, Mexico, approximately 386 km southwest of Cabo San Lucas (Renaud 2008). Individuals inhabit major river systems, including the Columbia, Fraser-Trinity, Klamath, Eel, and Sacramento-San Joaquin rivers, as well as smaller coastal streams (see Figure A-10a). In general, populations south of San Luis Obispo are scattered and irregular (Swift et al. 1993). Populations may exist in other rivers, but are easily overlooked and have been the subject of few targeted sampling efforts (Moyle 2002). The species is usually absent from highly-altered or polluted streams within its geographic range, although appears to be persistent in currently occupied suitable streams (Moyle 2002).

In the Central Valley, Pacific lamprey occur in both the lower Sacramento and San Joaquin Rivers (Moyle 2002) and many of their tributaries including the Stanislaus, Tuolumne, Merced, and King Rivers (Brown and Moyle 1993, 69 FR 77158).

Population trends are unknown in California, although anecdotal evidence indicates that populations have been in decline (Moyle 2002, 69 FR 77158).

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Figure A-10a. Pacific Lamprey Inland Range in California

A10.2.2 Distribution and Status in the Plan Area

Individuals outmigrating from Sacramento and San Joaquin River watersheds pass through the Plan Area during winter and spring on their way to the Pacific Ocean. Emigrating adults pass through the Plan Area on their way upstream towards spawning grounds primarily between March and June. It is unknown to what extent Pacific lamprey use the Plan Are for purposes other than a migration corridor.

Status and trend data are extremely sparse and unreliable. There are no monitoring programs that target Pacific lamprey in the Delta and those that catch Pacific lamprey do not catch them regularly enough to establish trends through time. In addition, Pacific lamprey are inconspicuous, often overlooked, and ammocoetes can be difficult to distinguish from ammocoetes of the co-occurring river lamprey (H. Webb, pers. comm).

A10.3 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

The habitat requirements of Pacific lamprey have not been well studied. It is thought that adults need clean, gravelly riffles in permanent streams to spawn successfully and that these requirements are thought to be similar to those of salmonids (Moyle 2002). Ammocoetes live in silty backwaters and eddies with muddy or sandy substrate into which they burrow. Ammocoetes require water temperatures that are lower than 25 °C (76 °F) (Moyle et al. 1995). Meeuwig et al. (2004) found significant death or deformation of eggs and early stage ammocoetes in water greater than 72 °F (22 °C). Lamprey can pass barriers that other fish cannot, although large dams and other habitat modifications remain barriers to migration. Oceanic adults are thought to remain relatively close to the mouths of their home spawning streams where host/prey concentrations may be higher (Moyle 2002).

A10.4 LIFE HISTORY

Pacific lamprey are anadromous, beginning their migration into freshwater towards upstream spawning areas primarily between early March and late June (Moyle 2002). Most upstream migration occurs at night and occurs in pulses. Spawning habitat requirements are thought to be similar to those of salmonids. There is some evidence that Pacific lamprey in larger river systems, such as the Klamath and Eel Rivers, have distinct runs similar to Chinook salmon (Moyle 2002). Both sexes contribute to nest construction by removing larger stones from a gravelly substrate, creating a shallow depression. These simple nests occur in gravelly substrata at a depth of 30-150 cm with moderately swift currents and water temperatures typically of 12-18 °C (53.6 to 64.4 °F) (Moyle 2002). External fertilization of eggs occurs just in front of the nest, after which the fertilized eggs are washed into the nest. Fecundity is unknown, but has been estimated at 98,000 to 238,400 eggs per female (Kan 1975 as cited in Close et al. 2002). Spawning is repeated until both individuals are spent. Adults typically die after spawning.

Eggs hatch into ammocoetes after approximately 19 days at 15 °C, spend a short time in the nest, and then drift downstream to suitable areas in sand or mud (Moyle 2002). Ammocoetes remain in freshwater for approximately 5 to 7 years, where they bury into silt and mud and feed on algae, organic material, and microorganisms. Ammocoetes change locations during this stage.

Ammocoetes begin metamorphosis into macropthalmia (juveniles) when they reach 14-16 cm total length (TL). Individuals develop external features (eyes, oral disc, and color changes) and experience internal and physiological changes that prepare them for their predatory life stage in the ocean (McPhail and Lindsey 1970). Downstream migration begins upon completion of this metamorphosis, generally coinciding with high flow events in winter and spring (Moyle 2002).

Adults spend 3-4 years in the ocean in British Columbia, but this length is thought to be shorter in more southern areas (Moyle 2002). Adult remain close to the mouths of the rivers from which they came, likely because their prey is most abundant in estuaries and other coastal areas (Moyle 2002). Individuals attack a wide variety of fishes, include salmon, Pacific herring, and flatfishes, in the ocean (Beamish 1980). Pacific lamprey are thought to be preyed upon in the ocean by sharks, other fish, otters, seals, and sea lions (Roffe and Mate 1984, Moyle 2002).

A10.5 Threats and Stressors

Evaluation of the threats and stressors to Pacific lamprey has been limited. Therefore, much of the following discussion is based on a recent workshop to identify the state of knowledge, including knowledge gaps, on the biology, population structure, habitat of and threats to Pacific lamprey (Luzier et al. 2009).

Reduced Access (Passage) to Spawning Habitat. Artificial barriers, including dams, culverts, water diversions, tidal gates, and other barriers, can impede or completely block the upstream migration of adults to spawning grounds, resulting in impacts to the distribution and abundance of lamprey (Klamath-Siskiyou Wildlands Center et al. 2003, Luzier et al. 2009). Lamprey adults may have difficulty passing over barriers using ladders and other passage structures designed for salmonids, possibly due to high water velocity, sharp angles, culverts with drop-offs, or insufficient resting areas (Kostow 2002). Hydroelectric projects and water diversions may entrain or impinge weak-swimming macropthalmia (Moursund et al. 2000).

Reduced Access (Passage) to Downstream Habitat. Artificial barriers, including dams, culverts, water diversions, tidal gates, and other barriers, can impede or completely block the downstream migration of ammocoetes and macropthalmia towards the ocean, resulting in impacts to the distribution and abundance of lamprey (Luzier et al. 2009). Lamprey tend to outmigrate deeper in the water column such that traditional spill gates meant to aid migration of salmonids may not be effective on lamprey and may block passage (Moursund et al. 2003). Pacific lamprey populations cannot persist for more than a few years above impassable barriers (Beamish and Northcote 1989).

Stranding. Rapid changes in stream flows as a result of reservoir management can dewater stream beds and strand ammocoetes residing in the substrate. Water diversions and instream construction projects, such as culvert replacements, may also dewater reaches of streams and strand ammocoetes (Streif 2007). Because Pacific lamprey ammocoetes burrow in upstream sediments for 5-7 years in high densities, a dewatering event may affect multiple age classes burrowing together in a single stream reach (Luzier et al. 2009).

Dredging. Dredging associated with channel or irrigation screen maintenance and mining may affect many age classes at once due to their "colonial" nature and long upstream life stage (5-7 years) (Luzier et al. 2009). Beamish and Youson (1987) found that only 3-26 percent of lamprey that pass through a dredge survive. Further, it has been suggested that suction dredge mining was responsible for the decline or even loss of populations in some basins (Kostow 2002).

Chemical Poisoning and Toxins. Ammocoetes spend 5-7 years living in silty areas that are known to accumulate high levels of toxins. As a result, lamprey tend to have high body burdens of toxins relative to other fish species (Haas and Ichikawa 2007, Bettaso and Goodman 2008). Despite this apparent tolerance for high levels of toxins, lamprey are thought to be susceptible to toxins (Kostow 2002).

Ocean Conditions. Reductions the availability of host/prey organisms in the ocean (e.g., salmon and flatfishes) as a result of poor ocean conditions may negatively affect lamprey survival and growth, although very little is known about the oceanic stage of Pacific lamprey (Luzier et al. 2009).

Water Temperature. Elevated water temperature (greater than 22 °C [72 °F]) can cause mortality or significant deformation of eggs and young ammocoetes in laboratory conditions (Meeuwig et al. 1999). Degraded streams with a water temperature greater than 22 °C during early/mid-summer while lamprey spawn and young ammocoetes develop may be common (Luzier et al. 2009).

Disease. Pacific lamprey disease incidence is not well understood, but it is thought that disease may impact lamprey health to the point at which their ability to reproduce and survive is reduced (Luzier et al. 2009).

Overutilization. The extent to which harvest affects the population level effect on Pacific lamprey has not been well studied, but could represent a large proportion of spawning adults. Pacific lamprey adults and ammocoetes are harvested for use as bait to catch other species (Luzier et al. 2009). In addition, the fish is important to tribes in the Pacific Coast for sustenance, medicine, and ceremonial purposes (Close et al. 2002). Pacific lamprey for food and commercial purposes has declined from historical levels and Washington and Oregon have banned harvest for bait. However, harvest has not declined in California, where there are no regulations on lamprey harvest (69 FR 77158).

Predation. Mammals, birds, and other fish species consume lamprey at all life stages (Luzier et al. 2009). Ammocoetes are consumed by terrestrial mammal and birds, fish, and other species. Adult lamprey are consumed by otters, pinnipeds, and sturgeon.

Stream and Floodplain Degradation. The high density and limited mobility of lamprey ammocoetes in streams can potentially make them more vulnerable to channel alterations such as channelization, loss of riffle and side channel habitat, and scouring (Streif 2007, Luzier et al. 2009). Loss or alteration of habitat can also limit spawning if occurring in spawning reaches.

Non-Native Species. Non-native species, including striped bass, centrarchids, and catfish, are believed to consume juvenile and adult lamprey and may pose a threat to population sizes of lamprey (Streif 2007, Luzier et al. 2009). Many of these non-native species have become established within the range of Pacific lamprey in the Central Valley and have populations that are thriving despite recent declines in many native species (Baxter et al. 2008).

Translocation. It is unknown whether migrating adults cue solely on ammocoete pheromones or on other upstream cues to guide them to natal streams to spawn. If an ammocoete pheromone cue does not drive adult migration, translocation of individuals to an area previously extirpated would not affect adult migration cues.

Climate Change. Future climate change is expected to further increase water temperatures and modify the timing of flow-related environmental cues upon which Pacific lamprey rely for life history events (e.g., outmigration, spawning, etc.) (Luzier et al. 2009).

Extirpation. It is unknown whether migrating adults cue solely on ammocoete pheromones or on other upstream cues to guide them to natal streams to spawn. If they cue solely on ammocoete pheromones, extirpation of local populations would have large effects on recolonization of natal streams (Luzier et al. 2009).

A10.6 RELEVANT CONSERVATION EFFORTS

Along with several tribes, state and federal agencies are increasingly incorporating Pacific lamprey into management and monitoring plans to increase the overall body of knowledge and conserve the species.

There have been very few efforts to conserve Pacific lamprey in the Central Valley of California. The CALFED Ecosystem Restoration Program (ERP) designated the entire lamprey family as “Enhance and/or Conserve” (CALFED Bay-Delta Program 2000). This designation indicates that the ERP will undertake actions to conserve and enhance their abundance and distribution and the community diversity in which they live for their long-term stability.

There has been work in the Columbia River basin to modify new or existing ladders and structures to facilitate lamprey passage, such as creating holding areas where lamprey can rest (Columbia River Basin Lamprey Technical Workgroup 2004).

The Pacific Lamprey Conservation Initiative, led by the USFWS, was initiated in 2007 to “facilitate communication and coordination relative to the conservation of Pacific lampreys throughout their range” (USFWS 2007). The goal of the initiative is to restore Pacific lamprey populations and improve their habitat. Anticipated actions from the Initiative include: development of a Pacific Lamprey Conservation Plan, identification of funding for implementation of the Initiative and Plan, development of a network of interested parties, funding immediate conservation actions, and improvements in communication of Pacific lamprey conservation efforts.

A10.7 Recovery Goals

A recovery plan has not been prepared for this species and no recovery goals have been established because the species is not listed under the Federal or California ESA.

A10.8 References

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A10.8.3 Federal Register Notices Cited

69 FR 77158. 2004. Endangered and Threatened Wildlife and Plants; 90-Day Finding on a Petition To List Three Species of Lampreys as Threatened or Endangered. Federal Register. 69: 77158.

APPENDIX A11. RIVER LAMPREY (*LAMPETRA AYRESII*)

A11.1 LEGAL STATUS

The river lamprey is not listed under the state or federal Endangered Species Acts (ESA).

A broad group of West Coast conservation organizations petitioned the U.S. Fish and Wildlife Service (USFWS) on January 27, 2003 to list river lamprey, along with three other lamprey species on the West Coast, as threatened or endangered (Klamath-Siskiyou Wildlands Center 2003). However, the petition was declined in a 90-day finding on December 27, 2004, citing insufficient evidence that listing was warranted (69 FR 77158).

A11.2 SPECIES DISTRIBUTION AND STATUS

A11.2.1 Range and Status

The river lamprey occurs from near Juneau, Alaska, to San Francisco Bay, California (Moyle 2002). Outside of California, there are widely scattered and isolated populations throughout its range. River lamprey are common in British Columbia, the center of their geographic range. Within California, river lamprey can be found in the Central Valley, Napa River, Sonoma Creek, Alameda Creek, Salmon Creek, and in tributaries of the lower Russian River (see Figure A-11a). In the Central Valley, river lamprey are found in the lower Sacramento and San Joaquin River drainages, including the Stanislaus and Tuolumne Rivers. They may exist in other tributaries of these rivers, but are easily overlooked and have been the subject of few targeted sampling efforts (Moyle 2002). The species appears to be more abundant in the lower Sacramento-San Joaquin River system than in other streams in California.

Population trends are unknown in California, although declines are thought to have occurred synonymously with freshwater habitat degradation (Moyle 2002).

A11.2.2 Distribution and Status in the Plan Area

Individuals outmigrating from Sacramento and San Joaquin River watersheds pass through the Delta on their way to the Pacific Ocean and emigrating adults pass through the Plan Area on their way upstream towards spawning grounds. The extent to which river lamprey use the Plan Area for purposes other than a migration corridor is unknown. However, outmigrating lamprey macropthalmia in the final stages of metamorphosis to adults hold just upstream of salt water until late spring. Depending on the position of X2, this location could be within the Plan Area.

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Figure A-11a. River Lamprey Inland Range in California

Status and trend data are extremely sparse and unreliable. There are no monitoring programs that target river lamprey in the Delta and those that catch river lamprey do not catch them regularly enough to establish trends through time. River lamprey are inconspicuous, often overlooked, and ammocoetes can be difficult to distinguish from ammocoetes of the co-occurring Pacific lamprey (H. Webb, pers. comm).

A11.3 Habitat Requirements and Special Conditions

The habitat requirements of river lamprey have not been well studied. It is thought that adults need clean, gravelly riffles in permanent streams to spawn successfully. These requirements are thought to be similar to those of salmonids. Ammocoetes live in silty backwaters and eddies with muddy or sandy substrate into which they burrow (Moyle et al. 1995). Ammocoetes require water temperatures that are lower than 25 °C (77 °F; Moyle et al. 1995). Lamprey can pass barriers that other fish cannot, although large dams and other habitat modifications remain barriers to migration. Lamprey may have difficulty passing over barriers using ladders and other passage structures designed for salmonids, possibly due to high water velocity, sharp angles, culverts with drop-offs, or insufficient rest areas (Kostow 2002). There has been some work in the Columbia River basin to modify new or existing ladders and structures to facilitate lamprey passage, such as creating holding areas where lamprey can rest (Columbia River Basin Lamprey Technical Workgroup 2004).

Although generally considered anadromous, river lamprey can live in freshwater as adults. For example, the population of river lamprey living in land-locked Sonoma Creek spend their entire life in freshwater.

A11.4 Life History

The biology of the river lamprey has not been well studied in California. As a result, much of this section is derived from information known for river lamprey from British Columbia. The potential exists for dissimilar life histories between fish in these two locations due to differences in physical factors (e.g., temperature, hydrology).

River lamprey are anadromous, beginning their migration into freshwater in the fall towards suitable spawning areas upstream (Moyle et al. 1995, Moyle 2002). Exact spawning locations are not known, although spawning habitat requirements are thought to be similar to those of salmonids. Fidelity to natal streams is also unknown. Spawning occurs from February through May in gravelly riffles in which individuals dig saucer-shaped depressions (Moyle 2002). Adults die after spawning. Fecundity is not well documented, but a study of two females in Cache Creek reported that one female (23 centimeters [cm; 9.1 inches] total length) produced approximately 11,400 eggs and the other (17.5 cm [6.9 inches] total length) produced approximately 37,300 eggs (Vladykov and Follett 1958). The eggs hatch into ammocoetes that remain in freshwater for approximately 3 to 5 years in silty or sandy low-velocity backwaters or stream edges where they bury into the substrate and filter-feed on algae, detritus, and microorganisms (Moyle 2002).

Ammocoetes begin metamorphosis into macropthalmia and then adults during summer at approximately 12 cm total length. This process takes nine to ten months during which individuals may shrink in length by up to 20 percent (Moyle 2002). Prior to entering the ocean, macropthalmia congregate just upstream of salt water until their esophagus opens (Beamish and Youson 1987). Once the esophagus is opened, new adults can properly osmoregulate and can then enter the ocean (Moyle 2002). Adults spend approximately 3 to 4 months in the ocean where they grow rapidly to 25 to 31 cm total length. If the ammocoete stage is 3 to 5 years, the total life span of river lamprey is estimated to be 6 to 7 years (Moyle et al. 1995).

River lamprey adults are parasitic during both freshwater and saltwater phases. Adults feed on a variety of host fish species that are small to intermediate size (4 to 12 inches total length) (Moyle et al 1995), the most common of which are thought to be herring and salmon (Beamish and Youson 1987). In Canada, river lamprey predation is considered to be a significant source of salmon mortality (Beamish and Neville 1995). Individuals feed by attaching to the back of their prey above the lateral line and eating the muscle tissue, even after the host fish dies (Moyle 2002). More than one lamprey can attach to a host salmon (Beamish and Youson 1987).

A11.5 THREATS AND STRESSORS

There have been no formal evaluations conducted that assess the threats and stressors to river lamprey. Therefore, much of the following discussion is based on limited resources or has been derived from the co-occurring Pacific lamprey as part of the Pacific Lamprey Conservation Initiative. The primary threat to river lamprey is thought to be loss or degradation of habitat through dams, diversions, toxics, stream channelization, dredging, and urbanization (Moyle et al. 1995, Luzier et al. 2009). Dams have altered flows in channels and limited access to spawning grounds. Toxics may have both lethal and sublethal effects on individuals. Stream channelization, dredging, and diversions have altered flow patterns and rates in channels. Urbanization has degraded habitat by increasing loads of certain toxics, changing runoff patterns, and altering the configuration of some channels. Future climate change is expected to further increase water temperatures and modify the timing of flow-related environmental cues upon which Pacific lamprey rely for life history events (e.g., outmigration, spawning, etc.).

A11.6 RELEVANT CONSERVATION EFFORTS

There have been very few efforts to conserve river lamprey in the Central Valley of California. The CALFED Ecosystem Restoration Program (ERP) designated the entire lamprey family as “Enhance and/or Conserve” (CALFED Bay-Delta Program 2000). This designation indicates that the ERP will undertake actions to conserve and enhance their abundance and distribution and the community diversity in which they live for their long-term stability.

River lamprey is currently listed as a covered species under the Butte County Habitat Conservation Plan, but specific conservation measures have not yet been written.

A11.7 Recovery Goals

A recovery plan has not been prepared for this species and no recovery goals have been established because the species is not listed under the Federal or California ESA.

A11.8 References

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A11.8.3 Federal Register Notices Cited

69 FR 77158. 2004. Endangered and Threatened Wildlife and Plants; 90-Day Finding on a Petition To List Three Species of Lampreys as Threatened or Endangered. Federal Register. 69: 77158.

APPENDIX A12. SAN JOAQUIN KIT FOX (*VULPES MACROTIS MUTICA*)

A12.1 LEGAL STATUS

The San Joaquin kit fox (*Vulpes macrotis mutica*) is a state and federally-listed species. It was listed by the U.S. Fish and Wildlife Service as an endangered species in 1967 and as a threatened species pursuant to the California Endangered Species Act in 1971. No critical habitat rules have been published for the San Joaquin kit fox.

A12.2 SPECIES DISTRIBUTION AND STATUS

A12.2.1 Range and Status

Grinnell et al. (1937) initially described the range of the San Joaquin kit fox prior to 1930 as extending from southern Kern County as far north as eastern Contra Costa County. Grinnell et al. (1937) note that by 1930 the range had been reduced by more than half, with the largest portion of the occupied range remaining in the western and southern parts of the valley. They considered the species largely absent from the eastern and central parts of the valley.

Although no complete surveys have been conducted of the historical range, kit foxes are currently thought to inhabit suitable habitat on the San Joaquin Valley floor and in the surrounding foothills of the coastal ranges, Sierra Nevada, and Tehachapi Mountains north to Contra Costa, Alameda, and San Joaquin counties on the west side of the valley, and near La Grange, Stanislaus County, on the east side of the Valley (USFWS 1998) (Figure A-12a). Kit foxes have been found on all the larger, scattered islands of natural land on the Valley floor in Kern, Tulare, Kings, Fresno, Madera, San Benito, Merced, Stanislaus, San Joaquin, Alameda, and Contra Costa counties. They also occur in the interior basins and ranges in Monterey, San Benito, San Luis Obispo, and, possibly, Santa Clara counties and in the upper Cuyama River watershed in northern Ventura and Santa Barbara counties and southeastern San Luis Obispo County (Laughrin 1970, Jensen 1972, Swick 1973, Morrell 1975).

USFWS (1998) reports that the largest extant populations of kit foxes are in western Kern County on and around the Elk Hills and Buena Vista Valley, Kern County, and in the Carrizo Plain National Area, San Luis Obispo County. Other relatively large populations have been reported to occur in the Central Coast around Fort Hunter Liggett, Monterey County, and Camp Roberts, Monterey, and San Luis Obispo counties. Occurrences further north are fewer and less frequent and include several in the Los Vaqueros watershed and surrounding area in Contra Costa County in the early 1990s (USFWS 1998, CNDDB 2009).

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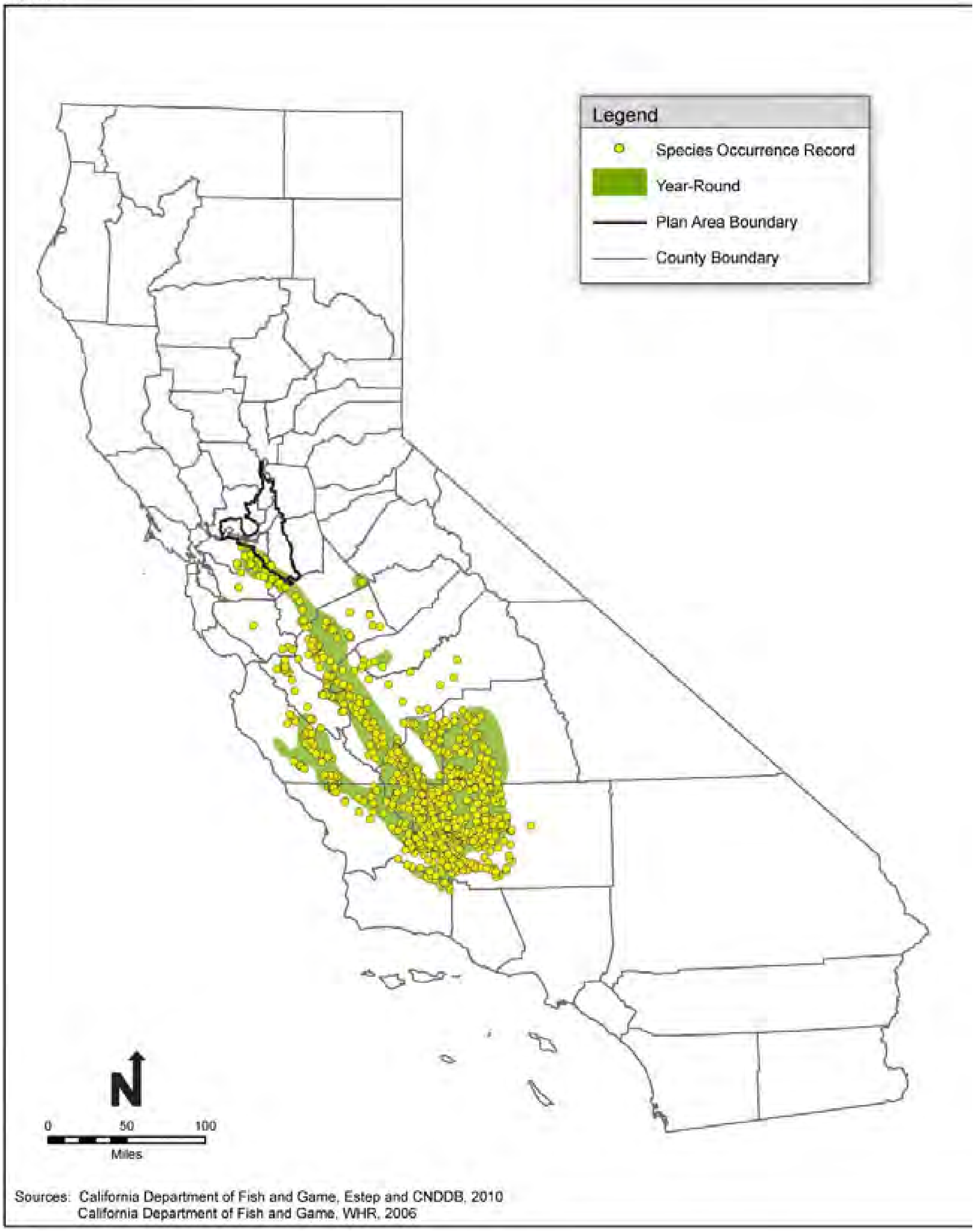

Figure A-12a. San Joaquin Kit Fox Statewide Range and Recorded Occurrences

Habitat loss, particularly on the San Joaquin Valley floor, has constrained the distribution of San Joaquin kit fox. Morrell (1975) reported that approximately 85 percent of the fox population in 1975 was found in only six counties (Kern, Tulare, Kings, San Luis Obispo, Fresno, and Monterey), and over half the population occurred in two of those counties: Kern (41 percent) and San Luis Obispo (10 percent). The 1983 recovery plan (USFWS 1983) estimated that the population of adult kit foxes over the entire range prior to 1930 may have been between 8,667 and 12,340. The estimate presented in the 1983 recovery plan was 6,961 adult foxes, representing a possible population decline of 20 to 43 percent.

More recently, Constable et al. (2009) found persistent but low populations in Merced County south of Santa Nella, but also questioned the viability and presence of kit fox populations north of Santa Nella due to habitat loss and fragmentation; declining populations of preferred prey, particularly kangaroo rats; low densities; and lack of reported population persistence.

Within this constrained, fragmented, and largely disturbed landscape, Cypher et al. (2000) showed that (1) population growth rates vary positively with reproductive success, (2) population density is positively related to both the current and the previous year's prey availability, and (3) prey abundance is strongly related to the previous years' effective precipitation (October to May). White and Garrott (1999) note that two density-dependent mechanisms may also regulate kit fox population patterns: (1) the rate of juvenile recruitment, which is inversely related to the density of adult foxes because higher proportions of juveniles are killed by coyotes at high fox densities and (2) kit fox populations are bounded by their territorial spacing behavior, which limits recruitment at high densities.

A12.2.2 Distribution and Status in the Plan Area

CNDDB (2009) reports eight occurrences of San Joaquin kit fox in the Plan Area. All occurrences are within the grassland landscape along the extreme western edge of the Plan Area south of Brentwood (Figure A-12b). This is considered the extreme northeastern edge of the San Joaquin kit fox range (USFWS 1998). The species has not been detected, nor is it expected to occur elsewhere within the Plan Area. Most of the reported occurrences are from the late-1980s to the mid-1990s. There have been very few reported occurrences of this species within the far northern portion of its range (Alameda, Contra Costa, and San Joaquin counties) since the mid-1990s. Of the 53 recorded occurrences in Contra Costa County between 1967 and 1997, only 15 were documented since 1986 (Duke et al. 1997). A recent survey of Contra Costa and Alameda counties within the known range of the kit fox found no evidence of recent occupancy (Clark et al. 2003). While recent survey results do not necessarily indicate absence of the species, they do indicate very low density of San Joaquin kit fox and suggest a declining population within the northern range of the species.

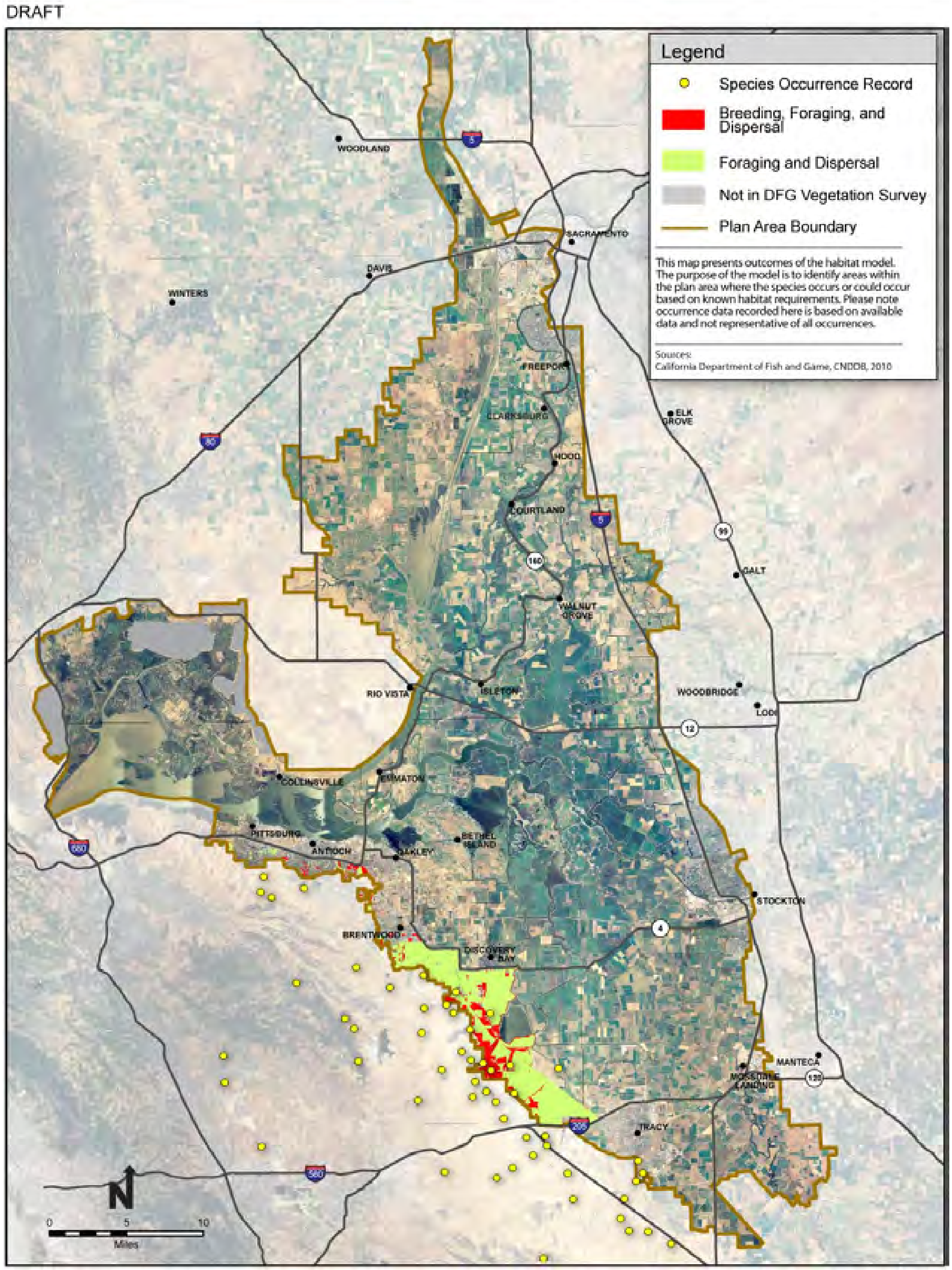

Figure A-12b. San Joaquin Kit Fox Habitat Model and Recorded Occurrences

A12.3 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

In the northern part of the range, the San Joaquin kit fox is associated primarily with foothill annual grasslands (Swick 1973, Hall 1983, Bell 1994) and sometimes with valley oak savanna and alkali grasslands (Bell 1994). In the vicinity of the Plan Area, San Joaquin kit foxes inhabit grazed grasslands and grasslands with associated wind farms and sometimes occur adjacent to and forage in tilled and fallow fields and irrigated row crops (Bell 1994). In the central and southern portions of the range, kit foxes are also found in remnant patches of native valley floor scrubland (e.g., valley sink scrub, valley saltbush scrub, Upper Sonoran subshrub, Interior Coast Range saltbush scrub), as well as grazed grasslands, agricultural lands, petroleum fields, and some urban areas (USFWS 1998). Remaining patches of northern hardpan vernal pool, northern claypan vernal pool, alkali meadow, and alkali playa types also provide foraging habitat when in association with grasslands or other suitable denning habitats.

Dens are typically in relatively flat terrain or in gently sloping hills, in washes, drainages, and roadside berms. Occupied habitats are usually associated with loose-textured soils to facilitate den construction (Grinnell et al 1937, Egoscue 1962, Morrell 1972). Shallow soils with close proximity to bedrock, soils with high water tables, and impenetrable hardpan layers are generally avoided (Morrell 1972, O'Farrell and Gilbertson 1979, O'Farrell et al. 1980, McCue et al. 1981). However, kit foxes will also modify burrows dug by other animals, such as California ground squirrel (*Otospermophilus beecheyi*[1]). Where this is common, particularly in the northern part of the range, dens may be found in soils with high clay content (Orloff et al. 1986). Kit foxes have also been documented using agricultural lands where adjacent uncultivated land occurs and provides suitable denning sites and a prey base (Jensen 1972, Kato 1986, Orloff et al. 1986).

A12.4 LIFE HISTORY

Description. The San Joaquin kit fox is the largest of eight subspecies of kit foxes, the smallest canid species in North America. Kit foxes have a small, slim body; long, slender legs; large ears set close together; a narrow nose; and a long, bushy tail tapering slightly toward the tip, which is typically carried low and straight (USFWS 1998). Males average 80.5 centimeters (cm) (2.64 feet) in total length and 29.5 cm (11.6 inches) in tail length; females average 76.9 cm (2.52 feet) in total length and 28.4 cm (11.2 inches) in tail length (Grinnell et al. 1937). The average weight of adult males is 2.3 kilograms (5.1 lbs); that of adult females is 2.1 kilograms (4.6 lbs) (Morrell 1972).

The color and texture of the coat of kit foxes vary geographically and seasonally. The most commonly described colorations are buff, tan, grizzled, or yellowish-gray dorsal coats (McGrew

[1] Formerly *Spermophilus beecheyi*

1979). Two distinctive coats develop each year: a tan summer coat and a silver-gray winter coat (Morrell 1972). The undersides vary from light buff to white (Grinnell et al. 1937), with the shoulders, lower sides, flanks, and chest varying from buff to a rust color. The ear pinna (external ear flap) is dark on the back side, with a thick border of white hairs on the forward-inner edge and inner base. The tail is distinctly black-tipped (USFWS 1998).

Activity. San Joaquin kit foxes are primarily nocturnal and active throughout the year (Grinnell et al. 1937, Morrell 1972). Adults and pups are sometimes observed resting and playing near the den entrance in the afternoons, but most aboveground activities begin near sunset and continue sporadically throughout the night (USFWS 1998). Morrell (1972) reported that hunting occurred only at night. However, this may not be true for populations that rely on diurnal ground squirrels as their principal prey, such as those in the northern range. This suggests that kit foxes are not entirely nocturnal and appear to adapt to the activities of available prey (Balestreri 1981, Hall 1983, Orloff et al. 1986, O'Farrell et al. 1987).

Reproduction. Kit foxes are capable of breeding at age one, but may not breed until their first year of adulthood (Morrell 1972). Adult pairs remain together all year, sharing the home range but not necessarily the same den (USFWS 1998). During September and October, adult females begin to clean and enlarge natal or pupping dens, usually selecting dens with multiple openings (Morrell 1972). Mating and conception take place between late-December and early-March (Egoscue 1956, Morrell 1972, Zoellick et al. 1987a). The median gestation period is estimated to range from 48 to 52 days (USFWS 1998). The majority of litters, of from two to six pups, are born sometime between mid-February and late-March (Egoscue 1962, Morrell 1972, Zoellick et al. 1987a).

During the time the female is lactating, she rarely hunts and is provisioned by the male. The pups emerge above ground at slightly more than 1 month of age and may already be weaned. After 4 to 5 months, usually in August or September, the family bonds begin to dissolve and the young begin dispersing. Occasionally a juvenile female will remain with the adult female for several more months (O'Neal et al. 1992). Koopman et al. (2000) found that 33 percent of juveniles disperse from their natal territory, with more males (49 percent) than females (24 percent). Others remain in their natal area. Dispersal was associated with mean annual litter size in males and prey abundance in females.

Home Range/Territory Size. Home ranges appear to be highly variable, from less than 2.6 square kilometers (sq km) (1 square mile [sq mi]) up to approximately 31 sq km (12 sq mi) (Morrell 1972, Knapp 1978, Zoellick et al. 1987b, Paveglio and Clifton 1988, Spiegel and Bradbury 1992, White and Ralls 1993). Morrell (1972) reported home ranges between 2.6 and 5.2 sq km (1 and 2 sq mi). Differences in home range size among study sites tend to be related to prey abundance (White and Ralls 1993, White and Garrott 1999). The USFWS (1999) mentions large kit fox home ranges in the northern range; however, little data are available for home range size in the northern portion of the range.

Foraging Behavior and Diet. San Joaquin kit fox diet varies geographically, seasonally, and annually based on variation in abundance of potential prey (USFWS 1998). In the southern and central portions of their range, kangaroo rats, pocket mice, white-footed mice (*Peromyscus* spp.), and other nocturnal rodents are key prey items. California ground squirrels, black-tailed hares, San Joaquin antelope squirrels, desert cottontails, ground-nesting birds, and insects are also taken (Jensen 1972, Scrivner et al. 1987a, Archon 1992). In the northern part of their range, kit foxes most frequently consume California ground squirrels (Orloff et al. 1986). Cottontails, black-tailed hares, pocket mice, and kangaroo rats are also eaten (Hall 1983).

A12.4.1 Threats and Stressors

Habitat Loss and Fragmentation. Habitat loss and fragmentation from urbanization and agricultural expansion is the principal factor in the decline of the San Joaquin kit fox in the San Joaquin Valley (Laughrin 1970, Jensen 1972, Morrell 1975, Knapp 1978). By 1979, an estimated 6.7 percent of the San Joaquin Valley floor's original native habitat south of Stanislaus County remained untilled and undeveloped (USFWS 1983). In the northern range, continued urbanization, primarily in Contra Costa and Alameda counties; water storage and conveyance projects; road construction; energy development; and other activities continue to reduce and fragment remaining grassland habitats. These land conversions contribute to kit fox declines through displacement, isolation of populations, creation of barriers to movement, direct and indirect mortality, and reduction of prey populations (USFWS 1998).

Grazing. While livestock grazing is not necessarily detrimental and may in fact be beneficial (Morrell 1975, Balestreri 1981, Orloff et al. 1986), intensive overgrazing that destroys shrub cover and reduces prey abundance may be detrimental (O'Farrell et al. 1980, O'Farrell and McCue 1981, USFWS 1983, Kato 1986).

Rodent Control. The use of pesticides and rodenticides also threatens kit foxes. Ground squirrel control programs in the 1970s severely reduced California ground squirrel populations in Contra Costa County and are thought to have contributed to kit fox declines in the northern range (Bell et al. 1994, USFWS 1998). Kit fox is also susceptible to secondary poisoning from rodenticides (Berry et al. 1992, Standley et al. 1992).

Predation. Human activities, including urbanization, agricultural expansion, and agricultural and grazing practices, may have increased some predator populations that are more adaptable to disturbed environments, including coyote and red fox, two primary predators of the San Joaquin kit fox. This, in turn, can result in increased competition for resources and additional human-induced predation affecting kit fox populations.

A12.5 Relevant Conservation Efforts

A recovery plan that proposed interim objectives of halting the decline of the San Joaquin kit fox and increasing population sizes above 1981 levels was approved in 1983 (USFWS 1983).

Subsequent to the recovery plan, the most significant conservation efforts have included land acquisitions by federal, state, and private agencies and organizations, including the U.S. Bureau of Land Management, USFWS, and The Nature Conservancy. Key acquisitions include the Carrizo Plain, Ciervo-Panoche Natural Area, and the Lokern Natural Area in the southern range. Other lands have been protected as mitigation for land conversions.

Past and continuing research, particularly on the Naval Petroleum Reserves in Kern County, provides data on a variety of topics that assist with long-term management and conservation of kit fox, including dispersal, mortality, movements and home ranges, habitat enhancement, relocation, supplemental feeding, and coyote control (Berry et al. 1987a, 1987b, Scrivner et al 1987b, Zoellick et al. 1987a, Cypher and Scrivner 1992, EG&G Energy Measurements 1992), as well as various survey efforts and life history studies (Hall 1983, Orloff et al. 1986, Archon 1992, Spiegel and Bradbury 1992, White and Ralls 1993, Bell et al. 1994, White et al. 1994).

The San Joaquin kit fox is a covered species in the San Joaquin County Multi-Species Habitat Conservation and Open Space Plan and the East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan, which limit or prohibit removal of occupied habitat that could potentially affect the species as a result of the implementation of covered activities.

A12.6 SPECIES HABITAT SUITABILITY MODEL

Model Approach. BDCP Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information systems (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which are incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and revise the vegetation input data as necessary.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements, and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate, as well as overestimate, the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small, isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; instead, the models indicate that non-habitat areas have a much lower probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf (2007). Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers; connectivity between habitat types; and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified, and each vegetation type or association is identified, along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or underestimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The San Joaquin kit fox model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), U.S. Department of Agriculture (USDA) 2005 aerial photography, and California Department of Water Resources (DWR) 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable San Joaquin kit fox habitat in the Plan Area. Vegetation types were assigned based on the species requirements, as described above, and the assumptions described below.

Upland Breeding, Foraging, and Dispersal Habitat. Upland breeding, foraging, and dispersal habitat includes grassland and agricultural habitats within the area south and west of Highway 4 from Antioch (Bypass Road to Balfour Road to Brentwood Boulevard), to Old River; then south along Old River to Clifton Court Forebay; along the western and southern sides of Clifton Court Forebay to Old River; then south along the county line to Byron Highway; then west of Byron Highway to I-205, north of I-205 to I-580, and west of I-580.

Upland Breeding, Foraging, and Dispersal Habitat from the BDCP composite vegetation layer consists of the following:

- Grassland

- Ruderal herbaceous grasses and forbs;
- California annual grasslands – herbaceous;
- *Bromus diandrus – Bromus hordeaceus;*
- Degraded vernal pool complex – California annual grasslands; and
- Degraded vernal pool complex – Ruderal herbaceous grasses and forbs.

- Vernal pool complex
  - Ruderal herbaceous grasses and forbs; and
  - California annual grasslands – herbaceous.

Upland Foraging and Dispersal Habitat from the BDCP composite vegetation layer consists of the following:

- Agricultural land – all types

Assumptions. Within the Plan Area, the San Joaquin kit fox has been detected only in grassland and adjoining agricultural habitats within the grassland landscape along the extreme southwestern edge of the Plan Area from approximately Brentwood to Tracy. This area is the northeasternmost edge of the San Joaquin kit fox range. The species is not known to or expected to occur elsewhere in the Plan Area.

In the northern part of the range, the San Joaquin kit fox is associated primarily with foothill annual grasslands (Swick 1973, Hall 1983, Bell 1994) and sometimes with valley oak savanna and alkali grasslands (Bell 1994). In the vicinity of the Plan Area, San Joaquin kit foxes inhabit grazed grasslands and sometimes occur adjacent to and forage in tilled and fallow fields and irrigated row crops (Bell 1994). Agricultural lands are likely used infrequently and inconsistently due to crop rotations and differences in suitability; thus, this model overestimates the extent of suitable agricultural foraging and dispersal habitat.

A12.6.1 Recovery Goals

The 1998 recovery plan for upland species of the San Joaquin Valley (USFWS 1998) incorporates and expands on the strategy provided in the initial 1983 San Joaquin kit fox recovery plan (USFWS 1983). The goal of the 1998 recovery plan is to establish and maintain a viable complex of kit fox populations (i.e., viable metapopulations) on private and public lands throughout the species' geographic range. The plan hinges on the enhanced protection and management of three geographically distinct core populations and a number of smaller satellite populations. The three core populations inhabit the Carrizo Plan Natural Area in San Luis Obispo County, natural lands of western Kern County (i.e., Elk Hills, Buena Vista Hill, Buena Vista Valley, Lokern Natural Area, and adjacent natural land), and the Ciervo-Panoche Natural

Area of western Fresno and eastern San Benito counties (USFWS 1998). Protection of smaller satellite populations will connect isolated natural lands to core and other populations.

The plan also includes a series of recovery actions that focus on land protection and maintenance or reestablishment of habitat corridors that link all occupied portions of the range. While there are no identified core populations in the northern range, the Habitat Protection and Population Interchange recovery actions (USFWS 1998) include:

> *Protect existing kit fox habitat in the northern, northeastern, and northwestern segments of their geographic range and existing connections between habitat in those areas and habitat farther south.*

Additional Ecology and Recovery Actions include determining habitat restoration and management prescriptions; determining the current geographic range of the species; monitoring populations; investigating use of farmlands; measuring movements between populations; determining the effects of rodent control; and evaluating the interactions between kit foxes and other canids.

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APPENDIX A13. RIPARIAN WOODRAT (*NEOTOMA FUSCIPES RIPARIA*)

A13.1 LEGAL STATUS

The riparian woodrat (*Neotoma fuscipes riparia*) is a federally listed species and a state species of special concern (Williams 1986). It was listed pursuant to the federal Endangered Species Act as endangered on February 23, 2000 (65 FR 8881). Critical habitat has not been designated for this species.

A13.2 SPECIES DISTRIBUTION AND STATUS

A13.2.1 Range and Status

The riparian woodrat is 1 of 11 recognized subspecies of the dusky-footed woodrat (*Neotoma fuscipes*). The species range extends from the Columbia River and the Willamette Valley in Oregon to northwestern Baja California. It is generally found in dense chaparral, oak and riparian woodland, and mixed coniferous forest that has a well-developed understory. Generally preferring fairly moist habitats, *N. fuscipes* is also found in drier communities, such as pinyon-juniper woodland, and favors brushy habitat or woodland that has an oak component (USFWS 1998).

The riparian woodrat has a limited distribution associated primarily with valley oak (*Quercus lobata*)-dominated riparian habitats of the Central Valley (Figure A-13a). Historical records indicate the subspecies was distributed along the San Joaquin, Stanislaus, and Tuolumne rivers, and possibly Corral Hollow, in San Joaquin, Stanislaus, and Merced counties, although Hooper (1938) thought the distribution could have extended south to northern Fresno County. The current distribution is highly restricted and is limited to riparian habitats along the lower portions of the San Joaquin and Stanislaus rivers in northern San Joaquin County. Riparian woodrat is found in a 100-hectare (247-acre) patch of riparian forest on the Stanislaus River in Caswell Memorial State Park (Williams 1986), and in San Joaquin River National Wildlife Refuge (P. Kelly pers. comm.). Williams (1993) estimated the population at Caswell State Park at 437 individuals. Since confirming their presence at San Joaquin River National Wildlife Refuge in 2003, more than 30 individual riparian woodrats have been captured at this location (P. Kelly pers. comm.).

Figure A-13a. Riparian Woodrat Statewide Range and Recorded Occurrences

1

A13.2.2 Distribution and Status in the Plan Area

There are no current records of riparian woodrat occurrences in the Plan Area. However, while occupancy has not been verified, the recorded occurrences northeast of Vernalis along the San Joaquin River, which is near the extreme southeastern tip of the Plan Area, are considered extant by CNDDB (2008) (Figure A-13b). The Caswell Memorial State Park population along the Stanislaus River is approximately 2 miles east of the Plan Area. The population of riparian woodrats at San Joaquin River National Wildlife Refuge is directly adjacent the Plan Area.

Small patches of potentially occupied valley oak riparian forest occur along the San Joaquin River from the southern tip of the Plan Area north to approximately the Interstate 5 overcrossing near Lathrop. Sufficiently large patches of oak-dominated riparian forest are lacking elsewhere in the Plan Area. A survey effort coordinated by DWR is currently ongoing to determine the presence or absence of the species in the Plan Area.

A13.3 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

The riparian woodrat occurs in riparian woodland with an overstory canopy of trees and a moderate-to-dense shrub understory with abundant dead branches and downed woody material (Williams 1986). Riparian woodrats are found primarily where there is a valley oak overstory and are most numerous in areas of dense shrub cover. While they will also occur in riparian habitats with other dominant overstory species, such as Oregon ash (*Fraxinus latifolia*), box elder (*Acer negundo*), and Hinds' walnut (*Juglans hindsii*) (Patrick Kelly pers. comm.), highest densities of woodrats and their houses have been found in willow thickets with an oak overstory (USFWS 1998).

The riparian woodrat typically lives in colonies of conical stick houses constructed with sticks, bark, plant cuttings, and other objects (Collins 1998), which range in size from 60 to 150 centimeters (cm) (24 to 59 inches) in height, and can be 120 to 240 cm (47 to 94 inches) in basal diameter. Williams (1993) reports similar house construction for riparian woodrat; however, unlike other subspecies that may construct arboreal houses, riparian woodrat houses appear to be mainly terrestrial. Houses typically are placed on the ground against or straddling a log or exposed roots of a standing tree and are often located in dense brush. With their general dependence on terrestrial stick houses, riparian woodrats may be vulnerable to flooding. While the woodrat itself can be arboreal and can escape flooding, its terrestrial houses, which are essential for survival, can be affected by flooding and thus potentially affect population viability (USFWS 1998).

DRAFT

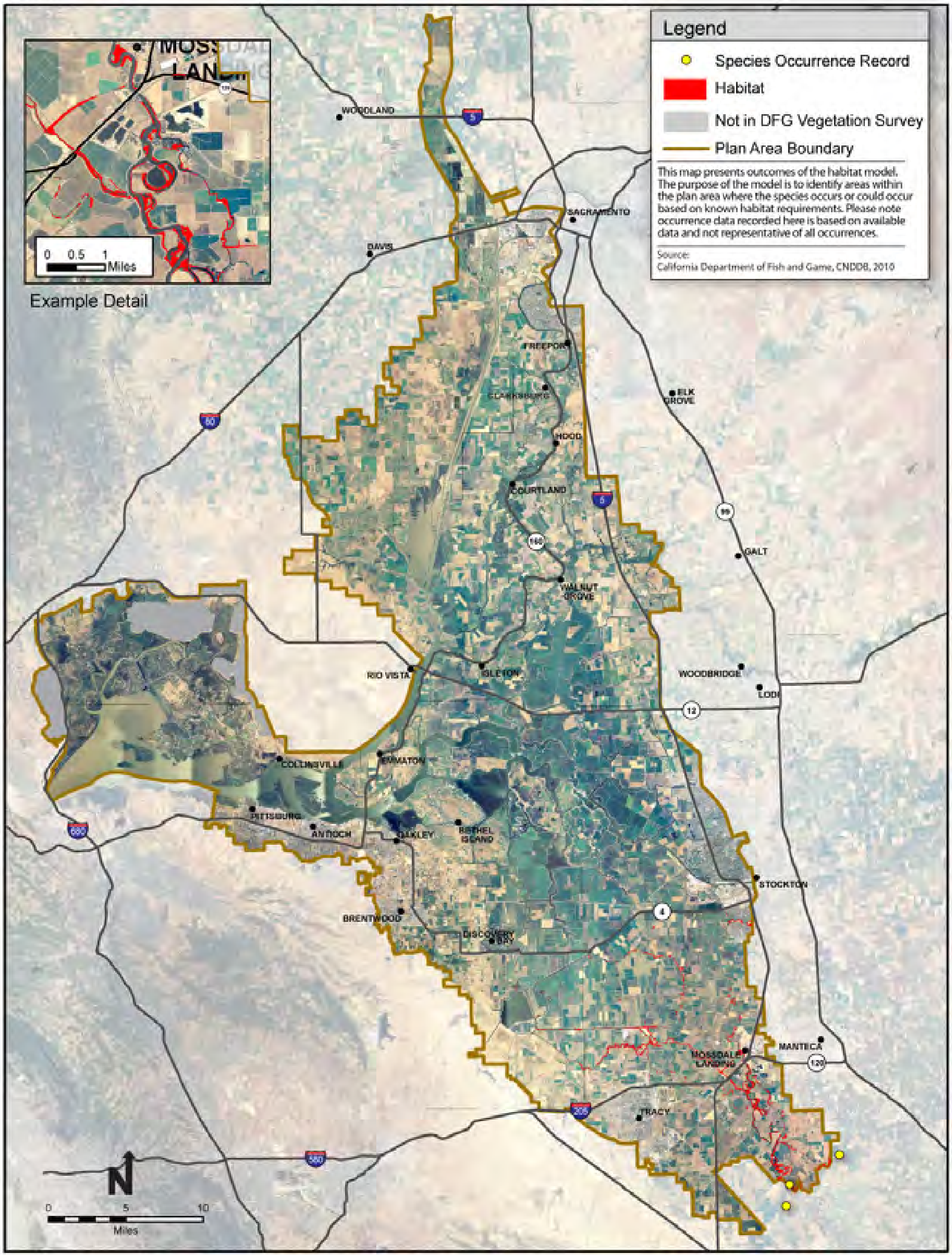

Figure A-13b. Riparian Woodrat Habitat Model and Recorded Occurrences

A13.4 LIFE HISTORY

Description. The riparian woodrat is a medium-sized rodent, with total length ranging from 434 to 452 millimeters (mm) (17.1 to 17.8 inches), tail length ranging from 207 to 217 mm (8.2 to 8.5 inches), and average weight of 243 grams (8.57 oz) in females and 266 grams (9.38 oz) in males (Hooper 1938). It is distinguished from other subspecies of woodrats by its larger size, more grayish color, white hind feet, and a more bicolored tail, which is lighter below contrasting with the darker dorsal color. The riparian woodrat's tail is well-furred and not scaled.

Activity and Social Structure. Riparian woodrats are primarily nocturnal, with peak activity at dawn and dusk. While riparian woodrat houses are generally constructed on the ground, woodrats may be found on the ground or in the foliage of trees and shrubs (Linsdale and Tevis 1951).

There is little information on the social structure of riparian woodrats. Assuming their activity and social structure is similar to *N. fuscipes*, they probably live in loosely cooperative societies and have a matrilineal (mother-offspring associations; through the maternal line) social structure that results in populations that are female-biased and in which adjacent females are closely related (Kelly 1990, *in litt*.). Females remain at their natal site throughout their lives. Males disperse away from their birth den and are highly territorial and aggressive, especially during the breeding season. Males mate with more than one female in a single breeding season; this is known as a polygynous mating system. The effective population size (i.e., successful breeders) is generally much smaller than the actual population size. This breeding system, in combination with the small size of the only known extant population, means that the riparian woodrat is at an increased risk of extinction because of inbreeding depression. Small, isolated populations are more susceptible to genetic, demographic, and environmental stochasticity than large, widely distributed populations (USFWS 1998).

Reproduction. There is also little information available on reproduction and dispersal of riparian woodrat. Again, assuming it is similar to *N. fuscipes*, the subspecies likely breeds from December to September, with the majority of litters born in mid-spring (Carraway and Verts 1991, *in litt.*). Following a gestation period of 28 to 33 days (Carraway and Verts 1991, *in litt.*), females give birth to one annual litter (Vestal 1938, *in litt.*). Litter size averages 2.6 young per litter, but ranges from 1 to 4 (Carraway and Verts 1991, *in litt.*). Juveniles rarely disperse more than 50 feet to establish home ranges in or adjacent to the maternal range (Linsdale and Tevis 1951, Collins 1998).

Diet. Woodrats as a group are generalist herbivores, consuming a wide variety of nuts and fruits, fungi, foliage, and some forbs (Linsdale and Tevis 1951). Riparian woodrat may be considered to be more specialized feeders, but there are no available studies on riparian woodrat diet.

A13.5 THREATS AND STRESSORS

Loss of Genetic Variability. Because there is only one known extant population of riparian woodrat of limited size and occupancy, it is at increased risk of harm or extinction because of genetic, demographic, and naturally occurring catastrophic events (e.g., drought, flooding, fire), that threaten small, isolated populations. In addition, because of its breeding behavior, the effective size of woodrat populations is generally much smaller than the actual population size, which increases the risk of inbreeding depression.

Habitat Loss and Fragmentation. There has been a nearly 90 percent reduction of historical riparian communities throughout the riparian forests along major streams flowing onto the floor of the northern San Joaquin Valley (Katibah 1983). The extent to which this reduction of available habitat has affected populations of riparian woodrat is unknown. However, loss and fragmentation of habitat are considered the principal reasons for the decline of this subspecies. Much of this loss was the result of conversion to agricultural land uses and the construction of large dams and canals, which diverted water for the irrigation of crops and permanently altered the hydrology of valley streams. Historically, cattle also probably impacted riparian woodrat populations since the thick undergrowth, which is particularly important to woodrats, is sensitive to trampling, browsing, and grazing by livestock (USFWS 1998).

Flooding and Fire. The increase of habitat conversion to agriculture, combined with construction of dams, has altered the timing, frequency, duration, and intensity of flooding. Although woodrats can easily climb trees and avoid drowning, their nests, which are essential to survival, can be destroyed (USFWS 1998). Wildfires are also of great concern because of habitat degradation and loss of individuals unable to avoid the fire. A catastrophic fire at Caswell Memorial State Park could potentially eliminate the only known occupied site for this species.

Other Threats. Other threats that could potentially affect the remaining occupied site for this subspecies include disease, predation, the use of rodenticides, and trampling by grazing animals.

A13.6 RELEVANT CONSERVATION EFFORTS

Although the only known population has some protection by residing in Caswell Memorial State Park, there are currently no conservation efforts under way specifically to benefit the riparian woodrat. The California Department of Parks and Recreation, however, has supported some general small-mammal studies and studies on the woodrat population at the park (Cook 1992, Williams 1993) and has developed a fire management plan to protect habitat within it.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-species Conservation Strategy designates the riparian woodrat as a "Contribute to Recovery" species (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its

control and within its scope that are necessary to contribute to the recovery of the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

The riparian woodrat is a covered species in the San Joaquin County Multi-species Habitat Conservation and Open Space Plan, which prohibits removal or disturbance of occupied riparian habitat that could potentially affect the subspecies as a result of the implementation of covered activities.

A13.7 Species Habitat Suitability Model

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which are incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and revise the vegetation input data as necessary.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements, and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate, as well as overestimate, the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small, isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; instead, the models indicate that non-habitat areas have a much lower probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf (2007). Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers; connectivity between habitat types; and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified, and each vegetation type or association is identified, along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or underestimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The riparian woodrat model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), USDA 2005 aerial photography, and DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable riparian woodrat habitat in the Plan Area. Vegetation types were assigned based on the species requirements, as described above, and the assumptions described below.

Habitat. Potentially occupied riparian woodrat habitat consists of the following valley riparian types from the BDCP composite vegetation layer in Conservation Zone 7:

- Valley oak – *Quercus lobata;*
- *Quercus lobata – Salix exigua-Rubus discolor;*
- *Salix gooddingii – Quercus lobata*/wetland herbs;
- *Salix gooddingii – Populus fremontii* (*Quercus lobata-Salix exigua-Rubus discolor*);
- *Quercus lobata/Rosa californiaca* (*Rubus discolor – Salix lasiolepis/Carex* spp.);
- *Quercus lobata – Acer negundo;*
- *Quercus lobata – Alnus rhombifolia (Salix lasiolepis – Populus fremontii – Quercus agrifolia*);
- *Quercus lobata – Fraxinus latifolia;*
- Box elder (*Acer negundo*);
- *Acer negundo – salix goodingii*);
- *Alnus rhombifolia/Cornus sericea;*
- *Alnus rhombifolia/Salix exigua (Rosa californica*);

- Black willow (*Salix gooddingii*) – Valley oak (*Quercus lobata*) restoration);
- Fremont cottonwood (*Populus fremontii*);
- Hinds' walnut (*Juglans hindsii*);
- Oregon ash (*Fraxinus latifolia*);
- Valley oak (*Quercus lobata*) restoration;
- White alder (*Alnus rhombifolia*); and
- White alder (*Alnus rhombifolia*) – Arroyo willow (*Salix lasiolepis*) restoration.

Some areas supporting the above vegetation types were excluded from the final model, based on landscape-scale selection criteria. In particular, riparian areas along smaller drainages (Paradise Cut, Tom Paine Slough) and some of the larger streams in the northern section of Conservation Zone 7 were excluded from the riparian woodrat habitat model due to a lack of trees and/or the narrow width of the riparian corridor. The final riparian woodrat habitat model is found south of State Route 4 and Old River Pipeline along the Stanislaus, San Joaquin, Old, and Middle rivers.

Assumptions. The riparian woodrat occurs in riparian woodland with an overstory canopy of trees and a moderate-to-dense shrub understory with abundant dead branches and downed woody material (Williams 1986). Riparian woodrats are found primarily where there is a valley oak overstory, but will also occur with other overstory species and are most numerous in areas of dense shrub cover. In riparian areas, highest densities of woodrats and their houses have been found in willow thickets with a valley oak overstory (USFWS 1998).

The current distribution is highly restricted and is limited to valley oak riparian habitats along the lower portions of the San Joaquin and Stanislaus rivers in northern San Joaquin County. A 100-hectare (247-acre) patch of riparian forest on the Stanislaus River in Caswell Memorial State Park is the only verified extant population of the riparian woodrat (Williams 1986). There are insufficient data on patch size or riparian width requirements for this species; however, the species has only been reported to occur in large, intact riparian patches associated with larger watercourses. While it may greatly overestimate the extent of potentially occupied habitat for this species – but to avoid including small, narrow patches of riparian along smaller streams in the Plan Area – for purposes of this model, it is assumed that all mapped instances of the riparian categories listed above that occur south of State Route 4 and Old River Pipeline along the Stanislaus, San Joaquin, Old, and Middle rivers are potentially occupied. It is also assumed that the species is absent north of north of State Route 4 and Old River Pipeline even where suitable habitat occurs. While somewhat arbitrary, for purposes of this model, this boundary is considered to represent the northern extent of all potentially-occupied habitat within the Plan Area based on the known distribution of the species and results of recent surveys in the Plan

Area. While survey access was not permitted within some portions of this area, it may also greatly overestimate the extent of potentially occupied habitat for this species.

A13.8 Recovery Goals

A recovery strategy for the riparian woodrat is included in the Recovery Plan for the Upland Species of the San Joaquin Valley, California (USFWS 1998). The recovery plan has not been updated since the 2000 listing of the riparian woodrat.

The recovery plan establishes an overall goal of three or more areas of occupied habitat, each supporting 400 or more individuals, with a total population of 5,000 or more independent individuals (i.e., excluding dependent young) during average precipitation years. The following initial conservation actions are included in the recovery plan to help achieve these goals.

1. Survey and map all riparian areas along the San Joaquin River and its major tributaries; this is the highest priority of the proposed conservation actions. A cost-effective survey can be carried out through a combination of aerial photo interpretation, selective truthing of photos on the ground, and judicious trapping where permission is required and given.
2. Develop an incentive program for preserving cover and riparian vegetation in collaboration with owners of riparian land and local levee-maintenance districts.
3. Develop a plan for the restoration of riparian habitat; the establishment of riparian corridors; and the reintroduction, if necessary, of riparian woodrats to suitable habitat.
4. Initiate a genetic study of the Caswell Memorial State Park woodrats, and any other riparian woodrat populations that can be sampled, to determine inbreeding levels, and devise a procedure for ensuring that translocations neither reduce genetic diversity in the parent population nor unduly restrict it in the translocated population.
5. Establish conservation agreements with willing landowners that do not already have conservation easements, as appropriate and necessary, to accomplish habitat restoration, linkage, and reintroduction goals.
6. Begin efforts to restore and link riparian habitat, and reintroduce woodrats, as appropriate.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan’s Multi-Species Conservation Strategy designates the riparian woodrat as a “Contribute to Recovery” species (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its control and within its scope that are necessary to contribute to the recovery of the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

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65 FR 8881. 2000. Final Rule: Endangered and threatened wildlife and plants; Final Rule to List the Riparian Brush Rabbit and the Riparian, or San Joaquin Valley, Woodrat as Endangered. Federal Register 65: 8881.

A13.9.3 Personal Communications

Kelly, Patrick. California State University Stanislaus, Professor of Zoology and Coordinator of Endangered Species Recovery Program. Comments from email made 9/17/10 and during a presentation at SAIC on 10/5/10.

APPENDIX A14. SALT MARSH HARVEST MOUSE (*REITHRODONTOMYS RAVIVENTRIS*)

A14.1 LEGAL STATUS

The U.S. Fish and Wildlife Service listed the salt marsh harvest mouse *(Reithrodontomys raviventris)* as endangered in 1970 (35 FR 16047). The State of California listed the mouse as endangered in 1971 (Fish and Game Code, Sections 2050 et seq.). The salt marsh harvest mouse is also designated as a state Fully Protected species. A recovery plan for the species was prepared in 1984 and is currently under revision. Critical habitat has not been designated for this species.

A14.2 SPECIES DISTRIBUTION AND STATUS

A14.2.1 Range and Status

The salt marsh harvest mouse is a small, native rodent endemic to the salt marshes of San Francisco, San Pablo, and Suisun Bays (Figure A-14a). The historical range of the species likely included most of the marshland in the San Francisco Bay Area. Closely associated with saline habitats, the species' eastern distribution is generally considered to extend as far as approximately Collinsville. The waters of wetlands and marshes east of this point are currently considered too fresh to support the habitat of this species (USFWS 2001).

The species has been divided into two subspecies. The southern subspecies *(R.r. raviventris)* occurs in the marshes of Corte Madera, Richmond, and South San Francisco Bay. The northern subspecies *(R.r. halicoetes)* is found in the marshes of San Pablo and Suisun bays, from San Rafael Bridge to approximately Collinsville on the north and from Martinez to Pittsburg on the south (USFWS 2001).

Today, the species potentially occupies an area representing approximately 15 percent of the historical salt marsh habitat that formerly occurred in the San Francisco Bay Area (Dedrick 1989). Much of this remaining habitat, isolated by dikes and landfill, is subject to backfilling, subsidence, and vegetation changes, making it unable to support harvest mice (Shellhammer 1989). Thus, remaining populations are small and separated by large areas of unsuitable habitat.

A14.2.2 Distribution and Status in the Plan Area

Reported occurrences of the salt marsh harvest mouse in the Plan Area are restricted to salt and brackish diked and tidal wetlands and adjacent uplands from Suisun Marsh eastward along the northern edge of the Sacramento River and the southern edge of the San Joaquin River as far east as the vicinity of Collinsville and Antioch, west of Sherman Island (Figure A-14b).

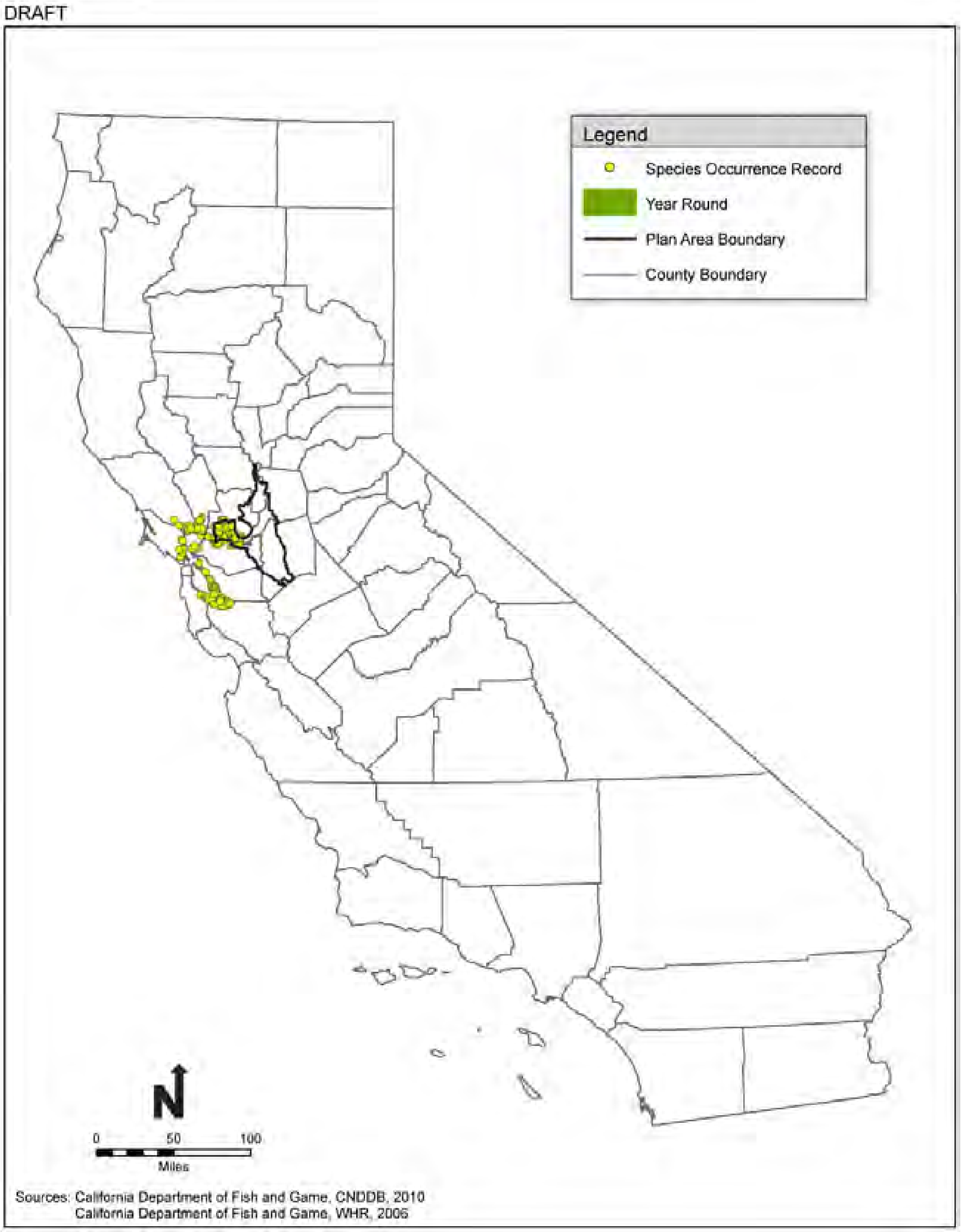

Figure A-14a. Salt Marsh Harvest Mouse Statewide Range and Recorded Occurrences

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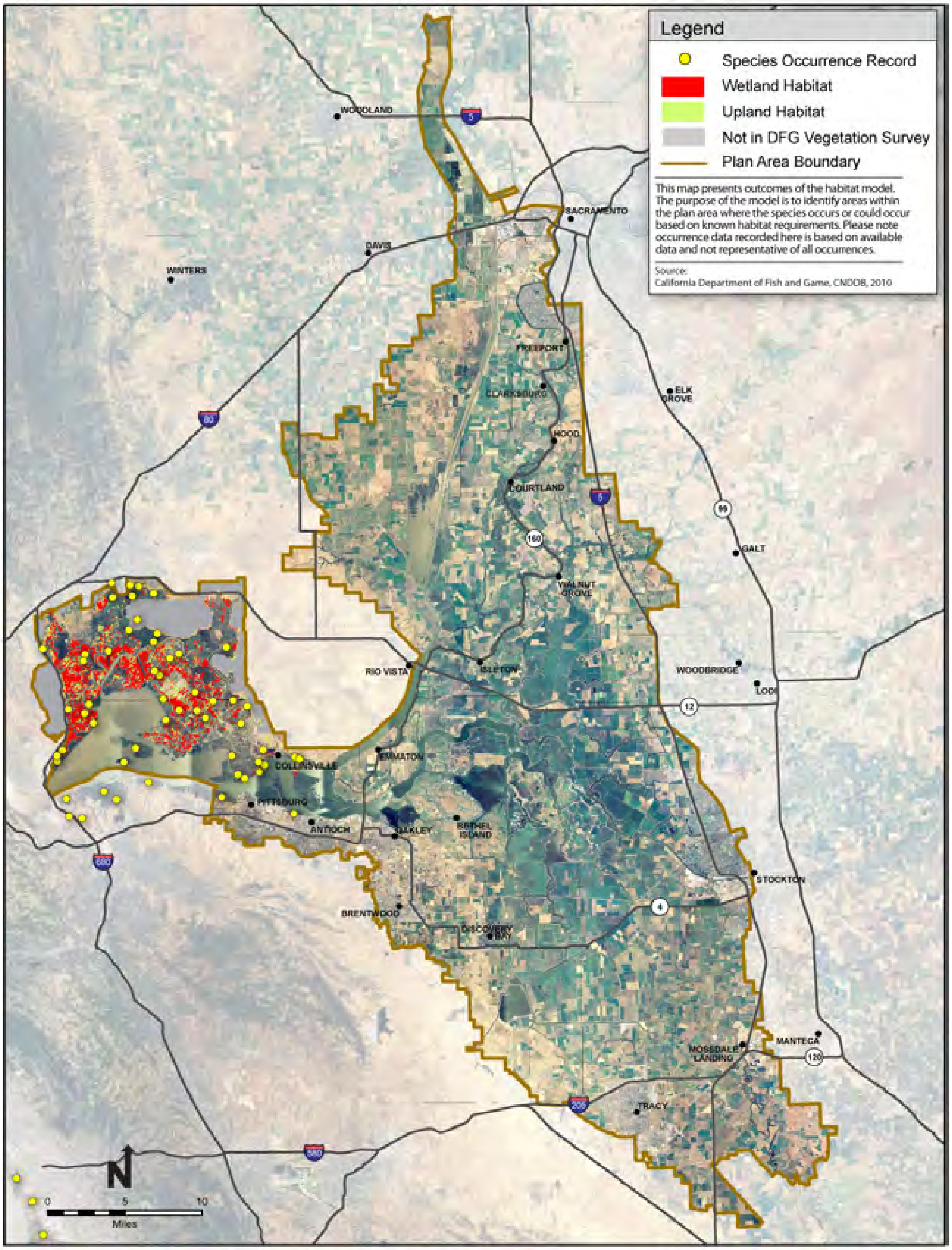

Figure A-14b. Salt Marsh Harvest Mouse Habitat Model and Recorded Occurrences

This is consistent with the range of the species as described by USFWS (2001).

A14.3 Habitat Requirements and Special Conditions

Salt marsh harvest mice depend on dense cover of native halophytes (salt-tolerant plants). Pickleweed (*Sarcocornia pacifica*, formerly *Salicornia virginica*) is the species' primary habitat (Shellhammer 1977). Deep (60–75 centimeters) and dense pickleweed, intermixed with fat hen *(Atriplex patula)* and alkali heath *(Frankenia grandifolia)*, is preferred. Salt marsh harvest mice are rarely found in alkali bulrush *(Schoenoplectus maritimus*[1]*)*, pure stands of salt grass *(Disticlis spicata)*, or cordgrass (*Spartina* spp.) (Shellhammer et al. 1982), which can displace pickleweed. However, more-recent research has documented the species in dense stands of three-square bulrush *(Schoenoplectus americanus)* in densities similar to that found in pickleweed (Patterson pers. comm.). Non-submerged escape cover is also required during high tides (Shellhammer et al. 1982). Fisler (1965) reported that populations can be concentrated on high marsh levels during periods of high tides. They have also been found in the top zone of tidal marshes and in transitional zones, which rarely flood (Shellhammer 1989). They will also move into adjacent grasslands during high tides. Fisler (1965) and Shellhammer et al. (1982) reported that the species will occupy adjoining grasslands during the highest winter tides and will occasionally use grasslands during spring and summer, when new growth affords sufficient cover. WESCO (1991) also reported use of nontidal uplands up to 150 feet from the wetland edge.

Within the Suisun Marsh, salt marsh harvest mice apparently respond well to carefully managed diked wetlands and have been reported in densities equal to that found in tidal wetlands (Patterson pers. comm.).

Salt marsh harvest mice have shown an ability to disperse considerable distances (Geissel et al. 1988); however, they apparently do not move through unvegetated areas, and thus, fragmentation of salt marsh habitats has limited salt marsh harvest mouse dispersal opportunities. A corridor of suitable vegetation is required for movement and dispersal into adjacent habitats.

A14.4 Life History

Description. The salt marsh harvest mouse is buff or brownish in color and has a long bicolored tail, large ears, and grooves in the outer surface of its upper incisors. The underside is variable, ranging from white to a cinnamon- or rufous-colored belly. Adult salt marsh harvest mice are 118 to 175 millimeters (mm) in length and weigh between 0.28 and 0.42 ounces (8 and 12 grams).

[1] Formerly known as *Scirpus maritimus*.

Activity. The maximum life expectancy for salt marsh harvest mice is generally considered to be approximately 1 year; however, California Department of Water Resources (DWR) data indicate that the life expectancy can be longer (Patterson pers. comm.). A generally solitary animal outside of the breeding season, this species typically remains beneath the canopy of dense low-lying vegetation and will sometimes use the ground runways of other rodents. Active year-round and primarily at night, this species responds to tidal action and can escape tidal or seasonal flooding by swimming or climbing, and will move into adjoining grasslands during the highest winter tides. Grasslands are otherwise used as habitat primarily when new grass growth affords suitable cover in spring and summer months. These movements probably occur only on a daily basis and do not represent a seasonal shift in habitat use. Young are able to disperse considerable distances, but can be restricted with fragmentation of suitable marsh habitats (Fisler 1965, Shellhammer et al. 1982 in LSA Associates 2007).

Reproduction. Salt marsh harvest mice breed from spring through autumn, with females reproductively active from March to November. The breeding season for *R. r. raviventris* usually begins in March, while the breeding for *R. r. halicoetes* begins approximately 2 months later, in May (Fisler 1965). Adults typically construct an aboveground nest of grasses and sedges about 150 to 175 mm (6 to 7 inches) in diameter. They sometimes construct the nest on top of bird nests and have been reported to use the nests of song sparrows. Females have a relatively low reproductive potential, bearing an average of four young per litter, following a gestation period of 21 to 24 days. Also, while *R. r. raviventris* often produces two litters per year, *R. r. halicoetes* usually produces only one due to the shorter breeding season (Fisler 1965). Adults make up the majority of the population.

Reproduction can also be suppressed by increasing populations of California meadow voles *(Microtus californicus)*, which respond to decreasing salinities and vegetation cover. In years when *Microtus* populations are high, breeding for salt marsh harvest mice is suppressed further into the spring. If *Microtus* populations are high enough in a given area, populations of harvest mice can be reduced to the point of local extirpation. However, when water salinities and vegetation cover increase, harvest mice have a competitive edge due to their ability to withstand higher salinities in the water and food, and populations can recover (Geissel et al. 1988).

Diet. The diet of the salt marsh harvest mouse consists of seeds, grasses, forbs, and insects. During winter, fresh green grasses are preferred. During the rest of the year, the stems and leaves of pickleweed and saltgrass are main food sources (Fisler 1965). As noted, salt marsh harvest mice can tolerate high salinities in both food and drink intake, which can give them a competitive advantage over *Microtus* when the salinity of the marsh increases (Geissel et al. 1988).

A14.5 THREATS AND STRESSORS

Loss and degradation of tidal marsh habitats continue to be the most significant threat to the salt marsh harvest mouse and other tidal marsh species. Tidal marshes have been reduced by 84 percent since historical times (Dedrick 1989). The loss and fragmentation of suitable habitats from commercial and residential development have isolated populations and reduced dispersal opportunities. The loss of tidal marsh habitat through filling and diking has largely been curtailed. However, other current factors associated with declining populations include the conversion of salt marshes to brackish marshes due to freshwater discharges from sewage treatment plants; introduction of nonnative cordgrass, saltgrass, and other plant species; predation by nonnative red foxes and feral cats; and invasion of runoff, industrial discharges, and sewage effluent (Shellhammer et al. 1982, DFG 2000, LSA Associates 2007). Probably the most significant long-term issue is the predicted sea level rise as high as 1.2 meters within this century.

A14.6 Relevant Conservation Efforts

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designates the salt marsh harvest mouse as a "Contribute to Recovery" species (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its control and within its scope that are necessary to contribute to the recovery of the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

The Suisun Marsh has been the subject of various conservation efforts for many years, particularly with respect to issues related to development and water quality within its boundaries. The California Department of Water Resources Suisun Marsh Program (http://www.iep.water.ca.gov/suisun/program/index.html) summarizes the major agreements, management plans, and legislation that have directed management of the Suisun Marsh since the mid-1970s. These efforts focus on the preservation and restoration of tidal marsh habitats.

The Nejedly-Bagley-Z'Berg Suisun Marsh Preservation Act (1974). The California Legislature enacted the Suisun Marsh Preservation Act to protect the marsh from urban development. It required the San Francisco Bay Conservation and Development Commission to develop a plan for the marsh and provides for various restrictions on development within marsh boundaries.

Suisun Marsh Protection Plan (1976). This plan was developed by the Bay Conservation and Development Commission (BCDC) and defines and limits development within primary and secondary management areas for the "future of the wildlife values of the area as threatened by potential residential, commercial and industrial development." It recommends that the state purchase 1,800 acres and maintain water quality. While the focus of the plan is on maintaining waterfowl habitat, it also addresses the importance of tidal wetlands and recommends restoring historical marsh areas to wetland status (managed or tidal).

The Suisun Marsh Protection Act (1977). This bill adopts and calls for implementation of the Suisun Marsh Protection Plan. AB 1717 designates the BCDC as the state agency with regulatory jurisdiction of the marsh and calls for the Suisun Resource Conservation District to have responsibility for water management in the marsh. The bill identifies (and focuses on) actions for the preservation of waterfowl needs, along with the retention of the diversity of wildlife. It states that land within the Suisun Marsh should be acquired for public use or resource management if it is suitable for restoration to tidal or managed marsh, but that such restoration cannot be required as a condition of private development.

State Water Resources Control Board (SWRCB) Water Rights Decision 1485 (1978). SWRCB adopted the Water Quality Control Plan for the Sacramento-San Joaquin Delta and issued Water Rights Decision 1485. The decision sets channel water salinity standards for the period from October to May and preserves the area as brackish water tidal marsh. It sets water quality standards in the marsh as a condition of export pumping. These come from the California Department of Fish and Game's (DFG's) recommendations, which were based on (1) the relative value of marsh plants as duck food; (2) the influence of soil salinity and other factors on distribution and growth of marsh plants; and (3) the relationships between channel water salinity and soil salinity. DFG concluded that improved management practices, improved drainage, water control facilities, and adequate quality of water were needed to achieve desired soil salinity conditions for waterfowl food plants.

Plan of Protection for the Suisun Marsh (1984). DWR and the U.S. Bureau of Reclamation (USBR) developed and began implementing the Plan of Protection (POP) in accordance with Water Rights Decision 1485. The POP implementation strategy was to construct large facilities and distribution systems to meet salinity standards (lower channel water salinity), in lieu of significant Central Valley Project/State Water Project storage releases estimated as high as 2 million acre-feet in dry/critical water years. The six-phase POP was the programmatic blue print (required by the SWRCB and embodied in the original Suisun Marsh Preservation Agreement). Two of the six phases were completed, including the Initial Facilities and the Suisun Marsh Salinity Control Gates.

Suisun Marsh Preservation Agreement (1987). This contractual agreement between DWR, USBR, DFG, and Suisun Resource Conservation District contains provisions for DWR and USBR to mitigate the effects on Suisun Marsh channel water salinity from the State Water Project and Central Valley Project operations and other upstream diversions. The Suisun Marsh Preservation Agreement requires DWR and USBR to meet salinity standards, sets a timeline for implementing the POP, and delineates monitoring and mitigation requirements. The Suisun Marsh Monitoring Agreement and the Suisun Marsh Mitigation Agreement were also signed at this time. The Suisun Marsh Mitigation Agreement defines habitat requirements to mitigate effects of facilities and operations, and the Suisun Marsh Monitoring Agreement defines requirements for monitoring salinity and species in the Suisun Marsh.

Bay-Delta Accord (1994). On December 15, 1994, federal and state agencies, working with agricultural, environmental, and urban stakeholders, reached an agreement on water quality standards and related provisions that would remain in effect for 3 years. This agreement, known as the Bay-Delta Accord, was based on a proposal developed by the stakeholders. Elements of the agreement include the following:

- Springtime export limits expressed as a percentage of Delta inflow;
- Regulation of the salinity gradient in the estuary so that a salt concentration of two parts per thousand is positioned where it may be more beneficial to aquatic life;
- Specified springtime flows on the lower San Joaquin River to benefit Chinook salmon; and
- Intermittent closure of the Delta Cross Channel gates to reduce entrainment of fish into the Delta.

SWRCB Water Quality Control Plan (1995–1998). In 1994, wildlife and fishery agencies and urban water users expressed concerns about the appropriateness of western Suisun Marsh channel water salinity standards. In May of 1995, the SWRCB modified the Suisun Marsh salinity objectives in the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Modeling analysis by the Suisun Marsh Planning Program showed that Suisun Marsh standards would be met most of the time at all Suisun Marsh compliance stations. Some standard exceedances would be expected in the western Suisun Marsh that participants in the Suisun Marsh Preservation Agreement (SMPA) agreed could be mitigated by more-active water control by landowners.

SWRCB Water Rights Decision 1641 (1999). The SWRCB issued Decision 1641 in December 1999, which updated salinity standards for Suisun Marsh. Increased outflow and salinity requirements for the Bay-Delta provided indirect benefits to the Suisun Marsh. DWR proposed that the SWRCB adopt the Amendment Three actions for Suisun Marsh in this decision. However, the SWRCB was unable to adopt Amendment Three actions because the Section 7 consultation with the USFWS had not concluded. However, the SWRCB did relieve USBR and DWR of their responsibility to meet salinity objectives at S-35 and S-97 in the western Suisun Marsh.

CALFED Multi-species Conservation Strategy and Record of Decision (2000). In August 2000, the Programmatic Record of Decision for the CALFED Bay-Delta Program was signed by 13 federal and state agencies with management and regulatory responsibilities in the San Francisco Bay estuary. Based on the analysis in the MSCS and the final programmatic environmental impact statement/environmental impact report, the CALFED agencies fulfilled the regulatory requirement for programmatic evaluation of the CALFED program.

Suisun Marsh Charter Implementation Plan (2001). The Suisun Marsh Charter was completed in 2001, and development of an Implementation Plan commenced. Charter participants collaborated on a joint presentation to the State of the Estuary Conference on the principles of the Charter Plan, including coordinated water quality, endangered species, and heritage value protection in the Suisun Marsh.

Habitat Management, Preservation, and Restoration Plan (2003). The Charter process was expanded to include additional federal and state agencies to develop a Suisun Marsh Plan that will balance the goals and objectives of the Bay-Delta Program, SMPA, and other management and restoration programs within the Suisun Marsh in a manner that is responsive to the concerns of all stakeholders and is based upon voluntary participation by private landowners.

In addition, several facilities have been constructed in the Suisun Marsh to protect and improve water quality and protect and enhance wildlife habitat including:

- Roaring River Distribution System (1979–80);
- Morrow Island Distribution System (1979–80);
- Goodyear Slough Outfall (1979–80);
- Suisun Marsh Salinity Control Gates (1988); and
- Cygnus and Lower Joyce Facilities (1991).

Several tidal marsh restoration projects are also planned or being implemented within the range of the salt marsh harvest mouse. These projects, implemented through the direction or support of the San Francisco Bay National Wildlife Refuge, National Biological Service, East Bay Regional Park District, Regional Water Quality Control Board, California Department of Fish and Game, and the City of San Jose include the following:

- Restoration of the 1,500-acre Napa Marsh Unit in the Napa River in the north bay;
- Restoration of the Knapp Property, a 452-acre former salt pond in the Alviso area, on the edge of the bay, between Alviso and Guadalupe Sloughs.
- Enhancement of the 325-acre Oro Loma Marsh, an area of diked salt marsh and adjacent uplands located along the shore of Hayward. The area will be restored to tidal marsh and seasonal wetland habitat.
- Restoration of the Baumberg Tract, an 835-acre inactive salt evaporator in Hayward, to tidal marsh and seasonal wetlands.
- Restoration of the Moseley Tract, located just north of the west approach to the Dumbarton Bridge from the Port of Oakland.

Salt marsh harvest mouse is also proposed for coverage under the Solano County Multispecies Habitat Conservation Plan.

A14.7 SPECIES HABITAT SUITABILITY MODEL

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which are incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and revise the vegetation input data as necessary.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements, and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate, as well as overestimate, the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small, isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; instead, the models indicate that non-habitat areas have a much lower probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percentage cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf (2007). Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers, connectivity between habitat types, and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified, and each vegetation type or association is identified, along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or underestimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The salt marsh harvest mouse model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and

Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), U.S. Department of Agriculture (USDA) 2005 aerial photography, and DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable salt marsh harvest mouse habitat in the Plan Area. Vegetation types were assigned based on the species requirements, as described above, and the assumptions described below.

Habitat. Salt marsh harvest mouse habitat consists of *Salicornia*[2]-dominated natural seasonal wetlands, other non-flooded wetlands, and upland habitats within 150 feet of the wetland edge west of the western edge of Sherman Island.

Salt marsh harvest mouse habitat in the Delta consists of the following wetland types from the BDCP composite vegetation layer:

- Tidal brackish emergent wetland, managed wetland, and alkali seasonal wetland complex;
- *Distichlis spicata – Salicornia virginica*[3];
- Pickleweed *(Salicornia virginica)*;
- *Salicornia virginica – Cotula coronopifolia*;
- *Salicornia virginica – Distichlis spicata*; and
- Alkali heath *(Frankenia salina)*.

And the following grassland types that occur within 150 feet of the wetland edge:

- Grassland;
- Ruderal herbaceous grasses and forbs;
- California annual grasslands – herbaceous;
- *Bromus diandrus – Bromus hordeaceus*; and
- Degraded vernal pool complex.

And the following vernal pool complex types that occur within 150 feet of the wetland edge:

- Vernal pool complex;
- Ruderal herbaceous grasses and forbs; and
- California annual grasslands – herbaceous.

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[2] Currently known as *Sarcocornia*.

[3] Currently known as *Sarcocornia pacifica.*

Salt marsh harvest mouse habitat in the Suisun Marsh includes the following vegetation types from the BDCP composite vegetation layer:

- *Distichlis*/*Salicornia*;
- *Salicornia* (generic);
- *Salicornia virginica*;
- *Salicornia*/*Atriplex*;
- *Salicornia*/*Cotula*;
- *Salicornia*/annual grasses;
- *Salicornia*/*Crypsis*;
- *Salicornia*/*Polygonum-Xanthium-Echinochloa*; and
- *Salicornia*/*Sesuvium*.

And the following upland types within 150 feet of the wetland edge:

- Annual grasses generic;
- Annual grasses/weeds;
- *Atriplex lentiformis* (generic);
- *Atriplex triangularis*;
- *Atriplex*/annual grasses;
- *Atriplex*/*Districhlis*;
- *Atriplex*/*S. Maritimus*;
- *Atriplex*/*Sesuvium*;
- *Baccharis*/annual grasses;
- *Bromus* spp./*Hordeum*;
- *Hordeum*/*Lolium*; and
- Perennial grass.

Assumptions. Historical and current records of this species indicate that its distribution extends eastward to approximately Collinsville and Antioch (Figure A-14a). This species is dependent on dense cover of native halophytes (salt-tolerant plants) and prefers pickleweed-dominated *(Sarcocornia pacifica* [formerly *Salicornia virginica*]) saline emergent wetlands and mixed-halophyte wetlands as its habitat (Shellhammer et al. 1982, Patterson pers. comm.). The species also uses adjacent upland habitats during periods of high tides (Fisler 1965, Shellhammer et al.

1982, WESCO 1991). For purposes of this model, all *Sarcocornia*- (formerly *Salicornia*)-dominated habitats along the western edge of Sherman Island westward are included within the potential range of the species. Some non-flooded mixed-halophyte wetlands and other vegetation associations where the species has been detected, including *Schoenoplectus americanus*, could not be sufficiently determined from the vegetation database, and thus the model may underestimate the extent of potentially occupied habitat in the Suisun Marsh. Suitability of habitat may also be dependent on other factors, such as patch size, tidal connectivity (diked marshes), and proximity to other land uses. However, data regarding the effects of these factors on potential occupancy for the salt marsh harvest mouse are insufficient. Thus, potential habitat for the salt marsh harvest mouse is not further restricted in this habitat model on the basis of these factors; in this respect, the model may overestimate potentially occupied habitat for the salt marsh harvest mouse.

A14.8 Recovery Goals

The Salt Marsh Harvest Mouse and California Clapper Rail Recovery Plan was finalized in 1984. It is considered outdated and is under revision by the USFWS. Both species will be covered under the Tidal Marsh Ecosystem Recovery Plan.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's MSCS designates the salt marsh harvest mouse as a "Contribute to Recovery" species (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its control and within its scope that are necessary to contribute to the recovery of the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

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A14.9.3 Personal Communications

Laura Patterson, Wildlife Biologist, California Department of Water Resources. Written comment on earlier draft.

APPENDIX A15. RIPARIAN BRUSH RABBIT (*SYLVILAGUS BACHMANI RIPARIUS*)

A15.1 LEGAL STATUS

The riparian brush rabbit (*Sylvilagus bachmani riparius*) is listed as endangered under the state and federal endangered species acts. It was initially listed as endangered by the State of California on May 29, 1994. The U.S. Fish and Wildlife Service (USFWS) proposed the species for endangered species protection on November 21, 1997, and reopened the proposal for further public input on April 13, 1998, to include survey data from the 1998 winter floods in its final determination on whether or not to list the species. The USFWS issued its final determination to list the species as endangered on February 23, 2000 (65 FR 8881).

Critical habitat has not been designated for this species because the USFWS believed it would not provide any additional benefit beyond that provided through being listed as endangered since the species was only known to occur within Caswell Memorial State Park (65 FR 8881). Subsequent rulings allow critical habitat to be designated post-listing following further analysis.

A15.2 SPECIES DISTRIBUTION AND STATUS

A15.2.1 Range and Status

One of eight species of brush rabbit in California, the riparian brush rabbit occupies a range that is disjunct from other brush rabbits, near sea level on the floor of the San Joaquin Valley (USFWS 1998). Documented occurrences are shown in Figure A-15a. Its historical distribution may have extended along portions of the San Joaquin River and its tributaries on the valley floor from at least Stanislaus County to the Delta (Orr 1935 in USFWS 1998). Populations are known to have historically occurred in riparian forests on the valley floor along the San Joaquin and Stanislaus rivers and some tributaries of the San Joaquin River (USFWS 1998). One population estimate within this historical range was about 110,000 individuals (USFWS 1998).

The dramatic decline of the riparian brush rabbit began in the 1940s with the building of dams constructed for irrigation and flood control on the major rivers of the Central Valley. Protection from flooding resulted in conversion of floodplains to croplands and the consequent reduction and fragmentation of remaining riparian communities. By the mid-1980s, the riparian forest within the species' former range had been reduced to a few small and widely scattered fragments totaling about 5,189 acres (2100 hectares) (USFWS 1998).

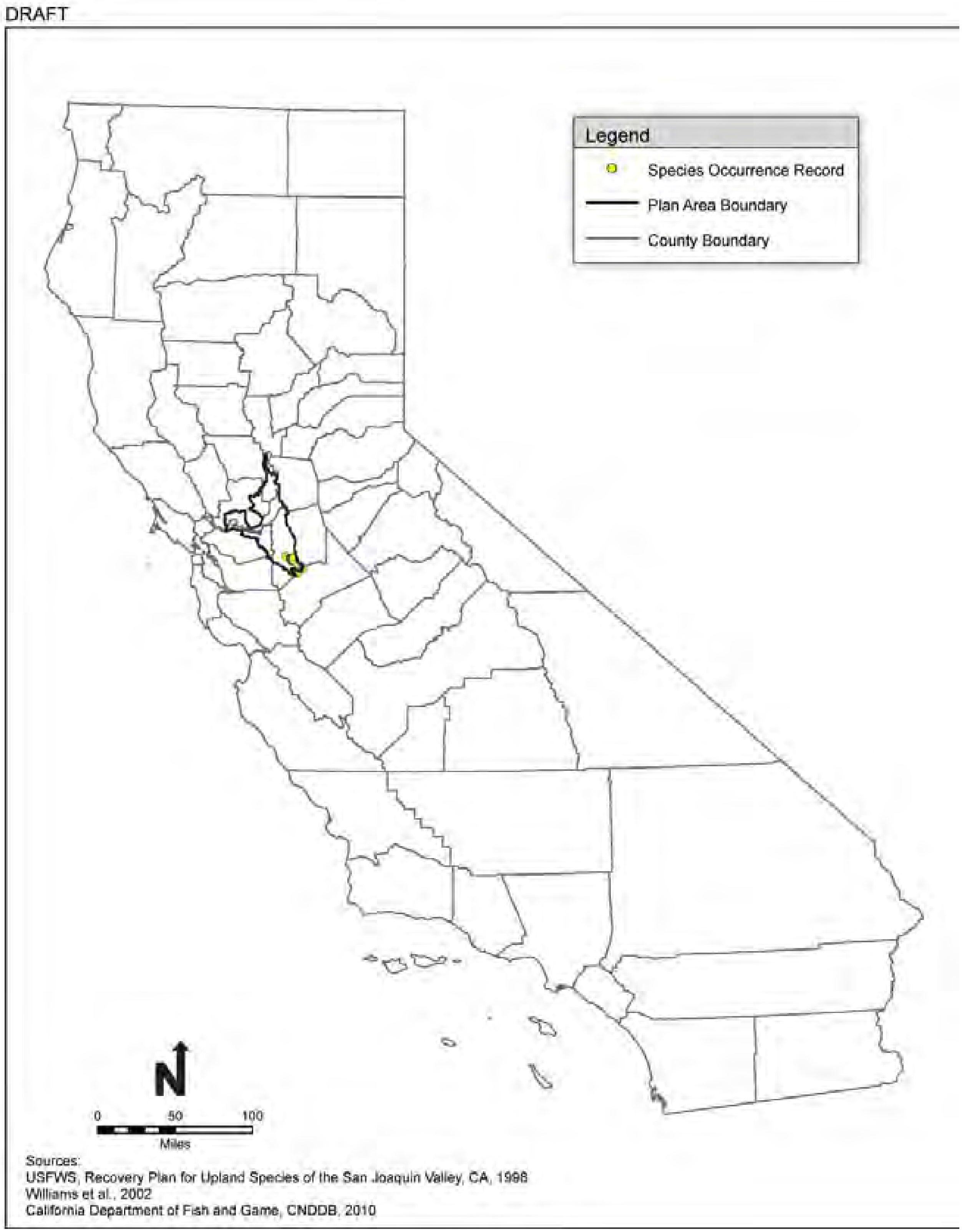

Figure A-15a. Riparian Brush Rabbit Statewide Range and Recorded Occurrences

Within this area, remaining populations of riparian brush rabbits occur in only two areas of San Joaquin County: an approximately 258-acre (104-hectare) patch in Caswell Memorial State Park on the Stanislaus River immediately southeast of the Plan Area; and in several small, isolated or semi-isolated patches totaling approximately 270 acres (109 hectares) along Paradise Cut and Tom Paine Slough and channels of the San Joaquin River in the south Delta within the Plan Area (Williams et al. 2002a, Williams et al. 2008).

While the Caswell Memorial State Park population has been known and considered to be the last occupied location for riparian brush rabbit for many years, the latter location has been known only since 1998 (Williams et al. 2008). While recent surveys conducted by staff at the Endangered Species Recovery Program have not detected additional occurrences within the Plan Area, researchers have identified additional suitable habitat and some potentially occupied un-surveyed areas (Patrick Kelly and Tristan Edgarian pers. comm.).

In 2005, a captive-bred population of approximately two-dozen animals was introduced to the Faith Ranch along the San Joaquin River in Stanislaus County adjacent to the San Joaquin River National Wildlife Refuge.

The most serious ongoing problem has been the lack of suitable habitat above the level of regular floods where the animals could find food and cover for protection from weather and predators. Flooding during the 1970s resulted in additional population declines, with estimates of the extant population ranging from just 15 to 20 individuals (DFG 2000). In January 1993, Caswell Memorial State Park was thought to support the only extant population, with an estimate of between 213 and 312 individuals. Flooding of the park in 1996 inundated more than 80 percent of the park, which contributed to additional population declines. The 1993 census was the last for which a reliable population estimate could be generated for the Caswell Memorial State Park population. Surveys conducted in 2002 (Williams et al. 2002a) resulted in the highest number of captures since the 1993 census, but are still not sufficient to generate a population estimate.

Access restrictions to the south Delta population prevent sufficient sampling to reliably estimate the population size; however, based on trapping conducted during 1998–99, this population is estimated to include between 25 and 100 individuals (Williams et al. 2002b).

A15.2.2 Distribution and Status in the Plan Area

Of the two extant populations of riparian brush rabbit, only the south Delta population (Paradise Cut and Tom Paine Slough) occurs within the Plan Area (Figure A-15b). As indicated above, occurrence locations in this area are on private land, and watercourses are managed for flood control, not wildlife management. Surveys conducted by the Endangered Species Recovery Program under contract with the California Department of Water Resources have not detected other occurrences within the Plan Area; however, surveys are incomplete due to the lack of property access.

DRAFT

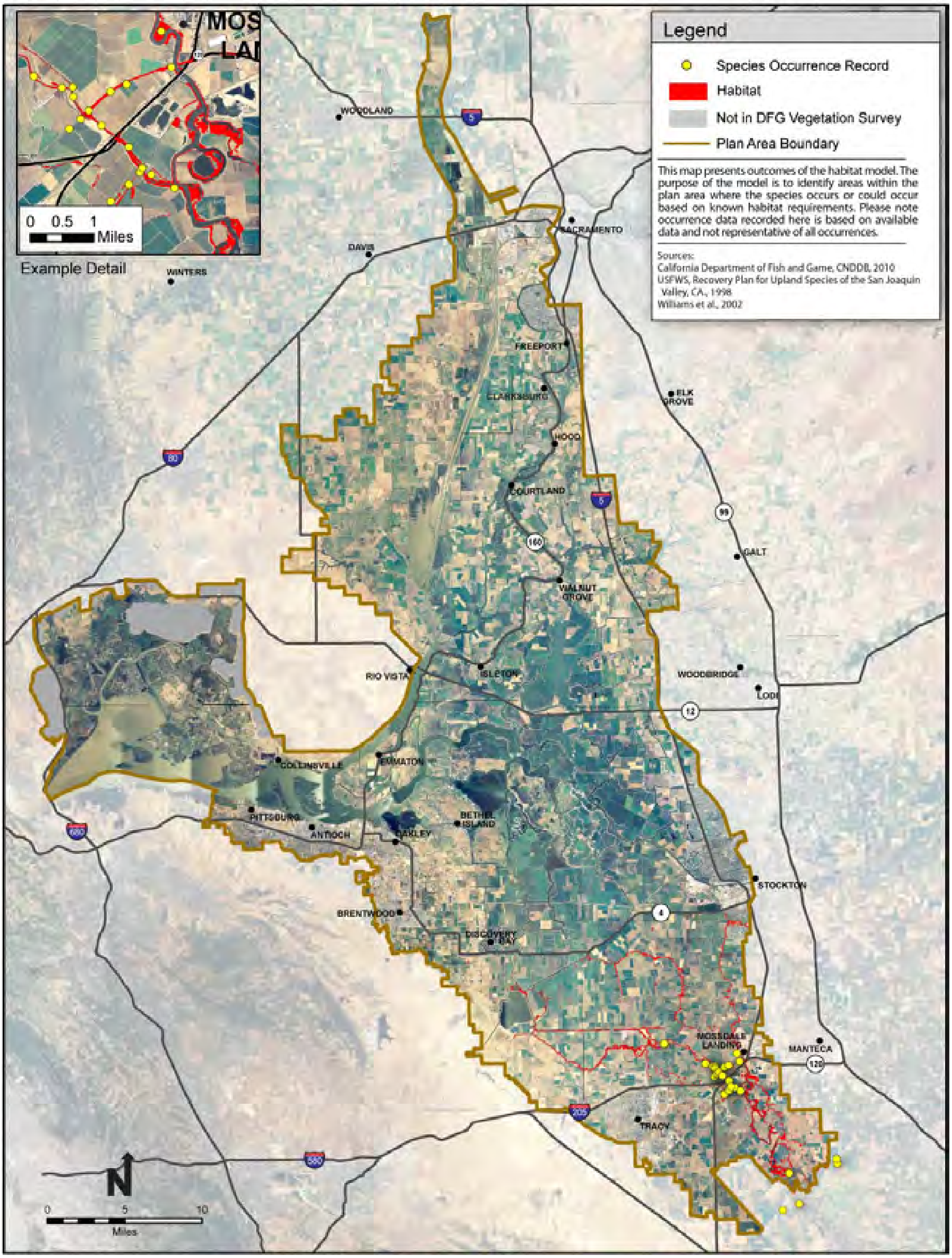

Figure A-15b. Riparian Brush Rabbit Habitat Model and Recorded Occurrences

A15.3 Habitat Requirements and Special Conditions

Riparian brush rabbits inhabit the brushy understory shrub layer of valley riparian forests. Closely associated with dense shrub vegetation, occupied sites tend to be in riparian settings with an open overstory canopy of valley oak (*Quercus lobata*) or savannah-like settings that support extensive patches of low-growing willow (*Salix* spp.), wild rose (*Rosa californica*), wild grape (*Vitis californica*), or blackberry (*Rubus* spp.) (Williams et al. 2008). The brush rabbits move through the dense brush and thickets by creating tunnels through the vegetation. Seasonally available weedy/ruderal cover, including patches of tall grass, forbs, and pepperweed (*Lepidium latifolium*) is also used, particularly where it connects to more-suitable woody cover (Williams et al. 2008). Generally, riparian forests that support a closed overstory canopy lack sufficient understory shrubs to support riparian brush rabbits (USFWS 1998). Small herbaceous openings in close proximity to cover are also required for foraging, and higher elevation areas are required to sustain populations during floods (USFWS 1998).

Sites inhabited by riparian brush rabbits usually have a mix of roses, blackberries, coyote bush (*Baccharis pilularis*), and grape vines, with high volumes of roses and coyote bushes (*Baccharis* spp.) in comparison to uninhabited sites (Williams 1988, Basey 1990, USFWS 1998). Williams and Basey (1986) also note that brush rabbit sites support significantly more ground litter and surface area of roses and significantly fewer willows in the canopy and understory than sites occupied by desert cottontails. This condition may indicate the presence of higher elevation areas that are not flooded regularly or heavily, an important element of brush rabbit habitat (Williams and Basey 1986).

Patch size is important, and fragmentation of intact riparian forests is a major issue restricting occupancy and overall distribution of the species. Brushy clumps smaller than 0.08 acre (0.03 hectare) are rarely occupied.

Flooding is a key issue for this species and is thought to be responsible for major population declines. Riparian brush rabbits are closely tied to brushy cover and will generally not cross large, open areas. They are thus unable to disperse beyond the dense brush, making them susceptible to mortality during flood events (Williams 1988, USFWS 1998).

A15.4 Life History

Description. The riparian brush rabbit is a small, brownish cottontail-like rabbit with a white belly; relatively short ears; and a small, inconspicuous tail. The hind legs are short and hind feet are slender and not covered with long or dense hair. The white belly and ventral tail hairs are gray near the skin, and the ears lack dark tips (Orr 1940, Ingles 1965, Chapman 1974). Adult riparian brush rabbits are about 13 inches (33 centimeters) long and can be distinguished from other subspecies by their relatively pale color, gray sides, darker back (Orr 1935), restricted range and habitat requirements, and skull characteristics. When looking down at the head from above, the riparian brush rabbit cheeks protrude outward rather than being straight or curving inward as in other subspecies (Orr 1935, 1940).

Features that distinguish the riparian brush rabbit from the desert cottontail (*S. audubonii*) include size and coloration. The riparian brush rabbit is smaller and darker grayish-brown, though populations of desert cottontails living along Central Valley rivers are about the same color as the riparian brush rabbit (which is lighter colored than many of the other subspecies). The tail of the brush rabbit is small and inconspicuous compared with the desert cottontail, and its ears are uniformly colored. The tail of the desert cottontail shows much white when viewed from behind, and the inner (medial) tips of the ears are black. When looked at from above, the cheeks of the brush rabbit protrude, whereas those of the desert cottontail are slightly concave (Sandoval et al. 2006)

Activity. Riparian brush rabbits are active throughout the year and are most active during the twilight hours around dawn and dusk. Depending on season, the main activity periods generally last from 2 to 4 hours. The period of least activity is from about 1030 hours to 1600 hours (10:30 am to 4:00 pm) (Chapman 1974).

Riparian brush rabbits typically remain hidden under protective shrub cover. They seldom venture more than 1 meter from cover. They often remain motionless while searching for signs of danger before moving short distances. When pursued, they leap back into the cover of shrubs instead of heading into open ground (Chapman 1974). Williams (1988) reported that they will generally not cross large, open areas, and hence are unable to disperse beyond the dense brush of the riparian forest. More recent observations, however, have suggested a somewhat more elastic range of conditions and that in some settings riparian brush rabbits will use larger, more exposed herbaceous habitats (Patrick Kelly and Tristan Edgarian pers. comm.).

Riparian brush rabbits have a limited ability to climb into bushes and trees. This trait probably has significant survival value, given that the riparian forests that are its preferred habitat are subject to inundation by periodic flooding (Chapman 1974, Williams 1988). Prolonged flooding of riparian areas can dramatically impact riparian brush rabbit populations (Kelly pers. comm.).

When weather conditions are appropriate, individuals may spend time in the early mornings and afternoons basking in the sun on a log or a dry form (a resting place for a rabbit). Ideal basking sites are a few inches from cover no more than about 18 inches (46 cm) above ground, with a partial, low-overstory canopy (Williams 1988, USFWS 1998).

Reproduction. The breeding season is generally from approximately January to May, although it can extend through the late summer (Kelly pers. comm.). The gestation period for brush rabbits is about 27 days, the usual litter size is three to four, and the females may produce three to four litters during the season. Females average 9 to 16 offspring per year, which remain in the nest for about 24 days. Although this is a relatively high reproductive rate, 5 out of 6 rabbits do not survive to the next breeding season (Mossman 1955, Chapman and Harman 1972). Their eyes open at 10 days, but they remain in the nest for another 2 weeks. The nest is a shallow burrow or depression (3–4 inches deep [7.6-10.2 cm]) lined with grasses and fur and covered by a plug of residual vegetation. Young mature at approximately 4 months old (Williams 1988, Larsen 1993, USFWS 1998).

Home Range/Territory Size. Data from studies being conducted at the San Joaquin National Wildlife Refuge (in preparation for publication) indicate that average home range size varies from year to year but ranges from 3.1 to 7.4 acres (1.3 to 3 hectares). Breeding season ranges are typically larger than non-breeding ranges, and male ranges are usually larger than female ranges, but not dramatically so. The average core area is typically less than half of the home range area (1.2–1.9 acres [0.5 to 0.8 hectares]) (Kelly pers. comm.). Home ranges generally conform to the size of the available brushy habitat (USFWS 1998). Individuals are intolerant of each other when they come too close, but there is no well-defined territoriality. Young are more tolerant of approach by another rabbit than are adults (Chapman 1974, USFWS 1998).

Foraging Behavior and Diet. Riparian brush rabbits feed at the edges of shrub cover rather than in large openings. Their diet consists of herbaceous vegetation, such as grasses, sedges, clover, and forbs and buds, bark, and leaves of woody plants. They consume herbaceous plants found along trails, firebreaks, or at the edge of brushy areas, and they eat the leaves, bark, and buds of many types of woody shrubs and vines within and at the edges of thickets. Grasses and other herbs are the most important food for brush rabbits, but shrubs such as California wild rose, coyote bush, and blackberry (*Rubus* spp.) also are eaten. When available, green clover (*Trifolium wormskioldii*) is preferred over all other foods (Orr 1940, Larsen 1993, USFWS 1998, Sandoval et al. 2006).

A15.5 THREATS AND STRESSORS

Restricted Range and Habitat Availability. The primary threats to the survival of the riparian brush rabbit are the limited extent of its existing habitat, extremely low numbers of individual animals, and few extant populations. The small size of its remaining population, the behavior of the species, and the highly limited and fragmented nature of remaining habitat restrict natural dispersal and put the species at risk from a variety of environmental factors. The existing population size does not meet the minimum population sizes that Thomas (1990) suggests are required to assure the medium- to long-term persistence of birds or mammals (i.e., the geometric mean of population size should be 1,000 for species with normally varying numbers and about 10,000 for species exhibiting a high variability in population size). The species is therefore considered at a high risk of imminent extinction from several consequent threats related to population genetics and dynamics and environmental variability (USFWS 1998).

Flooding. Periodic flooding still occurs along all major rivers in the Valley (Kindle 1984). With behavioral restrictions on its freedom of movement (low mobility) and the dearth of habitat suitably protected from frequent floods downstream of Caswell Memorial State Park, there is little chance that individuals that escape drowning or predation will meet mates or reproduce (USFWS 1998).

Predation. Limited and fragmented habitats and flooding increase the risk and extent of predation on riparian brush rabbits. The increased predation to which they are exposed while taking refuge on cleared levees or in exposed bushes or trees contributes directly to population decline and an elevated risk of extinction. Predators of riparian brush rabbits include red-tailed hawks (*Buteo jamaicensis*), Swainson's hawks (*B. swainsoni*), red-shouldered hawks (*B. lineatus*), great-horned owls (*Bubo virginianas*), gray foxes (*Urocyon cinereoargenteus*), coyotes (*Canis latrans*), dogs, and feral cats (Nolan 1984, USFWS 1998).

Fire. Wildfire also poses a major threat. Long-term fire suppression of Caswell Memorial State Park, combined with prolonged drought, has caused the buildup of high fuel loads from dead leaves; woody debris; and decadent, flammable shrubs. The dense, brushy habitat to which the rabbits are restricted is thus highly susceptible to catastrophic wildfire that would cause both high mortality and severe destruction of habitat. Recovery of the riparian brush rabbit population from such a devastating event would be improbable (USFWS 1998).

Disease. Like most rabbits, the riparian brush rabbit is subject to a variety of common diseases, including tularemia, plague, myxomatosis, silverwater, encephalitis, listeriosis, Q-fever, and brucellosis. These contagious, and generally fatal, diseases could be transmitted easily to riparian brush rabbits from neighboring populations of desert cottontails. In a widespread, genetically heterogeneous population, such an outbreak would be of minimal concern. However, in this small remnant brush rabbit population, this kind of epidemic could quickly eliminate the entire population (Williams 1988, USFWS 1998).

A15.6 Relevant Conservation Efforts

The Recovery Plan for Upland Species of the San Joaquin Valley, California (USFWS 1998) describes conservation efforts undertaken through the end of the 1990s.

In 1986, after surveys along rivers within its historical range indicated that there was only a single, small extant population in Caswell Memorial State Park (Williams and Basey 1986), the riparian brush rabbit was designated as a "Mammalian Species of Special Concern" by the DFG Wildlife Management Division. It was given Federal category-1 candidate status by USFWS in 1985 and remained a candidate for listing in USFWS's most recent Notice of Review (61 FR 7596). The riparian brush rabbit was proposed for listing by the USFWS on November 21, 1997 (62 FR 62276). The subspecies was listed as endangered by the State of California in May 1994 (Title 14, Division 1, California Administrative Code, Section 670.5, Animals of California declared to be endangered or threatened).

In addition to the passive protection afforded to the species by the status of Caswell as a State Park, the California Department of Parks and Recreation funded a study of ecology and habitat management of riparian brush rabbits (Williams 1988, Basey 1990) and a small mammal inventory (Cook 1992). California Department of Parks and Recreation, Bureau of Reclamation, and USFWS, through the Endangered Species Recovery Program, funded a population assessment in the winter of 1993 and 1996–1997 (Williams 1993). The California Department of Parks and Recreation has expanded fire trails in Caswell Memorial State Park, which provides additional edge habitat for rabbits and better access to fight fires. The agency also has an ongoing control program for feral animals, has curtailed measures intended to control ground squirrels (brush rabbits will eat treated bait meant for ground squirrels), and is involved in ongoing planning for habitat protection for wildlife in the park.

In 1999, the Endangered Species Recovery Program at California State University Stanislaus began implementing a Controlled Propagation and Reintroduction Plan for the Riparian Brush Rabbit (Williams et al. 2002a), which was recommended in the Recovery Plan for Upland Species of the San Joaquin Valley, California (USFWS 1998). The primary goal of the program is to prevent extinction by providing animals for reintroduction to establish new populations or augment existing populations. This effort is ongoing.

In response to development activities in the city of Lathrop, mitigation lands have been acquired along the San Joaquin River and Paradise Cut for purposes of preserving and restoring habitat for the riparian brush rabbit. The San Joaquin River Oxbow Preserve is a 30-acre (12-hectare) riparian forest established in 2004 as mitigation for the Union Pacific Homes development in Lathrop; this preserve is currently under ownership and management of the Center for Natural Lands Management. The preserve was established primarily to protect the riparian brush rabbit. The River Islands project also intends to implement a plan to manage and restore riparian and other wetland habitats in the Paradise Cut in part to enhance habitat for the riparian brush rabbit.

In 2005, the USFWS and the Endangered Species Recovery Program at California State University Stanislaus introduced a captive-bred population of approximately two-dozen animals to the Faith Ranch along the San Joaquin River in Stanislaus County adjacent to the San Joaquin River National Wildlife Refuge.

The riparian brush rabbit is a covered species under the San Joaquin County Multi-Species Habitat Conservation and Open Space Plan, which prohibits removal or disturbance of occupied riparian habitat that could potentially affect the subspecies as a result of the implementation of covered activities.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan’s Multi-Species Conservation Strategy (MSCS) designates the riparian brush rabbit as a “Contribute to Recovery” species (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its control and within its scope that are necessary to contribute to the recovery of the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

A15.7 SPECIES HABITAT SUITABILITY MODEL

Model Approach. BDCP Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information systems (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which are incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and revise the vegetation input data as necessary.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements, and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate, as well as overestimate, the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small, isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; instead, the models indicate that non-habitat areas have a much lower probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percentage cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf (2007). Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers; connectivity between habitat types; and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified, and each vegetation type or association is identified, along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or underestimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The riparian brush rabbit model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), USDA 2005 aerial photography, and DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable riparian brush rabbit habitat in the Plan Area. Vegetation types were assigned based on the species requirements, as described above, and the assumptions described below.

Habitat. Riparian brush rabbit habitat includes the following valley/foothill riparian and coastal scrub types from the BDCP composite vegetation layer:

- White alder *(Alnus rhombifolia)*;
- Box elder *(Acer negundo)*;
- Oregon ash (*Fraxinus latifolia*);
- White alder (*Alnus rhombifolia*) – Arroyo willow (*Salix lasiolepis*) restoration;
- *Alnus rhombifolia*/*Salix exigua (Rosa californica)*;
- *Acer negundo-Salix gooddingii*;
- Hinds walnut *(Juglans hindsii)*;
- Black willow *(Salix gooddingii)*;
- *Salix gooddingii-Populus fremontii (Quercus lobata-Salix exigua-Rubus discolor)*;
- *Salix gooddingii*/*Rubus discolor*;
- *Salix goodingii/*wetland herbs;
- *Salix lasiolepis – (Cornus sericea)/Scirpus spp.- (Phragmites australis – Typha spp.)* complex unit;
- Valley Oak (*Quercus lobata*);
- Valley Oak (*Quercus lobata*) restoration;
- *Quercus lobata*/*Rosa californica (Rubus discolor-Salix lasiolepis/Carex spp.)*;
- *Quercus lobata – Acer negundo*;
- *Quercus lobata – Alnus rhombifolia (Salix lasiolepis-Populus fremontii-Quercus agrifolia)*;
- *Quercus lobata – Fraxinus latifolia*;
- *Salix lasiolepis* – Mixed brambles *(Rosa californica-Vitis californica-Rubus discolor)*;

- *Salix exigua – (Salix lasiolepis – Rubus discolor – Rosa californica)*;
- Coyote bush *(Baccharis pilularis)*;
- *Baccharis pilularis*/Annual Grasses and Herbs;
- California wild rose *(Rosa californica)*;
- Blackberry *(Rubus discolor)*;
- Buttonbrush (*Cephalanthus occidentalis*);
- California Dogwood (*Cornus sericea*);
- *Cornus sericea – Salix exigua;*
- *Cornus sericea – Salix lasiolepis/ (Phargmites australis*);
- Microphyllous shrubland;
- Intermittently or Temporarily Flooded Deciduous Shrublands;
- Arroyo willow *(Salix lasiolepis)*;
- Mexican elderberry *(Sambucus mexicana)*;
- Fremont cottonwood *(Populus fremontii)*;
- *Alnus rhombifolia*/*Cornus sericea*;
- *Salix goodingii – Quercus lobata*/wetland herbs;
- Narrow-leaf willow *(Salix exiqua)*;
- Shining willow *(Salix lucida)*; and
- Black willow (*Salix gooddingii*) – Valley Oak (*Quercus lobata*) restoration.

The vegetation types were selected based on a review of understory and overstory composition from Hickson and Keeler-Wolf (2007) and species habitat requirements, but were not further differentiated based on percentage composition or species associations. Thus, the list includes lower- and high-quality vegetation associations. Potentially occupied habitat is restricted to the above types with a minimum patch size of 0.05 acre (0.02 hectare).

Assumptions. The current distribution is highly restricted. There are only two known extant populations, one of which occurs within the Plan Area near Paradise Cut and Tom Paine Slough in the south Delta. Riparian brush rabbits inhabit the brushy understory shrub layer of valley riparian forests. Closely associated with dense shrub vegetation, occupied sites tend to be in riparian settings with an open overstory canopy or savannah-like settings that support patches of low-growing wild rose, wild grape, blackberry, and coyote bush, where the brush rabbits move through the dense brush and thickets by creating tunnels through the vegetation. Generally, riparian forests that support a closed overstory canopy lack sufficient understory shrubs to support riparian brush rabbits (Williams 1988, Basey 1990, USFWS 1998).

Patch size is important, and fragmentation of intact riparian forests is a major issue restricting occupancy and overall distribution of the species. Brushy clumps smaller than 0.08 acre (0.03 hectare) are rarely occupied. A minimum patch size of 0.05 acre (0.02 hectare) is used to ensure all potential habitat is included.

While it may greatly overestimate the extent of potentially occupied habitat for this species, for purposes of this model, it is assumed that all mapped occurrences of the riparian categories listed above using a minimum patch size of 0.05 acre (0.02 hectare) are potentially occupied. Modeled habitat is geographically constrained to qualifying habitat south of State Route 4 and Old River Pipeline. While somewhat arbitrary, for purposes of this model, this boundary is considered to represent the northern extent of all potentially-occupied habitat within the Plan Area based on the known distribution of the species and results of recent surveys in the Plan Area. While survey access was not permitted within some portions of this area, it may also greatly overestimate the extent of potentially occupied habitat for this species.

A15.8 Recovery Goals

The following recovery actions for the riparian brush rabbit were outlined in the Recovery Plan for Upland Species of the San Joaquin Valley, California (USFWS 1998).

Because of the small size of remaining blocks of potential habitat and the severely limited dispersal capability of the riparian brush rabbit, the species is likely to require continuing special protection of its habitat and population. Realization of these limitations should remove barriers to the rapid establishment of as many populations in remnant habitat as possible and sustainment of these populations by reintroduction should any one become extinct. In furtherance of these objectives, the following actions are needed:

1. Establish an emergency plan and monitoring system to provide swift action to save individuals and habitat at Caswell Memorial State Park in the event of flooding, wildfire, or a disease epidemic.
2. Develop and implement a cooperative riparian brush rabbit conservation program that will include, at a minimum:
    a) Identifying and obtaining biological information needed in management decisions; researching captive breeding methodology using surrogate species; conducting genetic composition analysis on the riparian brush rabbit population prior to any captive breeding or introduction/reintroduction (the objective is to ensure the establishment of new populations neither depletes the genetic diversity of the source population nor unduly restricts diversity in the newly established population); and implementing the captive breeding program.
    b) Creating a riparian brush rabbit management plan for Caswell Memorial State Park that will incorporate elements detailed by Williams (1988) relating to predator and pest control; fire lines and access roads; campground, picnic, and recreation areas;

brush and fuel control; mosquito abatement; habitat enhancement; and expansion of the park.

c) Establishing at least three additional wild populations in the San Joaquin Valley in restored and expanded suitable habitat within the rabbit's historical range.
d) Creating a monitoring program of all riparian brush rabbit populations to assess population trends and status.
e) Creating a long-term reintroduction preplan for the prompt reestablishment of eliminated populations.
f) Establishing a cooperative program, to take effect once the minimum of four protected populations are established, to place excess young (or other animals as appropriate) from populations at carrying capacity onto private parcels with suitable habitat where owners are willing to enter into a management agreement.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy (MSCS) designates the riparian brush rabbit as a "Contribute to Recovery" species (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its control and within its scope that are necessary to contribute to the recovery of the species. Recovery is equivalent to the requirements of delisting a species under Federal and state endangered species acts.

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Patrick Kelly and Tristan Edgarian, graduate student, California State University, Stanislaus. Presentation to SAIC on October 5, 2010.

APPENDIX A16. TOWNSEND'S BIG-EARED BAT (*CORYNORHINUS TOWNSENDII*)

A16.1 LEGAL STATUS

The Townsend's big-eared bat (*Corynorhinus townsendii*) is designated as a state Mammal Species of Special Concern (Williams 1986) by the California Department of Fish and Game (DFG). The two subspecies occurring in California have no Federal regulatory status; however, the species was formerly listed as a United States Fish and Wildlife Service (USFWS) category 2 candidate (59 FR 58988) under the Endangered Species Act.

A16.2 SPECIES DISTRIBUTION AND STATUS

A16.2.1 Range and Status

Townsend's big-eared bats occur throughout most of western North America from British Columbia to central Mexico, east to the Black Hills of South Dakota, and across Texas to the Edwards Plateau (Hall 1981, Kunz and Martin 1982). There are five subspecies of Townsend's big-eared bat: *C.t. ingens, C.t. virginianus, C.t. pallescens, C.t. townsensii*, and *C.t. australis.* Two of these (*C.t. ingens* and *C.t. virginianus*) are found in isolated, relictual populations in the southern Great Plains and the Ozark and Appalachian Mountains and are listed as federally endangered. In California, the two subspecies found are *C.t. pallescens* and *C.t. townsendii*; the boundary between them is generally described as running north-south through the central portion of the Central Valley, with *C.t. townsendii* on the west side (Hall 1981).

In California, Townsend's big-eared bat populations have been concentrated primarily in the limestone formations of the Sierra Nevada and Klamath mountain ranges, the volcanic formations in the Columbian Plateau (e.g., Lava Beds National Monument), and throughout mining districts (Figure A-16a). The species also occurs throughout much of the northern and central Coast Ranges, including the San Francisco Bay Area, and in southern California.

Pierson and Rainey (1998a) reported on the distribution, status, and management of this species in California. They found that during the previous 40 years, there had been a 52 percent loss in the number of maternity colonies, a 45 percent decline in the number of available roosts, a 54 percent decline in the total number of animals, and a 33 percent decrease in the average size of remaining colonies for the species as a whole across the state. The populations that have shown the most marked declines are along the coast, in the Mother Lode country, and along the Colorado River. Townsend's big-eared bats have declined notably in San Francisco Bay Area counties, where native habitat and rural land have been converted to agriculture (i.e., wine production) or suburban/urban development.

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Figure A-16a. Townsend's Big-Eared Bat Statewide Range and Recorded Occurrences

At the Homestake Mine near the Yolo County line, an adult female population of 140 and a winter population of both males and females of 166 that had been recorded in 1950 had declined to 105 and 27, respectively, by 1987–1991 (Pierson and Rainey 1998a). Depressed populations may recover when roost sites are protected (e.g., gating a mine to prevent human entry) if suitable foraging habitat remains.

A16.2.2 Distribution and Status in the Plan Area

There are no documented occurrences of Townsend's big-eared bat in the Plan Area or in the immediate vicinity of the Plan Area (Figure A-16b). The nearest recorded occurrences are in northwestern Yolo County, where the species is documented (CNDDB 2008) at three mine sites in the Little Blue Ridge and at two sites in Alameda County, one near Calaveras Reservoir and the other in the hills south of Livermore (CNDDB 2008). The Plan Area does not support caves, mines, or other similar natural roosting habitat for this species. However, some populations of Townsend's big-eared bat may be located in buildings and other anthropogenic structures such as tunnels and bridges, and individuals have been reported to use basal hollows in large trees as roost sites. The species could potentially forage and roost in larger riparian corridors in the Plan Area. While no occurrences have been reported, potential roosting habitat in the Plan Area may include old barns and other buildings with suitable interior structure, and possibly bridges.

A16.3 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

In California, this species occurs in many habitats, including active agricultural areas, riparian communities, coastal habitat types, oak woodland, conifer forest, desert scrub, and native prairies. Pierson and Rainey (1998a) suggested that its distribution appears to be constrained primarily by the availability of suitable roosting sites and the degree of human disturbance at roosts.

Roosting. The roosting behavior of the Townsend's big-eared bat leaves it highly vulnerable to disturbance. Roosting habitat is mainly limited to caves, mines, tunnels, and other features that mimic caves, such as large tree hollows, abandoned buildings with cave-like attics, water diversion tunnels, and internal spaces in bridges. For example, of the six maternity colonies known along the California coast, five colonies are in the attics of old buildings and one colony is in a cave-like feature of a bridge (Fellers and Pierson 2002). Open spaces under bridges are often used as night roosts by individual animals. Within these features (caves, mines, other structures), bats typically roost in highly visible areas on open surfaces, rarely seeking shelter in crevices as many other bat species do (Dalquest 1947, Barbour and Davis 1969). The distribution of the Townsend's big-eared bat is limited to regions with appropriate roosting habitat.

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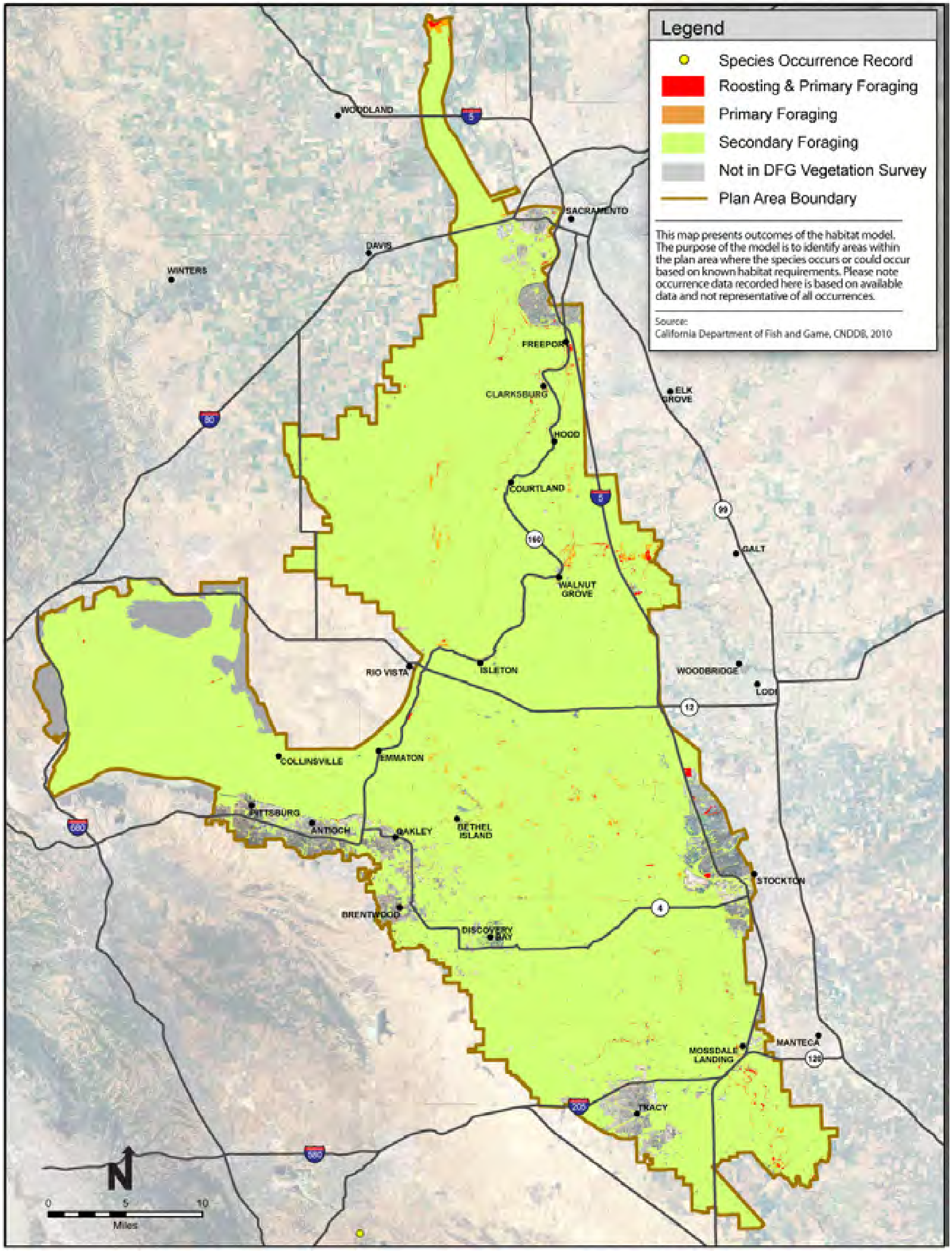

Figure A-16b. Townsend's Big-Eared Habitat Model and Recorded Occurrences

Foraging. Foraging occurs primarily along edges of wooded habitats and along streams (Kunz and Martin 1982). This species feeds both in the air and gleans insects off leaf surfaces. Radio-tracking and light-tagging studies have also documented it feeding in closed forest and woodland settings, within the canopy of oaks (Pierson and Rainey 1998b), particularly along vegetated stream corridors; over corn and alfalfa fields (Fellers and Pierson 2002); and occasionally over hay crops and vineyards. Telemetry studies found that commuting distances (from roost site to primary foraging area) varied from 1–13 kilometers (0.6–8.1 miles); because some individuals were not found, it is possible that they traveled even further (Fellers and Pierson 2002). Commuting distances vary among individuals and within the species based on season, sex, reproductive condition, and the availability of suitable foraging habitat (Fellers and Pierson 2002). Over 90 percent of the diet of the Townsend's big-eared bat consists of moths and butterflies.

A16.4 LIFE HISTORY

Description. The Townsend's big-eared bat is a medium-sized (8–14 grams [0.28–0.49 oz]) bat with rabbit-like ears; a small, indistinct face; and overall brownish coloration. This species is related in appearance to only one other bat with very large ears, the pallid bat (*Antrozous pallidus*), which is larger overall, light-colored, with large eyes and a distinct muzzle.

Seasonal Patterns. The life history of the Townsend's big-eared bat centers on reproduction and meeting the energetic demands of a small, insectivorous mammal. Its annual cycle includes an approximately 7- to 8-month period of peak activity in spring and summer when insects are most available and reproduction occurs. Pregnant females gather in maternity colonies that range in size from a few to several hundred individuals. Males usually roost elsewhere, singly or in small numbers. Maternity colonies form between March and June (based on local climatic factors), with a single pup born between May and July (Pearson et al. 1952). Maternity colonies cluster tightly together to share body heat, and the appearance of the cluster is characteristic of this species. Although roost site fidelity is variable in areas with many potential roost sites, it is quite high in California, where roosting habitat is scarce (Sherwin et al. 2003).

The Townsend's big-eared bat uses daily and seasonal periods of hibernation to conserve energy when it is inactive. In winter months, when insect prey is less available, this species extends hibernation over weeks or months, and it may migrate locally to suitable hibernation sites. In the Sacramento Valley, bats may hibernate, migrate, or reside year-round and alternate between activity and hibernation depending on weather and insect availability.

Reproduction. Females arrive at maternity roost sites in early spring and give birth to a single offspring in late spring or early summer after an approximately 3-month gestation period (Pearson et al. 1952). In California, young are born over a 3- to 5-week period beginning in late May. Maternity colonies disperse in fall, and mating occurs in fall and winter. The peak of copulation occurs from November through February, although some females apparently mate before arriving at hibernacula (Kunz and Martin 1982). Females are sexually mature and mate in their first autumn. However, as in most bats, females store sperm, and ovulation does not occur until early spring (Pearson et al. 1952). Ovulation may occur either before or after females leave hibernation. Young grow rapidly, reaching adult size in approximately 1 month, and are capable of flight in 2.5 to 3 weeks. They are fully weaned by 6 weeks (Pearson et al. 1952).

A16.5 Threats and Stressors

The cause of local population declines is most likely disturbance and destruction of roost sites. Activities such as recreation in caves and mines, abandoned mine closure, and renewed mining at historical sites have all contributed to this species' decline. For example, roosting habitat in historical mine shafts is lost when renewed mining uses open pit methods. Dependence on abandoned mines puts this species at risk if mine reclamation and renewed mining projects do not mitigate for roost loss, or do not conduct adequate biological surveys prior to mine closure.

The Townsend's big-eared bat is vulnerable to human disturbance; colonies have abandoned roost sites after human visitation (Humphrey and Kunz 1976). Pierson et al. (1999) also reported that Townsend's big-eared bats are threatened by the loss of clean water, the loss of roosting and foraging habitat, and the disturbance or destruction of winter roosts. The impacts on insect prey availability from the use of pesticides and herbicides may also threaten populations of this species.

A16.6 Relevant Conservation Efforts

A species conservation assessment and conservation strategy for the Townsend's big-eared bat (Pierson et al. 1999) was produced as part of efforts to allow opportunities for federal and state agencies and other interested parties to stabilize and recover this species and its ecosystems. This species is at risk of being listed as threatened or endangered under the Endangered Species Act. The conservation strategy addressed cave and mine management; pesticides; vegetation conversions; timber harvest; and inventory, monitoring, and research protocols.

Monitoring is needed to determine current population trends and status. More information is needed to help determine the seasonal home ranges and movements, particularly during winter months, and the foraging requirements in different habitats. In addition, information is needed to determine the amount of relatedness within and between different populations to help conserve populations.

Townsend's big-eared bat is a covered species in the permitted East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan and the in-progress Yolo County Natural Heritage Program Plan. These plans include a conservation strategy that conserves habitat and protects occupied roosting locations for this species.

A16.7 SPECIES HABITAT SUITABILITY MODEL

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which are incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and revise the vegetation input data as necessary.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements, and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate, as well as overestimate, the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small, isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; instead, the models indicate that non-habitat areas have a much lower probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percentage cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf (2007). Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers; connectivity between habitat types; and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified, and each vegetation type or association is identified, along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or underestimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The Townsend's big-eared bat model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), USDA 2005 aerial photography, and DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable Townsend's big-eared bat habitat in the Plan Area according to the species' two primary life requisite parameters, roosting habitat and foraging habitat. Vegetation types were assigned based on the species requirements, as described above, and the assumptions described below.

Roosting Habitat. Natural roosting habitat for Townsend's big-eared bat in the Plan Area is limited to (1) riparian habitats that support mature valley oak, walnut, coast live oak, and cottonwood riparian woodland and (2) mature eucalyptus stands, which would most likely be used by solitary or small groups of roosting males.

Roosting habitat in the Delta consists of the following vegetation types from the Hickson and Keeler-Wolf (2007) vegetation layer:

- Valley/foothill riparian
    - Hinds walnut (*Juglans hindsii*);
    - Fremont cottonwood *(Populus fremontii)*;
    - *Salix gooddingii-Populus fremontii (Quercus lobata-Salix exigua-Rubus discolor)*;
    - Coast live oak *(Quercus agrifolia)*;
    - Valley oak *(Quercus lobata)*;
    - *Quercus lobata – Rosa californica*;
    - *Quercus lobata – Acer negundo*;
    - *Quercus lobata – Alnus rhombifolia*; and
    - *Quercus lobata – Fraxinus latifolia*.
- Agricultural land
    - Eucalyptus.

Roosting habitat in the Suisun Marsh and Yolo Basin consists of the following vegetation types from the Boul and Keeler-Wolf (2008) and TAIC (2008) vegetation layers:

- Eucalyptus;
- *Eucalyptus globules*;

- Oaks;
- *Quercus agrifolia*;
- Fremont cottonwood-valley oak-willow (ash-sycamore) riparian forest NFD association; and
- Valley oak alliance – riparian.

Other roosting habitat in the Plan Area may include manmade features that mimic caves, including abandoned barns and other buildings, tunnels, and bridges.

Assumptions. Townsend's big-eared bat roosting habitat is limited to caves, mines, tunnels, and other features that mimic caves, such as large tree hollows, abandoned buildings with cave-like attics, water diversion tunnels, and internal spaces in bridges. Natural roosting habitat in the Plan Area is limited to large trees. Open spaces under bridges are often used as night roosts by individual animals. Within these features (caves, mines, other structures), bats typically roost in highly visible areas on open surfaces, rarely seeking shelter in crevices as many other bat species do (Dalquest 1947, Barbour and Davis 1969).

Foraging Habitat. The entire Plan Area is considered suitable foraging habitat for Townsend's big-eared bat. Modeled foraging habitat is divided into primary and secondary foraging habitat.

Primary foraging habitat in the Delta consists of the following valley riparian types from the BDCP composite vegetation layer:

- Valley/foothill riparian – all types.

Primary foraging habitat in the Suisun Marsh and Yolo Basin consists of the following riparian types from the BDCP composite vegetation layer:

- *Fraxinus latifolia*;
- Fremont cottonwood-Valley oak-Willow riparian forest;
- Mixed Fremont cottonwood – Willow;
- Mixed willow super alliance;
- *Quercus agrifolia*;
- *Salix lasiolepis/Quercus agrifolia*; and
- Valley oak alliance – Riparian.

Secondary foraging habitat in the Delta includes the following types from the BDCP composite vegetation layer:

- Agricultural land – All types;
- Alkali seasonal wetland complex – All types;

- Grassland – All types;
- Managed wetland – All types;
- Other natural seasonal wetlands – All types;
- Nontidal freshwater perennial emergent – All types;
- Tidal freshwater emergent wetland – All types;
- Tidal perennial aquatic – All types; and
- Vernal pool complex – All types.

Secondary foraging habitat in the Suisun Marsh and Yolo Basin consists of the following vegetation types from the Boul and Keeler-Wolf (2008) and TAIC (2008) vegetation layers:

- All non-riparian types.

Assumptions. Foraging occurs primarily along edges of wooded habitats and along streams (Kunz and Martin 1982). This species both feeds in the air and gleans insects off leaf surfaces. Radio-tracking and light-tagging studies have also documented it feeding in closed forest and woodland settings, within the canopy of oaks (Pierson and Rainey 1998b), particularly along vegetated stream corridors, over corn and alfalfa fields (Fellers and Pierson 2002); and occasionally over hay crops and vineyards. The Townsend's big-eared bat has also been captured while flying over damp, marshy patches of meadow and in willow riparian vegetation. There are no reported occurrences of this species in the Plan Area; thus, this model likely significantly overestimates the extent of potentially occupied habitat.

A16.8 Recovery Goals

A USFWS recovery plan has not been prepared for this species, and no recovery goals have been established.

A16.9 References

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APPENDIX A17. SUISUN SHREW (*SOREX ORNATUS SINUOSUS*)

A17.1 LEGAL STATUS

The Suisun shrew *(Sorex ornatus sinuosus)* is a California Department of Fish and Game Species of Special Concern (Williams 1986). The Suisun shrew has no federal regulatory status.

A17.2 SPECIES DISTRIBUTION AND STATUS

A17.2.1 Range and Status

The Suisun shrew, one of several subspecies of the ornate shrew, is endemic to the tidal saline and brackish salt marshes of Solano, Napa, and eastern Sonoma counties. While the historical range of the Suisun shrew is unknown, its current range was defined by Brown and Rudd (1981), who separated it from the ornate shrew *(S.o. californicus)*, which is found west of Sonoma Creek and Tubbs Island. The species' current distribution is restricted to isolated remnants of natural tidal and brackish marshes along the northern borders of San Pablo and Suisun bays, including a number of locations in Suisun Marsh, Southampton Marsh, and the Napa Marshes, and as far east as Grizzly Island, and as far west as Sonoma Creek and Tubbs Island (Figure A-17a) (Brown and Rudd 1981, Western Ecological Services 1986).

Western Ecological Services (1986) identified nine additional sites with a high probability of supporting Suisun shrew populations, including Skaggs Island, Appleby Bay/Coon Island, Steamboat Slough, Vallejo, Morrow Island, Cordelia Slough (Rush Ranch, Peytonia Slough), Hammond Island, Simmons/Wheeler Islands, and Collinsville.

Limited information exists on population densities. Newman (1970) estimated densities of 111 shrews per hectare (2.5 acres) in good quality habitat. Hays (1990) estimated densities from 10 to 100 shrews per acre at Rush Ranch in Solano County, depending on the presence or absence of large aggregations (one male with several females) of shrews. Hays (1990) found that shrews often occur in aggregations consisting of one dominant male and several females. Individuals, mainly subdominant males, were dispersed between these aggregations and returned in early spring to compete with resident males during the breeding season. Dispersing males may also occupy the deeper tidal marsh areas that were not considered in Hays (1990) (LSA Associates 2007).

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Figure A-17a. Suisun Shrew Statewide Range and Recorded Occurrences

A17.2.2 Distribution and Status in the Plan Area

The only reported occurrences of Suisun shrew in the Plan Area are from the Suisun Marsh Restoration Opportunity Area (Figure A-17b), where there is a substantial amount of suitable habitat west of Sherman Island and throughout the Suisun Marsh (Figure A-17b). With the possible exception of portions of Kimble and Sherman islands on the western edge of the Plan Area, there is little available tidal marsh habitat within the Delta with potential to support the Suisun shrew.

A17.3 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

Suisun shrews inhabit tidal marshes characterized by pickleweed *(Sarcocornia pacifica*[1]*)*, cordgrass *(Spartina foliosa)*, and gumplant *(Grindelia cuneifolia)*. The species also occurs in brackish tidal marshes dominated by California bulrush *(Schoenoplectus californicus*[2]*)* and cattail *(Typha latifolia)* (Rudd 1955). Rudd (1955) also noted that plant community structure, rather than species composition, was the primary factor determining occupancy. The species appears to prefer dense, low-lying vegetation where invertebrates are abundant. However, suitability apparently decreases with increased inundation frequency. Williams (1983) suggests the importance of marsh habitat that is not regularly flooded and is 6 to 8 feet (2 to 2.5 meters) above sea level. Adjacent upland habitats are also important in providing cover and sources of food particularly during prolonged flooding of marshes and dikes (Williams 1983). Driftwood and other litter above the mean high tide line may also be important for nesting and foraging sites (MacKay 2000).

Hays (1990) determined that shrews alter their microhabitat use seasonally. During the fall when the weather was hot and tides high, he noted that shrews were typically found under dense layers of matted plant material beneath large clumps of succulents such as *Sarcocornia* and *Jaumea*. During winter and early spring when tides were low and succulents above the line of frequent flooding died back, shrews were seen foraging mostly among arrowgrass *(Triglochin maritinum)*.

Once abundant around San Pablo and Suisun Bays, the availability of suitable tidal marsh habitat for Suisun shrew and other tidal marsh species has declined dramatically. Western Ecological Services (1986) estimated that natural tidal marsh in this area has decreased from 100,000 acres (40,469 hectares) to around 12,000 acres (4,856 hectares). Most of the remaining tidal marsh habitat occurs in small, isolated units, the largest of these in the Suisun Marsh.

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[1] Formerly known as *Salicornia virginica*.
[2] Formerly known as *Scirpus californicus*.

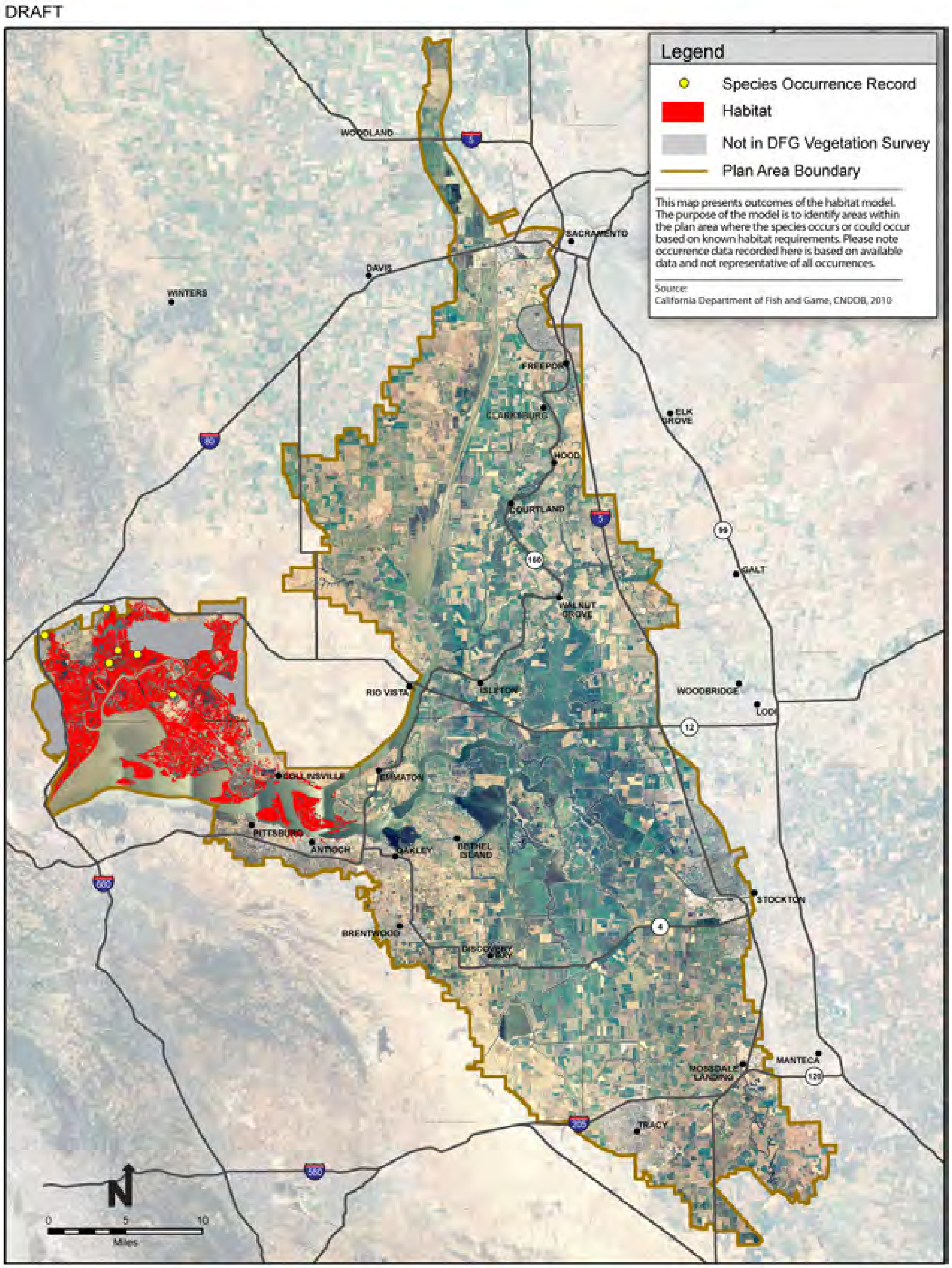

Figure A-17b. Suisun Shrew Habitat Model and Recorded Occurrences

A17.4 LIFE HISTORY

Description. The Suisun shrew is a small (98 to 106 millimeters [mm] [3.9 to 4.2 inches]), dark mammal with a long, pointed nose, an elongate, relatively narrow skull, and a 37- to 41-mm (1.5- to 1.6-inch) long scaly tail (Engles 1965). It is distinguished from other shrews by its darker pelage (fur) and localization to tidal marshes in and near San Pablo and Suisun bays. The skull is elongate, relatively narrow, and fragile (Rudd 1955).

Activity. With their high metabolic rate, Suisun shrews spend much of their time foraging. Genoud and Vogel (1989) reported that between 60 and 200 percent of their body mass is eaten daily; during peak lactation, females can consume up to 300 percent of body mass.

They access their territories by constructing shallow subterranean tunnels (Hays 1990) or share burrows and runways with harvest mice (*Reithrodontomys* spp.) and meadow mice (*Microtus* spp.).

Males are apparently more subject to local movements than females. While young females typically remain in their natal area, subdominant males intersperse within the aggregations of single dominant males and several females. Hays (1990) also concluded that dispersing shrews will most likely occupy and overwinter in deeper tidal marsh areas rather than in upland habitats.

As with all other *Sorex* species, the life span of shrews is short, with 16 months being considered the maximum age (Rudd 1955); thus, most individuals do not live to breed in a second season. Most die shortly after the breeding season, with females generally living slightly longer than males.

Reproduction. In early March, males reach sexual maturity and begin to migrate into population foci. The harem-structured population foci are reestablished within a narrow band of preferred habitat. Breeding occurs from April through October, with the reproductive peak in May (Newman and Rudd 1978). After breeding occurs, each population focus is left with one dominant male, several breeding females, and several immature females (Hays 1990).

Shrews construct domed, cup-like nests composed of paper scraps and dead plant material. Nests are directly on the soil surface below driftwood or wooden planks and are situated above the high tide line (Western Ecological Services 1986). Gestation is approximately three weeks, and two to nine young are produced. Another 3 weeks of altricial dependency occurs prior to weaning. Suisun shrews are capable of producing two litters in 1 year, but this is apparently rare (Rudd 1955).

Diet. The diet of Suisun shrews consists almost entirely of animal prey, including amphipods, isopods, and other invertebrate species (Hays 1990).

A17.5 Threats and Stressors

Habitat Degradation. Degradation of tidal marsh habitats continues to be the most significant threat to Suisun shrews and other tidal marsh species. Tidal marshes have been reduced by 84 percent since historical times (Dedrick 1989). The fragmentation of suitable habitats has isolated populations and reduced dispersal opportunities. While the loss of tidal marsh habitat through filling and diking has largely been curtailed, other current factors may be associated with declining populations, including the management of marshes in and around the Suisun, which may favor the growth of bulrush (LSA Associates 2007). Contaminants accumulated in the food chain, such as polychlorinated biphenyls (PCBs), heavy metals, and pesticides, may also degrade habitat conditions and threaten Suisun shrews (Western Ecological Services 1986).

A17.6 Relevant Conservation Efforts

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designates the Suisun shrew as "Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP has established a goal to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

The Suisun Marsh has been the subject of various conservation efforts for many years, particularly with respect to development and issues related to water quality within its boundaries. The California Department of Water Resources (DWR) Suisun Marsh Program (http://www.iep.water.ca.gov/suisun/program/index.html) summarizes the major agreements, management plans, and legislation that have directed management of the Suisun Marsh since the mid-1970s. These efforts focus on the preservation and restoration of tidal marsh habitats.

The Nejedly-Bagley-Z'Berg Suisun Marsh Preservation Act (1974). The California Legislature enacted the Suisun Marsh Preservation Act to protect the marsh from urban development. It required the San Francisco Bay Conservation and Development Commission (BCDC) to develop a plan for the marsh and provides for various restrictions on development within marsh boundaries.

Suisun Marsh Protection Plan (1976). This plan was developed by the BCDC and defines and limits development within primary and secondary management areas for the "future of the wildlife values of the area as threatened by potential residential, commercial and industrial development." It recommends that the state purchase 1,800 acres and maintain water quality. While the focus of the plan is on maintaining waterfowl habitat, it also addresses the importance of tidal wetlands and recommends restoring historical marsh areas to wetland status (managed or tidal).

The Suisun Marsh Protection Act (1977). This bill adopts and calls for implementation of the Suisun Marsh Protection Plan. Assembly Bill (AB) 1717 designates the BCDC as the state agency with regulatory jurisdiction of the marsh and calls for the Suisun Resource Conservation District to have responsibility for water management in the marsh. The bill identifies (and focuses on) actions for the preservation of waterfowl needs, along with the retention of the diversity of wildlife. It states that land within the Suisun Marsh should be acquired for public use or resource management if it is suitable for restoration to tidal or managed marsh, but that such restoration cannot be required as a condition of private development.

State Water Resources Control Board (SWRCB) Water Rights Decision 1485 (1978). SWRCB adopted the Water Quality Control Plan for the Sacramento-San Joaquin Delta and issued Water Rights Decision 1485. The decision sets channel water salinity standards for the period from October to May and preserves the area as brackish water tidal marsh. It sets water quality standards in the marsh as a condition of export pumping. These come from the California Department of Fish and Game's (DFG's) recommendations, which were based on (1) the relative value of marsh plants as duck food; (2) the influence of soil salinity and other factors on distribution and growth of marsh plants; and (3) the relationships between channel water salinity and soil salinity. DFG concluded that improved management practices, improved drainage, water control facilities, and adequate quality of water were needed to achieve desired soil salinity conditions for waterfowl food plants.

Plan of Protection for the Suisun Marsh (1984). DWR and the U.S. Bureau of Reclamation (USBR) developed and began implementing the Plan of Protection (POP) in accordance with Water Rights Decision 1485. The POP implementation strategy was to construct large facilities and distribution systems to meet salinity standards (lower channel water salinity), in lieu of significant Central Valley Project/State Water Project (CVP/SWP) storage releases estimated as high as 2 million acre-feet in dry/critical water years. The six-phase POP was the programmatic blue print (required by the SWRCB and embodied in the original Suisun Marsh Preservation Agreement). Two of the six phases were completed, including the Initial Facilities and the Suisun Marsh Salinity Control Gates.

Suisun Marsh Preservation Agreement (SMPA) (1987). This contractual agreement between DWR, USBR, DFG, and Suisun Resource Conservation District contains provisions for DWR and USBR to mitigate the effects on Suisun Marsh channel water salinity from the CVP/SWP operations and other upstream diversions. The SMPA requires DWR and USBR to meet salinity standards, sets a timeline for implementing the POP, and delineates monitoring and mitigation requirements. The Suisun Marsh Monitoring Agreement and the Suisun Marsh Mitigation Agreement were also signed at this time. The Suisun Marsh Mitigation Agreement defines habitat requirements to mitigate effects of facilities and operations, and the Suisun Marsh Monitoring Agreement defines requirements for monitoring salinity and species in the Suisun Marsh.

Bay-Delta Accord (1994). On December 15, 1994, federal and state agencies, working with agricultural, environmental, and urban stakeholders, reached an agreement on water quality standards and related provisions that would remain in effect for 3 years. This agreement, known as the Bay-Delta Accord, was based on a proposal developed by the stakeholders. Elements of the agreement include the following:

- Springtime export limits expressed as a percentage of Delta inflow;
- Regulation of the salinity gradient in the estuary so that a salt concentration of two parts per thousand is positioned where it may be more beneficial to aquatic life;
- Specified springtime flows on the lower San Joaquin River to benefit Chinook salmon; and
- Intermittent closure of the Delta Cross Channel gates to reduce entrainment of fish into the Delta.

SWRCB Water Quality Control Plan (1995–1998). In 1994, wildlife and fishery agencies and urban water users expressed concerns about the appropriateness of western Suisun Marsh channel water salinity standards. In May of 1995, the SWRCB modified the Suisun Marsh salinity objectives in the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Modeling analysis by the Suisun Marsh Planning Program showed that Suisun Marsh standards would be met most of the time at all Suisun Marsh compliance stations. Some standard exceedances would be expected in the western Suisun Marsh that participants in the SMPA agreed could be mitigated by more-active water control by landowners.

SWRCB Water Rights Decision 1641 (1999). The SWRCB issued Decision 1641 in December 1999, which updated salinity standards for Suisun Marsh. Increased outflow and salinity requirements for the Bay-Delta provided indirect benefits to the Suisun Marsh. DWR proposed that the SWRCB adopt the Amendment Three actions for Suisun Marsh in this decision. However, the SWRCB was unable to adopt Amendment Three actions because the Section 7 consultation with the U.S. Fish and Wildlife Service (USFWS) had not concluded. However, the SWRCB did relieve USBR and DWR of their responsibility to meet salinity objectives at S-35 and S-97 in the western Suisun Marsh.

CALFED Multi-species Conservation Strategy and Record of Decision (2000). In August 2000, the Programmatic Record of Decision for the CALFED Bay-Delta Program was signed by 13 federal and state agencies with management and regulatory responsibilities in the San Francisco Bay estuary. Based on the analysis in the multi-species conservation strategy and the final programmatic environmental impact statement/environmental impact report, the CALFED agencies fulfilled the regulatory requirement for programmatic evaluation of the CALFED program.

Suisun Marsh Charter Implementation Plan (2001). The Suisun Marsh Charter was completed in 2001, and development of an Implementation Plan commenced. Charter participants collaborated on a joint presentation to the State of the Estuary Conference on the principles of the Charter Plan, including coordinated water quality, endangered species, and heritage value protection in the Suisun Marsh.

Habitat Management, Preservation, and Restoration Plan (2003). The Charter process was expanded to include additional federal and state agencies to develop a Suisun Marsh Plan that will balance the goals and objectives of the Bay-Delta Program, SMPA, and other management and restoration programs within the Suisun Marsh in a manner that is responsive to the concerns of all stakeholders and is based upon voluntary participation by private landowners.

In addition, several facilities have been constructed in the Suisun Marsh to protect and improve water quality and protect and enhance wildlife habitat, including:

- Roaring River Distribution System (1979–80);
- Morrow Island Distribution System (1979–80;
- Goodyear Slough Outfall (1979–80);
- Suisun Marsh Salinity Control Gates (1988); and
- Cygnus and Lower Joyce Facilities (1991).

Several tidal marsh restoration projects are also planned or being implemented within the range of the Suisun shrew. These projects, implemented through the direction or support of the San Francisco Bay National Wildlife Refuge, National Biological Service, East Bay Regional Park District, Regional Water Quality Control Board, DFG, and the City of San Jose include the following:

- Restoration of the 1,500-acre Napa Marsh Unit in the Napa River in the north bay.
- Restoration of the Knapp Property, a 452-acre former salt pond in the Alviso area, on the edge of the bay, between Alviso and Guadalupe Sloughs.
- Enhancement of the 325-acre Oro Loma Marsh, an area of diked salt marsh and adjacent uplands located along the shore of Hayward. The area will be restored to tidal marsh and seasonal wetland habitat.
- Restoration of the Baumberg Tract, an 835-acre inactive salt evaporator in Hayward, to tidal marsh and seasonal wetlands.
- Restoration of the Moseley Tract, located just north of the west approach to the Dumbarton Bridge) from the Port of Oakland.

The Suisun shrew is also proposed for coverage under the Solano County Multispecies Habitat Conservation Plan.

A17.7 Species Habitat Suitability Model

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which are incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and revise the vegetation input data as necessary.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements, and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate, as well as overestimate, the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small, isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; instead, the models indicate that non-habitat areas have a much lower probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percentage cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf (2007). Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers; connectivity between habitat types; and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or underestimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The Suisun shrew model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), USDA 2005 aerial photography, and DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable Suisun shrew habitat in the Plan Area. Vegetation types were assigned based on the species requirements, as described above, and the assumptions described below.

Habitat. Suisun shrew habitat consists of all *Salicornia*[3]-dominated natural seasonal wetlands and *Scirpus*[4]/*Typha*-dominated tidal freshwater emergent wetlands located west of State Highway 160 on Sherman Island (Figure A-17b). Vegetation types designated as species habitat in this model correspond to the mapped vegetation associations in the BDCP GIS vegetation data layer.

Suisun shrew habitat in the Delta consists of the following types from the BDCP composite vegetation layer:

- Alkali seasonal wetland complex
- Managed wetlands
- Nontidal freshwater perennial emergent wetland
  - Broad-leaf cattail *(Typha latifolia)*
- Tidal freshwater emergent wetland and tidal brackish emergent wetland
  - Mixed *Scirpus* mapping unit;
  - Mixed *Scirpus*/floating aquatics complex;
  - Mixed *Scirpus*/submerged aquatics complex;
  - Hard-stem bulrush *(Scirpus acutus)*;
  - *Scirpus acutus* pure;
  - *Scirpus acutus* – *Typha angustifolia*;

[3] Currently known as *Sarcocornia*.
[4] Currently known as *Schoenoplectus*.

   - *Scirpus acutus – Typha latifolia*;
   - *Scirpus acutus – (Typha latifolia) – Phragmites australis*;
   - California bulrush *(Scirpus californicus)*;
   - *Scirpus californicus – Eichhornia crassipes*;
   - *Scirpus californicus – Scirpus acutus*;
   - American bulrush *(Scirpus americanus)*;
   - Narrow-leaf cattail *(Typha angustifolia)*; and
   - *Typha angustifolia – Distichlis spicata*.

Suisun shrew habitat in the Suisun Marsh consists of the following types from the BDCP composite vegetation layer:

- *Scirpus* (*californicus* or *acutus*)/Rosa;
- *Scirpus* (*californicus* or *acutus*)/wetland herb;
- *Scirpus* (*californicus* or *acutus*)-Typha spp.;
- *Scirpus americanus* (generic);
- *Scirpus americanus*/Lepidium;
- *Scirpus americanus*/Potentilla;
- *Scirpus californicus*/*S. acutus*;
- *Scirpus maritimus*;
- *Scirpus maritimus*/Salicornia;
- *Typha angustifolia*/Distichlis;
- *Typha angustifolia*/*S. americanus*;
- *Typha* species (generic);
- Bulrush - cattail fresh water marsh NFD super alliance;
- *Scirpus americanus*/*S. Californicus-S. acutus*;
- *Scirpus maritimus*/*Sesuvium*;
- *Typha angustifolia*;
- *Typha angustifolia*/*Phragmites*;
- *Typha angustifolia*/*Polygonum-Xanthium-Echino*;
- *Typha angustifolia/S. americanus*;

- *Distichlis*/*Salicornia*;
- *Salicornia* (generic);
- *Salicornia virginica*;
- *Salicornia/Atriplex*;
- *Salicornia/Cotula*;
- *Salicornia*/annual grasses;
- *Salicornia*/*Crypsis*;
- *Salicornia*/*Polygonum-Xanthium-Echinochloa*; and
- *Salicornia*/*Sesuvium*.

Assumptions. Historical and current records of this species indicate that its known distribution extends eastward to approximately Grizzly Island. For purposes of this model, the potential range of the Suisun shrew occurs in suitable habitats west of the western edge of Sherman Island. Suisun shrews are restricted to pickleweed *(Sarcocornia,* formerly *Salicornia)* and cordgrass *(Spartina foliosa)*-dominated saline tidal marshes and *Schoenoplectus* (formerly *Scirpus)/Typha*-dominated brackish marshes (Rudd 1955, Williams 1986). Suitability of habitat may also be dependent on other factors, such as patch size, tidal connectivity (diked marshes), and proximity to other land uses. However, data regarding the effects of these factors on potential occupancy for the Suisun shrew are insufficient. Thus, potential habitat for the Suisun shrew is not further restricted in this habitat model on the basis of these factors. Therefore, the model likely overestimates the extent of potentially occupied tidal marsh habitat.

A17.8 Recovery Goals

A USFWS recovery plan has not been prepared for this species, and no recovery goals have been established; however, the CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designates the Suisun shrew as "Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP has established a goal to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

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APPENDIX A18. TRICOLORED BLACKBIRD (*AGELAIUS TRICOLOR*)

A18.1 LEGAL STATUS

The tricolored blackbird *(Agelaius tricolor)* is designated as a state Bird Species of Special Concern by the California Department of Fish and Game (DFG) (Shuford and Gardali 2008). Nests are protected in California under *Fish and Game Code*, Section 3503.

The tricolored blackbird has no federal regulatory status; however, the species is protected under the federal Migratory Bird Treaty Act and is designated as a Bird of Conservation Concern by the U.S. Fish and Wildlife Service (USFWS 2002). A petition for federal listing was submitted in 2004. In 2006, the USFWS denied the petition based on insufficient scientific evidence to warrant listing the species under the federal Endangered Species Act.

A18.2 SPECIES DISTRIBUTION AND STATUS

A18.2.1 Range and Status

Tricolored blackbirds form the largest colonies of any North American passerine bird, and these colonies may consist of tens of thousands of breeding pairs (Beedy and Hamilton 1999). Tricolored blackbirds are largely endemic to California; the state is home to more than 95 percent of the global population, with breeding documented in 46 counties (Figure A-18a). More than 75 percent of the breeding population occurs in the Central Valley in any given year (Hamilton 2000). Recent surveys indicate that the overall range of the species is largely unchanged since the 1930s (Neff 1937, DeHaven et al. 1975, Beedy et al. 1991, Hamilton 1998). However, while the overall geographic distribution of the species may not have changed since historical times, there are now large gaps in their former range encompassing entire counties (e.g., Kings, San Joaquin, Riverside, and San Bernardino counties).

Historical population sizes are unknown, but by the mid-1930s, following the removal of most major wetland areas in the state, populations still likely exceeded 1.1 million adult birds (Hamilton 1998). In the first systematically conducted range-wide surveys, Neff (1937) documented 252 colonies of tricolored blackbirds in 26 California counties, including over 700,000 adults in just eight Central Valley counties. Surveys conducted in the 1960s and 1970s indicate that range-wide populations declined by more than 50 percent during the 30- to 35-year period following Neff's surveys in the 1930s (Orians 1961, Payne 1969, DeHaven et al. 1975).

More recently, the USFWS, DFG, and California Audubon cosponsored systematic tricolored blackbird surveys throughout California in 1994, 1997, 1999, and 2000 (Hamilton et al. 1995, Beedy and Hamilton 1997, Hamilton 2000).

DRAFT

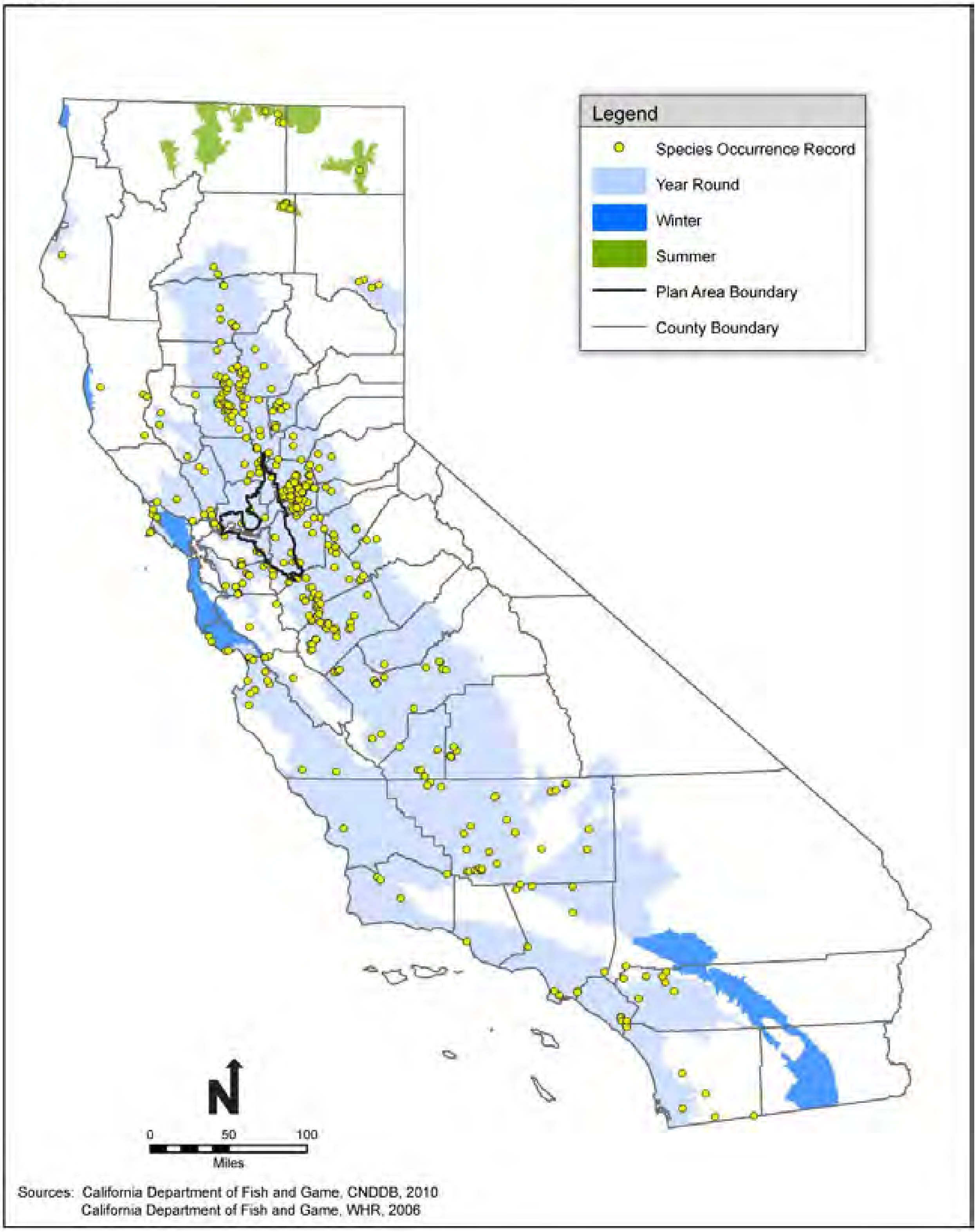

Figure A-18a. Tricolored Blackbird Statewide Range and Recorded Occurrences

Results of these surveys indicate a significantly declining trend in populations in California since the 1930s and a particularly dramatic decline since 1994. Hamilton (2000) reported a 56 percent statewide decline between 1994 and 2000 (from 369,359 to 162,508 adults) and a 69 percent decline in the Sacramento Valley during that period (from 98,362 to 30,979 adults).

The most recent statewide surveys have been coordinated by the Point Reyes Bird Observatory and California Audubon with assistance from Partners in Flight, USFWS, and DFG. Surveys conducted in 2008 included 35 counties from San Diego County to Shasta County. A total of 395,321 birds were estimated, with Kern, Tulare, and Merced counties in the San Joaquin Valley accounting for 314,936 (79.7 percent) of the total (University of California Davis 2008).

While survey results over the past several years may suggest a stable or possibly increasing population in the state, the data also indicate that populations continue to decline in several areas of the state where the species was formerly common, particularly in Southern California and several Central Valley counties, including San Joaquin County, where no active colonies were documented in 2008. Thus, while the number of birds may have increased statewide, they have concentrated into a significantly smaller effective range (University of California, Davis 2008).

A18.2.2 Distribution and Status in the Plan Area

There are few reported tricolored blackbird nesting colonies in the Plan Area (Figure A-18b). The 2009 California Department of Water Resources (DWR) surveys identified two confirmed breeding sites, one in the central Delta and one north and west of the Sacramento River in the north Delta, and numerous other detections of foraging or roosting tricolored blackbirds.

Beedy et al. (1991) reported historical occurrences at Stone Lakes and at sites near Tracy, near Durham Ferry, and at Birds Landing (from Neff 1937). California Natural Diversity Database reported occurrences in and near the Yolo Bypass; near Stockton, Manteca, and Tracy in the southeastern corner of the Plan Area; and along the eastern edge of the Suisun Marsh; however, few of these are recent reports. Statewide surveys conducted in 2008 reported no active colonies within the Plan Area. However, surveys in 2007 revealed a highly successful colony of more than 30,000 breeding adults in milk thistle on the Conaway Ranch in the Yolo Bypass. This was one of only three documented colonies statewide that were large and successful, and this colony was estimated to have produced about 30,000 young (Meese 2007). Other than the DWR 2009 survey results, the nearest reported active colonies were west of Byron at Marsh Creek Reservoir (University of California, Davis 2008) and in the Yolo Bypass (Feliz pers. comm.). Thus, the species is generally considered an uncommon breeder in the Plan Area; historical nesting activity was generally restricted to the northern and southern ends of the Plan Area.

The Delta is also recognized as a major wintering area for tricolored blackbirds (Hamilton 2004, Beedy 2008). Large wintering flocks have been reported on Sherman Island.

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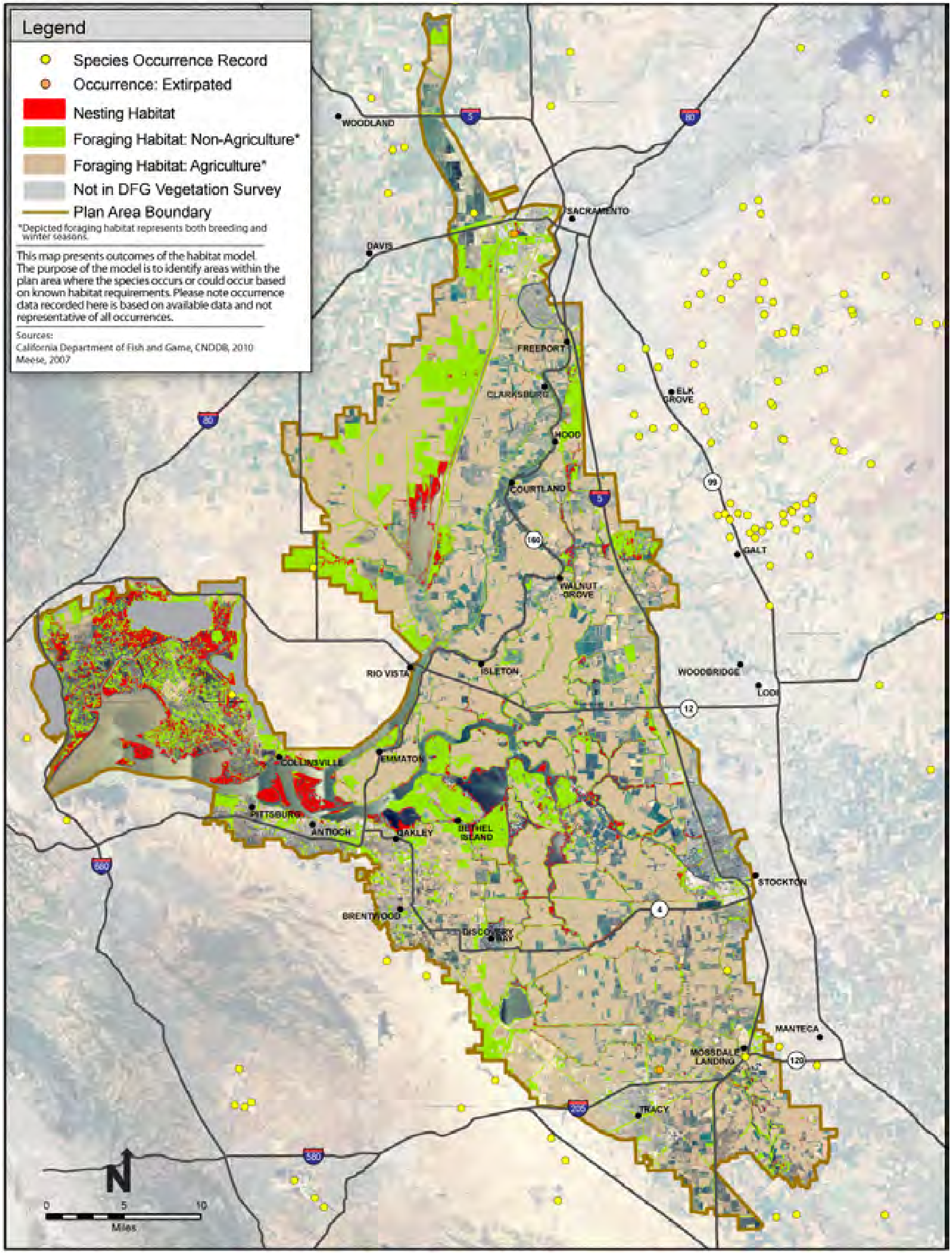

Figure A-18b. Tricolored Blackbird Habitat Model and Recorded Occurrences

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A18.3 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

Tricolored blackbirds are among the most colonial of North American passerine birds (Bent 1958, Orians 1961, Payne 1969, Beedy and Hamilton 1999). The species' highly synchronized and colonial breeding system may have adapted to exploit a rapidly changing environment in which the locations of secure nesting habitat and rich insect food supplies were ephemeral and likely to change each year (Orians 1961, Collier 1968, Payne 1969).

Nesting. Tricolored blackbirds have three basic requirements for selecting their breeding colony sites: (1) open, accessible water; (2) a protected nesting substrate, including flooded, thorny, or spiny vegetation; and (3) a suitable foraging space providing adequate insect prey within a few miles of the nesting colony (Hamilton et al. 1995, Beedy and Hamilton 1999).

As many as 30,000 nests have been recorded in cattail (*Typha* spp.) marshes of 10 acres or less, with individual nests less than 0.5 meters from each other (Neff 1937, DeHaven et al. 1975). Nest heights range from a few centimeters (cm) to about 1.5 meters above water or ground at colony sites in freshwater marshes (Neff 1937) and up to 3 meters in the canopies of willows (*Salix* spp.) and other riparian trees; nests are rarely built on the ground. The species typically selects breeding sites adjacent to open, accessible water and places its nests in a protected nesting substrate, often including flooded, thorny, or spiny vegetation. Breeding colonies must have suitable foraging space providing adequate insect prey within a few kilometers (Beedy and Hamilton 1999).

Males initially select breeding sites and establish nesting territories. Females select the nest site location. The first nests in a colony generally occur in the densest vegetation, usually in the interior of the nesting habitat. As the colony forms, nests are added in concentric circles gradually or in synchronous pulses (Collier 1968).

Over time, the selection of nesting habitat has changed dramatically as freshwater marsh habitat has been removed. Almost 93 percent of the 252 breeding colonies reported by Neff (1937) were in freshwater marshes dominated by tules (*Schoenoplectus*[1] spp.) and cattails (*Typha* spp.). The remaining colonies in Neff's study were in willows (*Salix* spp.), blackberries (*Rubus* spp.), thistles (*Cirsium* and *Centaurea* spp.), or nettles (*Urtica* spp.). In contrast, only 53 percent of the colonies reported during the 1970s were in cattails and tules (DeHaven et al. 1975).

An increasing percentage of colonies in the 1980s and 1990s were reported in Himalaya blackberry *(Rubus discolor)* (Beedy et al. 1991), and some of the largest recent colonies are in silage and grain fields (Hamilton et al. 1995, Beedy and Hamilton 1997, Hamilton 2000). Other substrates where tricolored blackbirds have been observed nesting include giant cane *(Arundo donax)*, safflower *(Carthamus tinctorius)* (DeHaven et al. 1975), tamarisk trees (*Tamarix* spp.),

[1] Formerly known as *Scirpus*.

elderberry/poison oak (*Sambucus* spp. and *Toxicodendron diversilobum*), and riparian scrublands and forests.

Foraging. Tricolored blackbirds forage in areas that provide abundant insects, including pastures, dry seasonal pools, agricultural fields planted with crops such as alfalfa and rice, feedlots, and dairies. Tomatoes may occasionally be used as foraging habitat. With the loss of the natural flooding cycle and most native wetland and upland habitats in the Central Valley, breeding tricolored blackbirds now forage primarily in anthropogenic habitats. Tricolored blackbirds have been able to exploit foraging conditions created when shallow flood irrigation, mowing, or grazing keeps the vegetation at an optimal height (less than 15 cm). Preferred foraging habitats include crops such as rice, alfalfa, sunflowers, irrigated pastures, and ripening or cut grain fields (e.g., oats, wheat, silage), as well as annual grasslands and shrublands.

In recent years, an increasing percentage and now large majority of adults have foraged on grains provided to livestock, for example, in cattle feedlots and dairies. Tricolored blackbirds also forage in remnant native habitats, including wet and dry vernal pools and other seasonal wetlands, riparian scrub habitats, and open marsh borders. Vineyards, orchards, and row crops (sugar beets, corn, peas, beets, onions, etc.) do not provide suitable nesting substrates or foraging habitats for tricolored blackbirds (Beedy and Hamilton 1999). Both adults feed the nestlings; adults feeding young typically forage within 3 miles of the colony, but can range up to 8 miles from the colony (Beedy and Hamilton 1999).

Some small breeding colonies may occur at private and public lakes, reservoirs, and parks, provided that they are near suitable foraging habitats. Many of these colonies are surrounded by shopping centers, subdivisions, and other urban development; adults from such colonies forage in undeveloped uplands nearby.

Wintering tricolored blackbirds are associated primarily with open rangeland and dairies in the Sacramento-San Joaquin Delta (Hamilton 2004).

A18.4 LIFE HISTORY

Description. The tricolored blackbird is a medium-sized passerine (8.8 inches [22 cm] in length with 14-inch [36 cm] wingspan) that closely resembles the red-winged blackbird *(Agelaius phoeniceus)*, with subtle differences in coloration, bill shape, and overall morphology (Beedy and Hamilton 1999). The adult male is black, with shades of glossy blue, and has a bright red patch on the wing (an epaulet), similar to that of a red-winged blackbird. However, the epaulet of tricolored blackbirds is deeper red with a white lower border, as opposed to an orange-red patch with a yellowish border or no border at all. The adult females are brownish and black, streaked with gray, with small reddish epaulets (rarely visible in the field) and a pale gray or whitish chin and throat. Tricolored blackbirds have longer, slightly narrower wingtips and thinner bills than red-winged blackbirds (Beedy and Hamilton 1999).

Seasonal Patterns. Many tricolored blackbirds reside throughout the year in the Central Valley of California. However, local populations can move considerable distances, and some are migratory and move from inland breeding locations to wintering habitats in the Sacramento-San Joaquin River Delta and coastal areas. During the first breeding effort of the season, most birds nest in the San Joaquin Valley and in Sacramento County. They may later move northward throughout the Sacramento Valley, northeast California, and southern Oregon to nest again (Hamilton 1998). Thus, individual tricolored blackbirds may occupy and breed at several sites, or renest at the same site, during a given breeding season, depending on environmental conditions and their previous nesting success (Hamilton 1998, Beedy and Hamilton 1999, Meese 2006). In the fall, after the nesting season, large roosts form at managed wildlife refuges and other marshes near abundant food supplies such as rice *(Oryza sativa)* and water grass *(Echinochloa crusgalli)* (Beedy and Hamilton 1997). During winter, many tricolored blackbirds move out of the Sacramento Valley to the Sacramento–San Joaquin River Delta. Large flocks also winter in the central and southern San Joaquin Valley and at the dairy farms in coastal areas such as Point Reyes and Monterey County (Beedy and Hamilton 1997). From early March to early April, these flocks move from wintering areas to their breeding colonies in Sacramento County and the San Joaquin Valley (Beedy and Hamilton 1997).

Reproduction. Tricolored blackbirds nest colonially, enabling them to synchronize their timing of nest building and egg laying (Beedy and Hamilton 1999). A few breeding colonies documented during fall months (September to November) had more-protracted nest-building periods that led to asynchronous egg laying and fledging of young (Orians 1960). In the Central Valley, adults typically arrive on the breeding grounds from early March to early April (Hamilton 2004). Females usually breed in their first year, but most males apparently defer breeding until they are at least 2 years old (Payne 1969). Females typically lay three to four eggs and incubate them for 11 to 14 days (Emlen 1941, Orians 1961); then both parents feed young until they fledge 9 to 14 days after hatching (Beedy and Hamilton 1999).

Tricolored blackbird young transition from hatchlings to fledglings in approximately 24 days. Thus, a successful nesting effort requires approximately 45 days from nest initiation to independence of young (Hamilton et al. 1995). However, because birds may continue to be recruited into the nesting colony following the initial nest establishment, the colony itself remains active and in various stages of the breeding cycle for an extended period. This period may sometimes last more than 90 days, but generally requires a minimum of 50 days for a complete breeding cycle of a less-asynchronous colony (Beedy and Hamilton 1997).

Foraging Behavior and Diet. Like other blackbirds, tricolored blackbirds often forage in flocks. They usually forage on the ground by walking, hopping, or taking short flights. Most forage within 3 miles of their colony sites (Orians 1961).

Diets of adult tricolored blackbirds are dependent on geographic location and the availability of local insect foods. Among the most important prey for adults provisioning nestlings include Coleopterans (beetles), Orthopterans (grasshoppers, locusts), Hemipterans (true bugs), other larval insects, and Arachnids (spiders and allies) (Crase and DeHaven 1977, Beedy and Hamilton 1999). The primary diet of a colony depends on the local food availability (large hatches of dragonflies [Odonata] are especially favorable to this species [Meese pers. comm. as cited in: Yolo Natural Heritage Program 2008]). Individuals are also attracted to large outbreaks of grasshoppers (Orians 1961). Adult females require insects to form eggs, and nestlings require insects because they are unable to digest plant materials until they are at least 9 days old and ready to leave their nests (Beedy and Hamilton 1999). During the non-breeding season, tricolored blackbirds often congregate at dairy feedlots to consume grains and other livestock feed, while others forage on insects, grains, and other plant material in grasslands and agricultural fields (Skorupa et al. 1980, Beedy and Hamilton 1999).

A18.5 Threats and Stressors

Habitat Loss and Alteration. The most significant historical and ongoing threat to the tricolored blackbird is habitat loss and alteration. The initial conversion from native landscapes to agriculture removed vast wetland areas in the state and caused initial declines in populations. The more-recent conversion of suitable agricultural lands to urban areas has permanently removed historical breeding and foraging habitat for this species.

In urbanizing areas, habitat fragmentation and proximity to human disturbances has also led to abandonment of large historical colonies (Beedy and Hamilton 1999).

In Sacramento County, a historical breeding center of this species, the conversion of grassland and pastures to vineyards expanded from 7,537 acres in 1996, to 13,171 acres in 1998 (DeHaven 2000), to 16,709 acres in 2003 (California Agricultural Statistics Service, http://www.nass.usda.gov/ca). Conversions of pastures and grasslands to vineyards in Sacramento County and elsewhere in the species' range in the Central Valley have resulted in the recent loss of several large colonies and the elimination of extensive areas of suitable foraging habitat for this species (Cook 1999, DeHaven 2000, Hamilton 2004, Yolo Natural Heritage Program 2008).

Direct Mortality During Crop Harvest. Entire colonies (up to tens of thousands of nests) in cereal crops and silage are often destroyed by harvesting and plowing of agricultural lands (Beedy and Hamilton 1999, Hamilton 2004, Cook and Toft 2005). While adult birds can fly away, eggs and fledglings cannot. The concentrations of a high proportion of the known population in a few breeding colonies increases the risk of major reproductive failures, especially in vulnerable habitats such as active agricultural fields (Yolo Natural Heritage Program 2008).

Predation. Historical accounts documented the destruction of nesting colonies by a diversity of avian, mammalian, and reptilian predators (Beedy and Hamilton 1999). Recently, especially in perennial freshwater marshes of the Central Valley, entire colonies have been lost to black-crowned night-herons *(Nycticorax nycticorax)* and common ravens *(Corvus corax)*. Recently, cattle egrets *(Bubulcus ibis)* have been observed preying on tricolored blackbird nests, and at one colony in Tulare County, more than 125 egrets were present throughout the breeding season (Meese 2007). Some large colonies (up to 100,000 adults) may lose greater than 50 percent of nests to coyotes *(Canis latrans)*, especially in silage fields, but also in freshwater marshes when water is withdrawn (Hamilton et al. 1995). Thus, water management by humans often has the effect of increasing predator access to active colonies (Yolo Natural Heritage Program 2008).

Human Disturbances. Tricolored blackbird colonies are highly sensitive to human disturbances. Close proximity to urbanizing areas can cause colonies to be permanently abandoned. Increases in noise, loose pets, and human presence can cause nest abandonment. Even entry into colonies for management or scientific purposes can cause disturbances and should be avoided (Beedy and Hamilton 1999).

Poisoning and Contamination. Various poisons and contaminants have caused mass mortality of tricolored blackbirds. McCabe (1932) described the strychnine poisoning of 30,000 breeding adults as part of an agricultural experiment. Neff (1942) considered poisoning to regulate numbers of blackbirds preying upon crops (especially rice) to be a major source of mortality. This practice continued until the 1960s, and thousands of tricolored blackbirds and other blackbirds were exterminated to control damage to rice crops in the Central Valley. Beedy and Hayworth (1992) observed a complete nesting failure of a large colony (about 47,000 breeding adults) at Kesterson Reservoir in Merced County; selenium toxicosis was diagnosed as the primary cause of death. At a colony in Kern County, all eggs sprayed by mosquito abatement oil failed to hatch (Beedy and Hamilton 1999). Hosea (1986) attributed the loss of at least two colonies to aerial herbicide applications (Yolo Natural Heritage Program 2008).

Other Conservation Issues. Important information gaps in the ecology of the species include the effects of land use changes on the reproductive success of colonies and on the distribution of wintering birds; the relationship of invertebrate prey abundance and brood size; winter distribution, diet, and survival rates; and measures of suitable foraging habitat (Beedy and Hamilton 1999, Meese 2007).

Tricolored blackbirds have been the focus of recent management concern due to population decline, very limited global range, and vulnerability of large breeding colonies to habitat losses, predation, and human-induced impacts.

A18.6 Relevant Conservation Efforts

There are no statewide, regional, or local conservation efforts that are specific to the conservation of the tricolored blackbird. However, a conservation strategy for this species was prepared recently (Tricolored Blackbird Working Group 2007). Recommendations for the species conservation (Beedy and Hamilton 1999, Hamilton 2004) include frequent monitoring of breeding and wintering population sizes, colony locations, and reproductive success; protection of colony locations and foraging habitats; protection of colonies on farmland by avoiding harvesting/tilling until young have fledged; providing adequate protection in Habitat

Conservation Plans; focusing on dairy dependence for breeding and wintering populations; developing or restoring breeding habitat near reservoirs, rice fields, alfalfa fields, and other optimal foraging habitats; and managing major predators in or near breeding colonies, including common ravens, black-crowned night-herons, cattle egrets, and coyotes when feasible.

The tricolored blackbird is also a covered species in other neighboring regional conservation plans, including the approved San Joaquin County Multi-species Habitat Conservation and Open Space Plan, the East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan, and the Natomas Basin Habitat Conservation Plan. It is proposed for coverage in the in-progress South Sacramento County Habitat Conservation Plan, the Solano County Multispecies Habitat Conservation Plan, the Yolo County Natural Heritage Program Plan, and the Butte Regional Conservation Plan.

A18.7 Species Habitat Suitability Model

Model Approach. BDCP Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which are incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and revise the vegetation input data as necessary.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements, and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate, as well as overestimate, the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small, isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; instead, the models indicate that non-habitat areas have a much lower probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percentage cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf (2007). Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers; connectivity between habitat types; and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or underestimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The tricolored blackbird model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), USDA 2005 aerial photography, and DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable tricolored blackbird habitat in the Plan Area according to the species' two primary life requisites, nesting habitat and foraging habitat. Vegetation types were assigned to a suitability category based on the species requirements, as described above, and the assumptions described below.

Nesting Habitat. There are few reported historical occurrences of tricolored blackbird breeding colonies within the Plan Area (Neff 1937, Beedy et al. 1991, CNDDB 2008), and few recent occurrences (University of California, Davis 2008). This is likely due in part to the lack of breeding habitat throughout most of the Delta. The 2009 California Department of Water Resources (DWR) surveys identified two confirmed breeding sites, one in the central Delta and one north and west of the Sacramento River in the north Delta. A large colony of over 30,000 breeding adults was also found in the Yolo Bypass north of Interstate 80 in 2007 (Meese 2007).

Potentially suitable breeding habitat within the Plan Area consists of all bulrush (*Scirpus*[2] spp.) and cattail (*Typha* spp.) alliances and blackberry (*Rubus* spp.) brambles located within 500 m of open water. Nesting habitat in the Delta consists of the following types from the BDCP composite vegetation layer:

- Managed wetlands

[2] Currently known as *Schoenoplectus*.

- o *Scirpus* spp. in managed wetlands.
- Freshwater perennial emergent wetlands
    - o Broad-leaf cattail *(Typha latifolia).*
- Tidal freshwater emergent wetland and tidal brackish emergent wetland
    - o Mixed *Scirpus* mapping unit;
    - o Mixed *Scirpus*/floating aquatics complex;
    - o Mixed *Scirpus*/submerged aquatics complex;
    - o Hard-stem bulrush *(Scirpus acutus);*
    - o *Scirpus acutus* pure;
    - o *Scirpus acutus – Typha angustifolia;*
    - o *Scirpus acutus – Typha latifolia;*
    - o *Scirpus acutus – (Typha latifolia) – Phragmites australis;*
    - o California bulrush *(Scirpus californicus);*
    - o *Scirpus californicus – Eichhornia crassipes;*
    - o *Scirpus californicus – Scirpus acutus;*
    - o American bulrush *(Scirpus americanus);*
    - o Narrow-leaf cattail *(Typha angustifolia);* and
    - o *Typha angustifolia – Distichlis spicata.*
- Nontidal freshwater perennial emergent
    - o American bulrush (*Scirpus americanus*);
    - o Hard-stem bulrush (*Scirpus acutus*);
    - o Mixed *Scirpus*/floating aquatics (*Hydrocotyle – Eichhornia*) complex;
    - o Mixed *Scirpus*/submerged aquatics (*Egeria-Cabomba-Myriophyllum* spp.) complex;
    - o Mixed *Scirpus* mapping unit;
    - o Broad-leaf cattail *(Typha latifolia);*
    - o Narrow-leaf cattail (*Typha angustifolia*);
    - o Perennial pepperweed (*Lepidium latifolium*);
    - o *Scirpus acutus* – (*Typha latifolia*) – *Phragmites australis*;
    - o *Scirpus acutus – Typha angustifolia*;
    - o *Scirpus acutus* pure;
    - o *Scirpus acutus – Typha latifolia*;
- Valley/foothill riparian

- Blackberry *(Rubus discolor);*
- Mexican elderberry *(Sambucus mexicana);*
- *Salix lasiolepis* – Mixed brambles *(Rosa californica – Vitis californica – Rubus discolor);*
- *Salix exigua-(Salix lasiolepis)-Rubus discolor – Rosa californica;*
- *Salix gooddingii*/*Rubus discolor;* and
- Giant cane *(Arundo donax).*

Nesting habitat in the Suisun Marsh and Yolo Basin consists of the following types from the BDCP composite vegetation layer:

- *Scirpus (californicus or acutus)/rosa;*
- *Scirpus (californicus or acutus)*/wetland herb;
- *Scirpus (californicus or acutus)-Typha* spp.;
- *Scirpus americanus* (generic);
- *Scirpus americanus/Lepidium;*
- *Scirpus americanus/Potentilla;*
- *Scirpus californicus/S. acutus;*
- *Scirpus maritimus;*
- *Scirpus maritimus/Salicornia*[3]*;*
- *Typha angustifolia/Distichlis;*
- *Typha angustifolia/S. americanus;*
- *Typha* species (generic);
- Bulrush - Cattail freshwater marsh NFD super alliance;
- *Scirpus americanus/S. californicus-S. acutus;*
- *Scirpus maritimus/Sesuvium;*
- *Typha angustifolia;*
- *Typha angustifolia/Phragmites;*
- *Typha angustifolia/Polygonum-Xanthium-Echino;* and
- *Typha angustifolia/S. americanus.*

[3] Currently known as *Sarcocornia*.

Assumptions. Beedy et al (1991) reported breeding colonies occupying sites as small as 0.1 acre. Therefore, all potentially suitable vegetation types are considered potential breeding habitats regardless of patch size. The mapping unit size of 1 acre may contribute to underestimating the extent of suitable breeding habitat in the Plan Area. Hamilton (2004) reported that open water within 500 m of nesting substrate is a requirement for colony settlement.

Other important factors regarding the selection of breeding sites include the condition of the vegetation and the extent of open water associated with emergent vegetation along canals. For example, Hamilton (2004) suggests that cattail marsh that has not been recently burned may be too dense and preclude settlement. Hamilton (2004) also suggests that strips of emergent vegetation along canals that are less than 10 m wide may be avoided due to insufficient open water habitat. However, because these factors cannot be adequately identified using the available mapping tools, for purposes of this model, all potentially suitable vegetation types are considered potential breeding habitats, regardless of condition, and all potentially suitable habitat along canals is considered potential breeding habitat, regardless of canal width. Thus, this aspect of the model may contribute to overestimating potentially suitable breeding habitat.

Foraging Habitat. Breeding season foraging habitat consists of all grassland, managed wetland, and natural seasonal wetland categories, and most agricultural lands, with the exception of vineyards and orchards and other perennial crops within 13 km (8 miles) of potentially suitable breeding habitat. Winter season foraging habitat consists of all of these categories without distance restrictions.

Non-agricultural foraging habitat in the Delta consists of the following types from the BDCP composite vegetation layer:

- Grassland
    - All types.
- Managed wetland
    - All types.
- Alkali seasonal wetland complex
    - All types.
- Other natural seasonal wetland
    - All types.
- Vernal pool complex
    - Annual grasses generic;
    - Annual grasses/weeds;

  - California annual grasslands;
  - *Distichlis* (generic);
  - *Distichlis spicata;*
  - *Distichlis spicata* – annual grasses;
  - *Distichlis*/annual grasses;
  - *Distichlis*/*S. Maritimus;*
  - Ruderal herbaceous grasses and forbs;
  - Italian rye-grass *(Lolium multiflorum);*
  - *Salicornia virginica*[4]*;* and
  - *Salicornia*/annual grasses.

Non-agricultural foraging habitat in the Suisun Marsh and Yolo Basin consists of the following types from the BDCP composite vegetation layer:

- *Bromus* spp./*Hordeum;*
- *Crypsis schoenoides;*
- *Crypsis* spp. – wetland grasses – wetland forbs;
- Cultivated annual graminoid;
- *Cynodon dactylon;*
- *Distichlis*/annual grasses;
- *Distichlis* (generic);
- *Distichlis spicata;*
- *Distichlis*/annual grasses;
- *Distichlis/Cotula;*
- *Distichlis/Juncus;*
- *Distichlis/Lotus;*
- *Distichlis/S. americanus;*
- *Distichlis/S. maritimus;*
- *Distichlis/Salicornia;*
- *Distichlis-Juncus-Triglochin-Glaux;*
- *Hordeum/Lolium;*

[4] Currently known as *Sarcocornia pacifica*.

- *Lotus corniculatus;*
- Medium upland herbs;
- Medium wetland graminoids;
- Medium wetland herbs;
- Pasture;
- Perennial grass;
- Short upland graminoids;
- Short wetland graminoids;
- Tall wetland graminoids;
- Upland annual grasslands and forbs formation; and
- Upland herbs.

A18.7.1 Agriculture

The following DWR 2007 land use survey types are included as suitable agricultural foraging habitats for tricolored blackbirds. These types represent the typical agricultural crop types and uses in the Plan Area that are included in the DWR 2007 land use survey. Rotational crop types that are not common to the Plan Area are not included here. Pasture types are mostly perennial; alfalfa is semi-perennial (3 to 7 years); and all other types are annually or seasonally rotated irrigated crops, only some of which provide suitable habitat for tricolored blackbirds.

- Grain and hay crops
    - Barley;
    - Wheat;
    - Oats; and
    - Miscellaneous and mixed grain and hay.
- Field crops
    - Safflower;
    - Sugar beets;
    - Corn;
    - Grain sorghum;
    - Sudan;
    - Beans;
    - Miscellaneous field; and
    - Sunflowers.
- Pasture

  - Alfalfa and alfalfa mixtures;
  - Clover;
  - Mixed pasture;
  - Native pasture;
  - Induced high water table native pasture; and
  - Miscellaneous grasses.
- Truck, nursery, and berry crops
  - Asparagus;
  - Beans;
  - Onions and garlic;
  - Tomatoes; and
  - Peppers.
- Idle
  - Land not cropped the current or previous crop season, but cropped within the past three years; and
  - New lands being prepped for crop production.
- Semiagricultural and incidental to agricultural
  - Livestock feed lots; and
  - Dairies.

Assumptions. During the breeding season, tricolored blackbirds usually forage within 5 km (3.1 miles) of the colony, but can range up to 13 km (8 miles) from the colony (Beedy and Hamilton 1999). However, during the winter, the species forages widely throughout the Plan Area without regard to proximity of colony sites or breeding habitats.

Suitable agricultural lands generally include pasturelands, grain and hay crops, safflower and sorghum, and certain other annually rotated irrigated crops. Tricolored blackbirds also forage in livestock feedlots, dairies, and poultry farms. Not all agricultural crop types are considered suitable for foraging, but because the Grain and hay; Field; and Truck, nursery, and berry crop types listed above are seasonally rotated, the value of individual fields changes each year. Therefore, these crop types are not differentiated based on their seasonal value and are instead combined into a category of seasonally rotated croplands. As a result, this model overestimates the extent of available agricultural foraging habitat in any given year.

A18.8 RECOVERY GOALS

A USFWS recovery plan has not been prepared for this species, and no recovery goals have been established.

A18.9 REFERENCES

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APPENDIX A19. SUISUN SONG SPARROW (*MELOSPIZA MELODIA MAXILLARIS*)

A19.1 LEGAL STATUS

The Suisun song sparrow *(Melospiza melodia maxillaris)* has no federal legal status. A petition for listing it as a federal endangered species was submitted in 1987, but the U.S. Fish and Wildlife Service (USFWS) considered the petition unwarranted.

The species is a third priority California Bird Species of Special Concern (Spautz and Nur 2008).

A19.2 SPECIES DISTRIBUTION AND STATUS

A19.2.1 Range and Status

The Suisun song sparrow is one of 24 subspecies of *Melospiza melodia*, and one of three that occur in the San Francisco Bay estuary (Modesto song sparrow *[M.m. mailliardi]* may be a fourth subspecies; however, its taxonomic status is currently under review, and further research is necessary to determine its status as a valid subspecies [Gardali 2008]). *M.m. samuelis* occurs in salt marshes of north San Francisco and San Pablo bays, and *M.m. pusillula* occurs in salt marshes of south San Francisco Bay. The Suisun song sparrow is endemic to the salt marshes of the Suisun Bay, and while it has been confirmed to be phenotypically distinct from neighboring subspecies (Patten 2001), genetic differentiation has not been confirmed (Chan and Arcese 2002). Its year-round range is confined to tidal salt and brackish marshes of the Suisun Bay area from the Carquinez Strait east to Antioch at the confluence of the San Joaquin and Sacramento rivers (Grinnell and Miller 1944, Spautz and Nur 2008). The current range remains relatively unchanged since Grinnel and Miller's (1944) description. However, the current distribution of the species within this area is defined by the extent of remaining tidal marsh habitats, which occur primarily along the fringes of the Carquinez Strait and Suisun Bay (Figure A-19a).

Spautz and Nur (2008), citing unpublished data from the Point Reyes Bird Observatory, estimated the total population of Suisun song sparrows as 43,000 to 66,000 breeding pairs, approximately one-third of the estimated historical population size (Spautz and Nur 2008). The subspecies occurs in virtually every tidal marsh in Suisun Bay; however, densities differ widely based on habitat conditions and suitability (Spautz and Nur 2008).

A19.2.2 Distribution and Status in the Plan Area

The range of the Suisun song sparrow extends into the Plan Area to approximately Kimbal Island. However, the majority of the range of the species is included within the Suisun Marsh Restoration Opportunity Area (Figure A-19b). There are several reported occurrences from Kimbal Island, Browns Island, and in the Suisun Marsh in the western portion of the Plan Area.

DRAFT

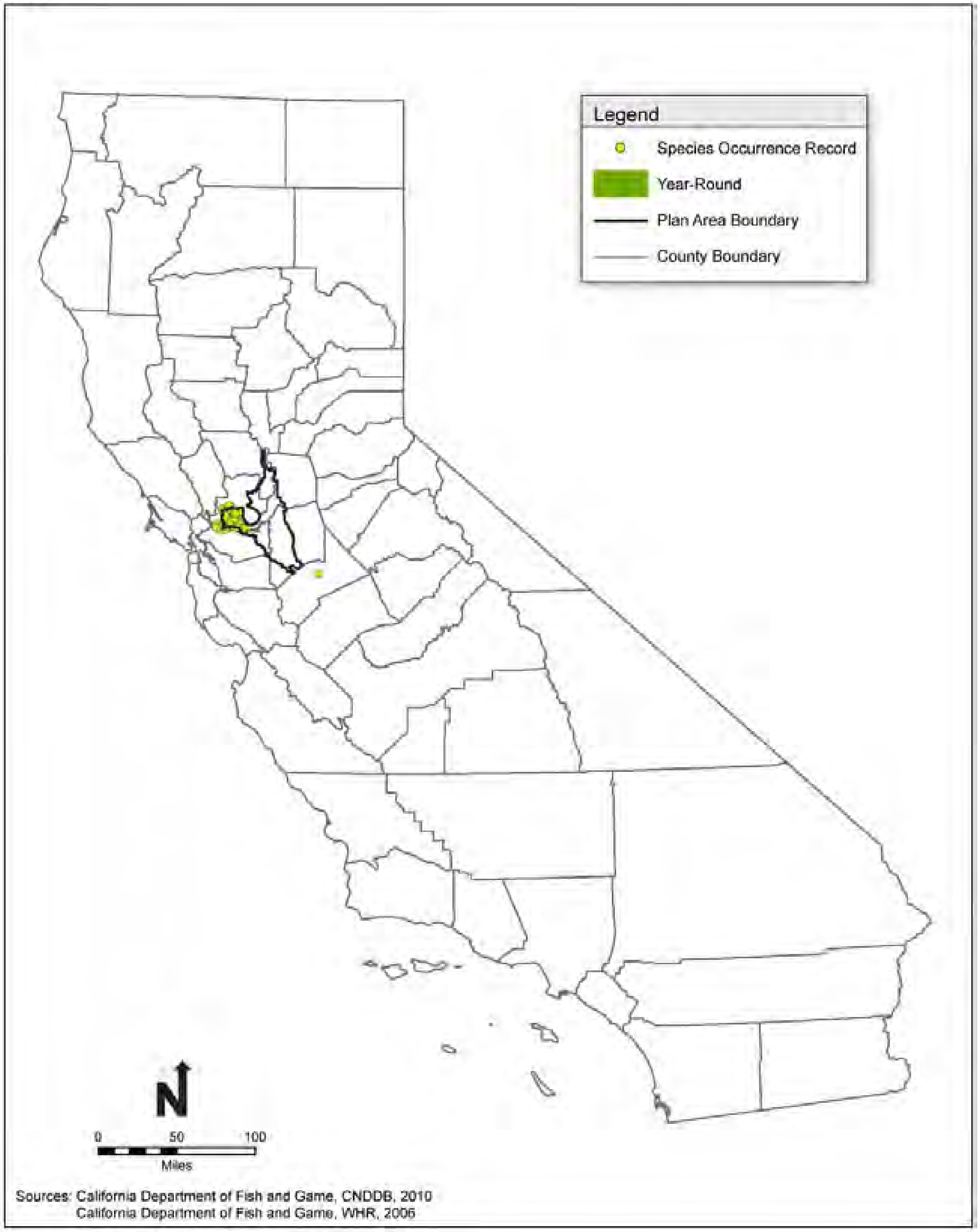

Figure A-19a. Suisun Song Sparrow Statewide Range and Recorded Occurrences

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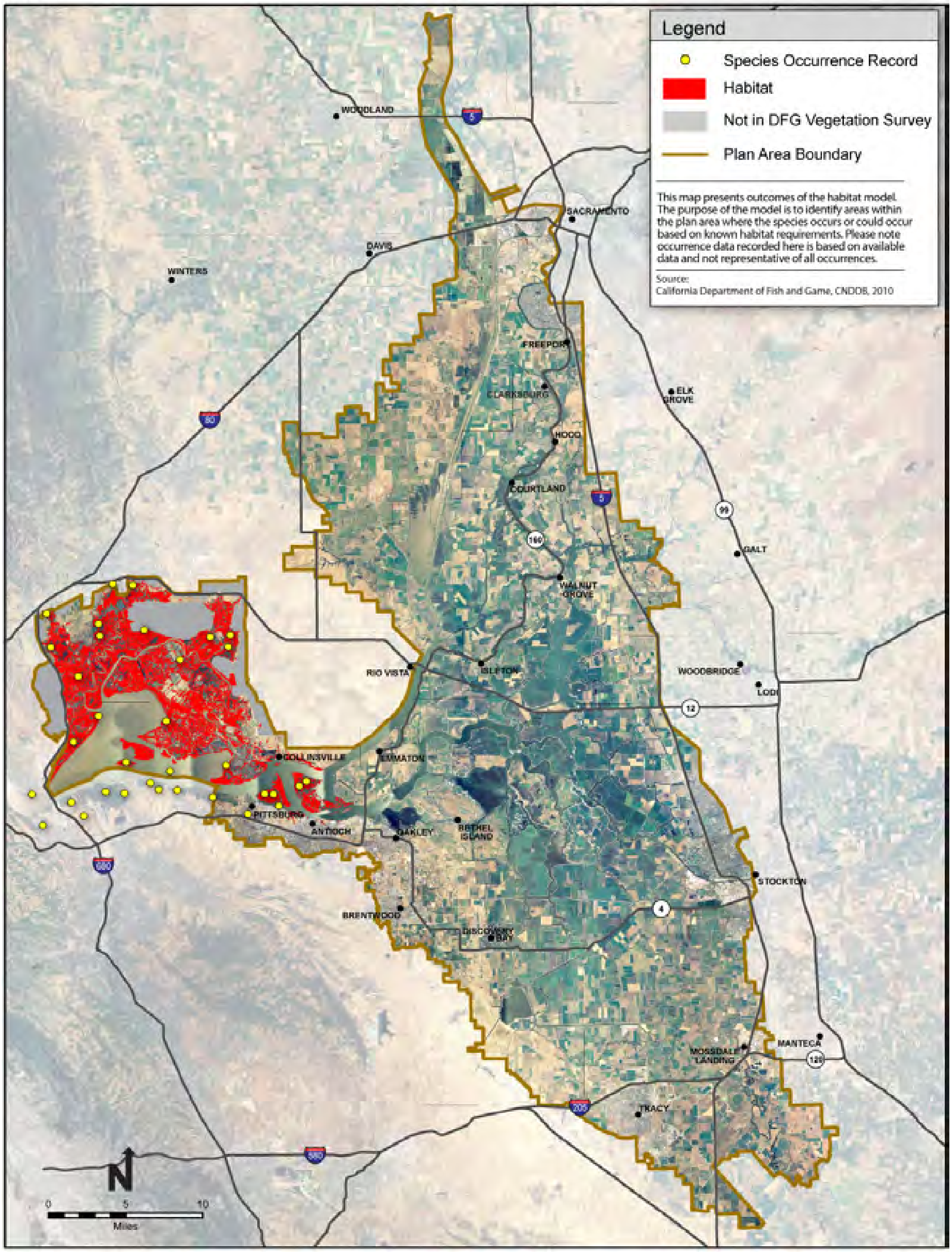

Figure A-19b. Suisun Song Sparrow Habitat Model and Recorded Occurrences

A19.3 Habitat Requirements and Special Conditions

Suisun song sparrows are associated with tidal marsh habitats dominated by *Sarcocornia*[1], *Spartina*, and *Grindelia*. In brackish marsh habitats, these types are interspersed mostly with *Schoenoplectus*[2], *Typha*, and *Juncus*. Dense vegetation is required for nesting sites, song perches, and refuge from predators (Marshall 1948). There is also an association with tidal channels in areas where *Sarcocornia* or *Spartina* are the dominant landscape cover and *Grindelia* or shrubs occur along the edges of the channels, providing nesting and perching habitat (Spautz and Nur 2008). The association with channels is weaker in brackish marshes with extensive cover of *Schoenoplectus* and *Typha* (Spautz and Nur 2008).

While dense vegetation is characteristic, exposed ground is important for foraging. The song sparrow is the only obligate ground foraging bird in the tidal brackish marsh, and the species occupies an uncontested niche by foraging on the surface of the mud (Larsen 1989). In tidal marsh habitats, openings in the dense *Sarcocornia*, created by small mammals or tidal action, are required for foraging access. In *Schoenoplectus/Typha*-dominated habitats, plant spacing needs to be sufficient to provide openings for foraging and movement on the ground (Marshall 1948).

Spautz et al. (2006) analyzed abundance with a series of vegetation and habitat variables. They found a positive correlation with shrub cover, particularly *Gindelia stricta* and *Baccharis pilularis* (coyote bush), marsh size, and proportion of adjacent natural upland. In general, they found that song sparrows tend to be denser along upland edges of large marshes, especially where shrubs are present (Spautz et al. 2006). Abundance ranges from approximately 3 to 15 birds per hectare (2.5 acres), depending on habitat quality (Marshall 1948, Marshall and Dedrick 1994, Spautz and Nur 2008).

Nesting territories are established linearly every 10 to 50 meters (33 to 164 feet) along sloughs or other channels or along upland edges of marshes. Open marshes away from meandering channels are usually avoided. Each territory requires sufficient area for nesting and foraging, including tidally exposed mud, water, and vegetation suitable for nesting and cover (Walton 1975).

Nests are constructed in a variety of substrates, including *Schoenoplectus americanus*, *S. maritimus*, *S. acutus*, *Grindelia stricta*, *Lepidium latifolium*, *Sarcocornia pacifica*, and *Distichlis spicata*, among others (Spautz and Nur 2008). Nest heights average 36 centimeters (1.2 feet) (Herzog et al. 2004, Spautz et al. 2006) and are usually placed at a height in the vegetation where they can clear flood tide levels while still having cover from taller plants to minimize exposure to predation (Johnston 1956).

[1] Formerly known as *Salicornia*.
[2] Formerly known as *Scirpus*.

A19.4 LIFE HISTORY

Description. The Suisun song sparrow is a small passerine with a large head and plump build, conical bill, short rounded wings, and slender tail with a blunt tip (Arcese et al. 2002). Plumage is characterized by a dark streaked breast and mantle, usually well-defined on a gray or whitish background. The longitudinal streaks align into rows on the back and ventrally gather into a variably defined spot on the chest, leaving the lower belly largely unstreaked. Eyebrows are grayish, and a broad, dark stripe borders the whitish throat. Legs and feet are a pinkish color. The Suisun song sparrow is the darkest of the three subspecies occurring in the San Francisco Bay estuary. Coloration on the back is dark reddish-brown, which distinguishes it from the olive-brown of *M.m. samuelis* and the yellowish gray or plain gray of *M.m. pusillula* (Larsen 1989). The Suisun song sparrow also has a larger, thicker bill than the other neighboring subspecies (Marshall 1948).

Seasonal Patterns. The Suisun song sparrow is non-migratory and occupies the same territory year-round.

Reproduction. The Suisun song sparrow begins breeding relatively early in the spring, an adaptation thought to avoid the highest spring tides, which is a mortality factor for eggs and young (Johnston 1954). Breeding generally occurs from March to June, but this species can produce more than one brood per year and construct up to three nests each year. These activities are influenced by tidal activity and associated habitat and food availability and the outcome of the initial nesting attempt (Johnston 1954). Clutch size averages 3.2 eggs per nest; over the breeding season, the average total number of eggs per pair ranges from 7.5 to 9.1 (Johnston 1956). Productivity per pair over the season varies from 2.0 to 5.8 fledglings per pair per season (Johnston 1956).

Home Range/Territory Size. During the breeding season, the Suisun song sparrow occupies small territories (approximately 0.04 hectares [0.1 acre] in optimal habitat), usually adjacent to the territories of other Suisun song sparrows in a single linear arrangement along the edges of sloughs and bays. Each pair remains within its limited territory during the breeding season. All requirements for nesting and foraging, including tidally exposed mud, water, light, and vegetation suitable for nesting and cover is met within the territory. During the fall and winter, adults and young may range up to 183 meters (600 feet) from the territory and occupy adjacent seasonal marshes or grasslands, but continue to occupy the same general area and return to the same breeding territory each year (Marshall 1948, Walton 1975).

Foraging Behavior and Diet. Suisun song sparrows forage on the bare surface of tidally exposed mud and along slough margins in the salt and brackish marshes of Suisun Bay during low tides. They feed on *Schoenoplectus* and other seeds once they have fallen to the ground, insects (mostly mosquito larvae and flies), and other invertebrates exposed during low tides (Marshall 1948, Walton 1975). While foraging, the Suisun song sparrow hops along the ground with both feet together, scratches leaf litter by pushing both feet simultaneously, or flycatches using hopping and darting motions with outstretched wings for balance (Bent 1968).

A19.5 Threats and Stressors

Habitat Loss and Fragmentation. Habitat loss and fragmentation, caused by diking, levee construction, channelization, invasive species, and urbanization, is considered the primary threat to the continued existence of the Suisun song sparrow (Larsen 1989, Spautz and Nur 2008). Throughout most of the Suisun Marsh, the tidal marsh has been reduced to small fragments that are separated by dispersal barriers or only connected by very narrow strips of vegetation remaining along the banks of tidal sloughs, reducing dispersal, gene flow, and reproduction (Larsen 1989). Large-scale habitat loss can also occur through the effects of global climate change and the resulting rise in sea level. With a projected 0.4-meter (1.3-foot) rise in sea level (IPCC 2001), large areas of tidal marsh in the Suisun Marsh could be inundated, thus making them unsuitable for the Suisun song sparrow (Spautz and Nur 2008). This may be of particular concern in the Suisun Marsh and similar areas where urbanization around the marsh perimeter has removed adjacent natural habitat and thus restricted potential expansion of the marsh in response to sea level rise over time (Orr et al. 2003).

Nest Predation. Spautz and Nur (2008) note that reproductive failure caused by high levels of nest predation may also be a significant threat to the Suisun song sparrow. Nonnative predators include the house cat *(Felix catus)*, Norway rat *(Rattus norvegicus)*, and red fox *(Vulpes fulva)*. Native predators include the American crow *(Corvus brachyrynchos)* and common raven *(Corvus corax)*.

Toxics. While there are regulations that protect most of the remaining tidal marshes inhabited by Suisun song sparrows, the urbanization of the surrounding area contributes to other threats that may alter water salinity and introduce toxins into the system, such as oil spills, chemical contamination, sewage, and other waste. Shipping activities along major channels, including oil tanker traffic and the presence of toxic waste dumps in the area, pose potential contamination issues (Larsen 1989).

Diking, channelization, development, and a substantial decrease in freshwater outflow from the Sacramento-San Joaquin Delta have greatly reduced the habitat that supports this subspecies. The remaining habitat is highly fragmented, existing in thin strips along the inside edges of tidal sloughs.

Salinity Changes. Normal salinity of the Suisun Marsh is a function of the amount of freshwater outflow it receives from the Sacramento-San Joaquin Delta. Disruption of normal outflows can have a detrimental effect on this species. While the Suisun song sparrow has the ability to adapt to short-term changes in water salinity, the species requires a relatively narrow range of saline conditions for long-term survival. Significant alterations in the salinity content can result in undesirable habitat changes, lower reproductive output, competition, and genetic dilution from neighboring subspecies that have a greater range of tolerance (Larsen 1989).

A19.6 RELEVANT CONSERVATION EFFORTS

The Suisun Marsh has been the subject of various conservation efforts for many years, particularly with respect to development and issues related to water quality within its boundaries. The California Department of Water Resources (DWR) Suisun Marsh Program (http://www.iep.water.ca.gov/suisun/program/index.html) summarizes the major agreements, management plans, and legislation that have directed management of the Suisun Marsh since the mid-1970s. These efforts focus on the preservation and restoration of tidal marsh habitats.

The Nejedly-Bagley-Z'Berg Suisun Marsh Preservation Act (1974). The California Legislature enacted the Suisun Marsh Preservation Act to protect the marsh from urban development. It required the San Francisco Bay Conservation and Development Commission (BCDC) to develop a plan for the marsh and provides for various restrictions on development within marsh boundaries.

Suisun Marsh Protection Plan (1976). This plan was developed by the BCDC and defines and limits development within primary and secondary management areas for the "future of the wildlife values of the area as threatened by potential residential, commercial and industrial development." It recommends that the state purchase 1,800 acres (728 hectares) and maintain water quality. While the focus of the plan is on maintaining waterfowl habitat, it also addresses the importance of tidal wetlands and recommends restoring historical marsh areas to wetland status (managed or tidal).

The Suisun Marsh Protection Act (1977). This bill adopts and calls for implementation of the Suisun Marsh Protection Plan. Assembly Bill (AB) 1717 designates the BCDC as the state agency with regulatory jurisdiction of the marsh and calls for the Suisun Resource Conservation District to have responsibility for water management in the marsh. The bill identifies (and focuses on) actions for the preservation of waterfowl needs, along with the retention of the diversity of wildlife. It states that land within the Suisun Marsh should be acquired for public use or resource management if it is suitable for restoration to tidal or managed marsh, but that such restoration cannot be required as a condition of private development.

State Water Resources Control Board (SWRCB) Water Rights Decision 1485 (1978). SWRCB adopted the Water Quality Control Plan for the Sacramento-San Joaquin Delta and issued Water Rights Decision 1485. The decision sets channel water salinity standards for the period from October to May and preserves the area as brackish water tidal marsh. It sets water quality standards in the marsh as a condition of export pumping. These come from the California Department of Fish and Game's (DFG's) recommendations, which were based on (1) the relative value of marsh plants as duck food; (2) the influence of soil salinity and other factors on distribution and growth of marsh plants; and (3) the relationships between channel water salinity and soil salinity. DFG concluded that improved management practices, improved drainage, water control facilities, and adequate quality of water were needed to achieve desired soil salinity conditions for waterfowl food plants.

Plan of Protection for the Suisun Marsh (1984). DWR and the U.S. Bureau of Reclamation (USBR) developed and began implementing the Plan of Protection (POP) in accordance with Water Rights Decision 1485. The POP implementation strategy was to construct large facilities and distribution systems to meet salinity standards (lower channel water salinity), in lieu of significant Central Valley Project/State Water Project storage releases estimated as high as 2 million acre-feet in dry/critical water years. The six-phase POP was the programmatic blue print (required by the SWRCB and embodied in the original Suisun Marsh Preservation Agreement). Two of the six phases were completed, including the Initial Facilities and the Suisun Marsh Salinity Control Gates.

Suisun Marsh Preservation Agreement (SMPA) (1987). This contractual agreement between DWR, USBR, DFG, and Suisun Resource Conservation District contains provisions for DWR and USBR to mitigate the effects on Suisun Marsh channel water salinity from the State Water Project and Central Valley Project operations and other upstream diversions. The SMPA requires DWR and USBR to meet salinity standards, sets a timeline for implementing the POP, and delineates monitoring and mitigation requirements. The Suisun Marsh Monitoring Agreement and the Suisun Marsh Mitigation Agreement were also signed at this time. The Suisun Marsh Mitigation Agreement defines habitat requirements to mitigate effects of facilities and operations, and the Suisun Marsh Monitoring Agreement defines requirements for monitoring salinity and species in the Suisun Marsh.

Bay-Delta Accord (1994). On December 15, 1994, federal and state agencies, working with agricultural, environmental and urban stakeholders, reached an agreement on water quality standards and related provisions that would remain in effect for 3 years. This agreement, known as the Bay-Delta Accord, was based on a proposal developed by the stakeholders. Elements of the agreement include the following:

- Springtime export limits expressed as a percentage of Delta inflow;
- Regulation of the salinity gradient in the estuary so that a salt concentration of two parts per thousand is positioned where it may be more beneficial to aquatic life;
- Specified springtime flows on the lower San Joaquin River to benefit Chinook salmon; and
- Intermittent closure of the Delta Cross Channel gates to reduce entrainment of fish into the Delta.

SWRCB Water Quality Control Plan (1995–1998). In 1994, wildlife and fishery agencies and urban water users expressed concerns about the appropriateness of western Suisun Marsh channel water salinity standards. In May of 1995, the SWRCB modified the Suisun Marsh salinity objectives in the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Modeling analysis by the Suisun Marsh Planning Program showed that Suisun Marsh standards would be met most of the time at all Suisun Marsh compliance stations. Some standard exceedances would be expected in the western Suisun Marsh that participants in the SMPA agreed could be mitigated by more-active water control by landowners.

SWRCB Water Rights Decision 1641 (1999). The SWRCB issued Decision 1641 in December 1999, which updated salinity standards for Suisun Marsh. Increased outflow and salinity requirements for the Bay-Delta provided indirect benefits to the Suisun Marsh. DWR proposed that the SWRCB adopt the Amendment Three actions for Suisun Marsh in this decision. However, the SWRCB was unable to adopt Amendment Three actions because the Section 7 consultation with the U.S. Fish and Wildlife Service (USFWS) had not concluded. However, the SWRCB did relieve USBR and DWR of their responsibility to meet salinity objectives at S-35 and S-97 in the western Suisun Marsh.

Suisun Marsh Charter Implementation Plan (2001). The Suisun Marsh Charter was completed in 2001, and development of an Implementation Plan commenced. Charter participants collaborated on a joint presentation to the State of the Estuary Conference on the principles of the Charter Plan, including coordinated water quality, endangered species, and heritage value protection in the Suisun Marsh.

Habitat Management, Preservation, and Restoration Plan (2003). The Charter process was expanded to include additional federal and state agencies to develop a Suisun Marsh Plan that will balance the goals and objectives of the Bay-Delta Program, SMPA, and other management and restoration programs within the Suisun Marsh in a manner that is responsive to the concerns of all stakeholders and is based upon voluntary participation by private landowners.

In addition, several facilities have been constructed in the Suisun Marsh to protect and improve water quality and protect and enhance wildlife habitat, including:

- Roaring River Distribution System (1979–80);
- Morrow Island Distribution System (1979–80;
- Goodyear Slough Outfall (1979–80);
- Suisun Marsh Salinity Control Gates (1988); and
- Cygnus and Lower Joyce Facilities (1991).

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy (MSCS) designation for Suisun song sparrow is “Recovery” (CALFED Bay-Delta Program 2000). This means that the ERP has established a goal to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

The Suisun song sparrow is also proposed for coverage under the Solano County Multispecies Habitat Conservation Plan.

A19.7 Species Habitat Suitability Model

Model Approach. BDCP Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information systems (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which are incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and revise the vegetation input data as necessary.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements, and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate, as well as overestimate, the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small, isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; instead, the models indicate that non-habitat areas have a much lower probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percentage cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf (2007). Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers; connectivity between habitat types; and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or underestimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The Suisun song sparrow model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), USDA 2005 aerial photography, and DWR 2007 land use survey of the Delta and Suisun Marsh area-version. Using these data sets, the model maps the distribution of suitable Suisun song sparrow habitat in the Plan Area. Vegetation types were assigned based on the species requirements, as described above, and the assumptions described below.

Breeding Habitat. Suisun song sparrow habitat consists of all *Salicornia*[3]-dominated tidal brackish emergent wetland and all *Typha*-, *Scirpus*[4]-, and *Juncus*-dominated tidal freshwater emergent wetland within the Plan Area west of Sherman Island.

Suisun song sparrow habitat in the Delta consists of the following types from the BDCP composite vegetation layer:

- Managed wetland
    - o *Scirpus*[6] spp. in managed wetlands.
- Alkali seasonal wetland complex
    - o *Distichlis spicata – Salicornia virginica*[5]*;*
    - o *Distichlis spicata – Juncus baltica;*
    - o *Juncus bufonius* (salt grasses);
    - o *Juncus balticus* – meadow vegetation;
    - o Pickleweed *(Salicornia virginica);* and
    - o *Salicornia virginica – Cotula coronopifolia.*
- Freshwater perennial emergent wetland
    - o Broad-leaf cattail *(Typha latifolia).*
- Tidal freshwater emergent wetland and tidal brackish emergent wetland
    - o Mixed *Scirpus* mapping unit;
    - o Mixed *Scirpus*/floating aquatics complex;

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[3] Currently known as *Sarcocornia*.
[4] Currently known as *Schoenoplectus*.
[5] Currently known as *Sarcocornia pacifica*.

- Mixed *Scirpus*/submerged aquatics complex;
- Hard-stem bulrush *(Scirpus acutus);*
- *Scirpus acutus* pure;
- *Scirpus acutus – Typha angustifolia;*
- *Scirpus acutus – Typha latifolia;*
- *Scirpus acutus – (Typha latifolia) – Phragmites australis;*
- California bulrush *(Scirpus californicus);*
- *Scirpus californicus – Eichhornia crassipes;*
- *Scirpus californicus – Scirpus acutus;*
- American bulrush *(Scirpus americanus);*
- Narrow-leaf cattail *(Typha angustifolia);* and
- *Typha angustifolia – Distichlis spicata.*

Suisun song sparrow habitat in the Suisun Marsh consists of the following types from the BDCP composite vegetation layer:

- Bulrush – cattail freshwater marsh NFD super alliance;
- *Grindelia stricta* var. *stricta;*
- *Juncus balticus;*
- *Juncus balticus/Conium;*
- *Juncus balticus/Lepidium;*
- *Juncus balticus/Potentilla;*
- *Ledidium* (generic);
- *Lepidum/Distichlis;*
- *Salicornia* (generic);
- *Salicornia virginica;*
- *Salicornia/*annual grasses;
- *Salicornia/Atriplex;*
- *Salicornia/Cotula;*
- *Salicornia/Crypsis;*
- *Salicornia/Polygonum-Xanthium-Echinochloa;*
- *Salicornia/Sesuvium;*
- *Scirpus (californicus* or *acutus)-Typha* spp.;

- *Scirpus (californicus* or *acutus)-Rosa;*
- *Scirpus (californicus* or *acutus)/*wetland herb;
- *Scirpus americanus* (generic);
- *Scirpus americanus/Lepidium;*
- *Scirpus americanus/Potentilla;*
- *Scirpus americanus/S. Californicus-S. acutus;*
- *Scirpus californicus/S. acutus;*
- *Scirpus maritimus;*
- *Scirpus maritimus/Salicornia;*
- *Scirpus maritimus/Sesuvium;*
- *Typha angustifolia* (dead stalks);
- *Typha angustifolia/Distichlis;*
- *Typha angustifolia/Phragmites;*
- *Typha angustifolia/Polygonum-Xanthium-Echino;*
- *Typha angustifolia/S. americanus;* and
- *Typha* species (generic).

Assumptions. Suisun song sparrows are found exclusively in tidal marshes of the Suisun Bay and as far east as Kimbal Island in the western Delta (Spautz and Nur 2008). They nest and forage in tidal brackish emergent wetland habitats dominated by *Spartina*, *Salicornia*, and *Grindelia* spp. and tidal freshwater emergent wetland habitats dominated by *Scirpus*, *Typha*, and *Juncus* spp. and, to an increasing extent, *Lepidium latifolium* (Spautz and Nur 2008). Specific habitat elements, including proximity to tidal channels, percentage of shrub cover, and site-specific vegetation associations that could potentially refine the extent of the suitable habitat conditions were not sufficiently identified in the GIS databases, and thus were not used in the model. Therefore, the model likely overestimates the extent of potentially occupied tidal marsh habitat.

A19.8 Recovery Goals

A USFWS recovery plan has not been prepared for this species, and no recovery goals have been established; however, the CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for Suisun song sparrow is "Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP has established a goal to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

A19.9 References

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APPENDIX A20. YELLOW-BREASTED CHAT (*ICTERIA VIRENS*)

A20.1 LEGAL STATUS

The yellow-breasted chat *(Icteria virens)* is designated as a state Bird Species of Special Concern by the California Department of Fish and Game (DFG) (Shuford and Gardali 2008). In California, nests are protected under *Fish and Game Code*, Section 3503. The yellow-breasted chat has no federal regulatory status; however, the species is protected under the federal Migratory Bird Treaty Act.

A20.2 SPECIES DISTRIBUTION AND STATUS

A20.2.1 Range and Status

The yellow-breasted chat is a neotropical migrant songbird that breeds in North America and winters in Central America, primarily in Mexico and Guatemala, although a few birds winter in southern California (Small 1994). The species' range includes most of the continental United States and Mexico. Yellow-breasted chats are widespread summer residents of eastern North America; however, they have a much more fragmented distribution in western North America (USFS 2008). In western North America, their range includes the Cascade Range; central Oregon valleys; southern Idaho and northern Nevada; and portions of California, Utah, western Colorado, and central Arizona (USFS 2008).

Grinnell and Miller (1944) reported that chats bred over the entire length and breadth of California exclusive of higher mountains and coastal islands, and were more numerous toward the interior. In migration, chats were similarly widespread with fewer restrictions as to habitat (dense riparian plant growth). In California, the species' current range is not completely known because of population declines (Small 1994); however, the species is thought to inhabit most of its historical range, with the exception of most of the Central Valley (Comrack 2008) (Figure A-20a).

This species was formerly a common summer resident in coastal southern and central California, along the Colorado River, and throughout the Central Valley (Grinnell and Miller 1944). However, the species is currently reported as an uncommon resident in riparian habitats on the Modoc Plateau, Klamath Mountain region, along the north and south Coast Ranges, in the Sierra Nevada foothills, and in the Transverse and Peninsular Ranges (Small 1994, Eckerle and Thompson 2001). It appears to be extirpated from the San Joaquin and Sacramento valleys, but still occurs along some foothill tributaries.

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Figure A-20a. Yellow-Breasted Chat Statewide Range and Recorded Occurrences

Few data are available regarding population decreases or increases over large sections of the species' range (Eckerle and Thompson 2001). California Breeding Bird Survey data from 1966 through 1998 show an increasing trend of 1.1 percent per year (Sauer et al. 1999, Ricketts and Kus 2000). However, these data are not considered statistically significant and should be interpreted with caution (Ricketts and Kus 2000). The species has apparently declined dramatically in southern California (Garrett and Dunn 1981).

A20.2.2 Distribution and Status in the Plan Area

Comrack (2008) includes the central Delta within the current breeding range of the yellow-breasted chat. There are few breeding records of yellow-breasted chat from this area or elsewhere within the Plan Area (Figure A-20b). Most are fall and winter migrants found along Putah Creek near the northern edge of the Plan Area in Yolo and Solano Counties or along the Cosumnes River within the Cosumnes River Preserve. The National Audubon Society (2008) notes that several pairs of yellow-breasted chat have been recorded at several locations in the Sacramento-San Joaquin Delta, including Liberty Island, Sherman Island, and Piper Slough. However, no additional information was found to confirm nesting activity at these locations. Comrack (2008) also reported breeding records from the Contra Costa Breeding Bird Atlas within the Delta and additional breeding records from White Slough in San Joaquin County. Recent Delta Habitat Conservation and Conveyance Program (DHCCP) field surveys have confirmed late-spring and summer occurrences of chats within the Plan Area. While breeding has not yet been confirmed, this suggests a reasonable possibility that the species is breeding within the Plan Area.

A20.3 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

Yellow-breasted chats nest and forage in dense riparian thickets of willows, vines, and brush associated with streams and other wetland habitats (Small 1994). The species has been classified as an open-canopy obligatory species (i.e., it prefers open overstory and brushy understory), with population density directly related to shrub density to a height of 4.5 meters (14.8 feet) (Crawford et al. 1981). Some taller trees, such as tall willows (*Salix* spp.), cottonwood (*Populus* spp.), and sycamore (*Platanus* spp.) are also required for song perches (Dunn and Garrett 1997). Several studies indicate a strong association with early successional vegetation, including clearcut areas and powerline corridors with dense shrubby vegetation such as Himalayan blackberry (*Rubus discolor*), wild grape (*Vitis* spp.), and/or willows (*Salix* spp.), with sapling-sized trees as opposed to mature riparian forest (Kroodsma 1982, Melhop and Lynch 1986, Annand and Thompson 1997, Comrack 2008). Kroodsma (1982) also reported a preference for blackberry (*Rubus* spp.) thickets and avoidance of areas with a high percentage of grass cover.

Yellow-breasted chats occur up to 1,463 meters (4,800 feet) in valley foothill riparian habitats and up to 1,981 meters (6,499 feet) east of the Sierra Nevada in desert riparian habitats (DeSante and Ainley 1980, Garrett and Dunn 1981, Gaines 1992). Nests are usually constructed low to the ground (usually within 1 meter) in dense shrubs (Barber and Martin 1997, Ricketts 1999).

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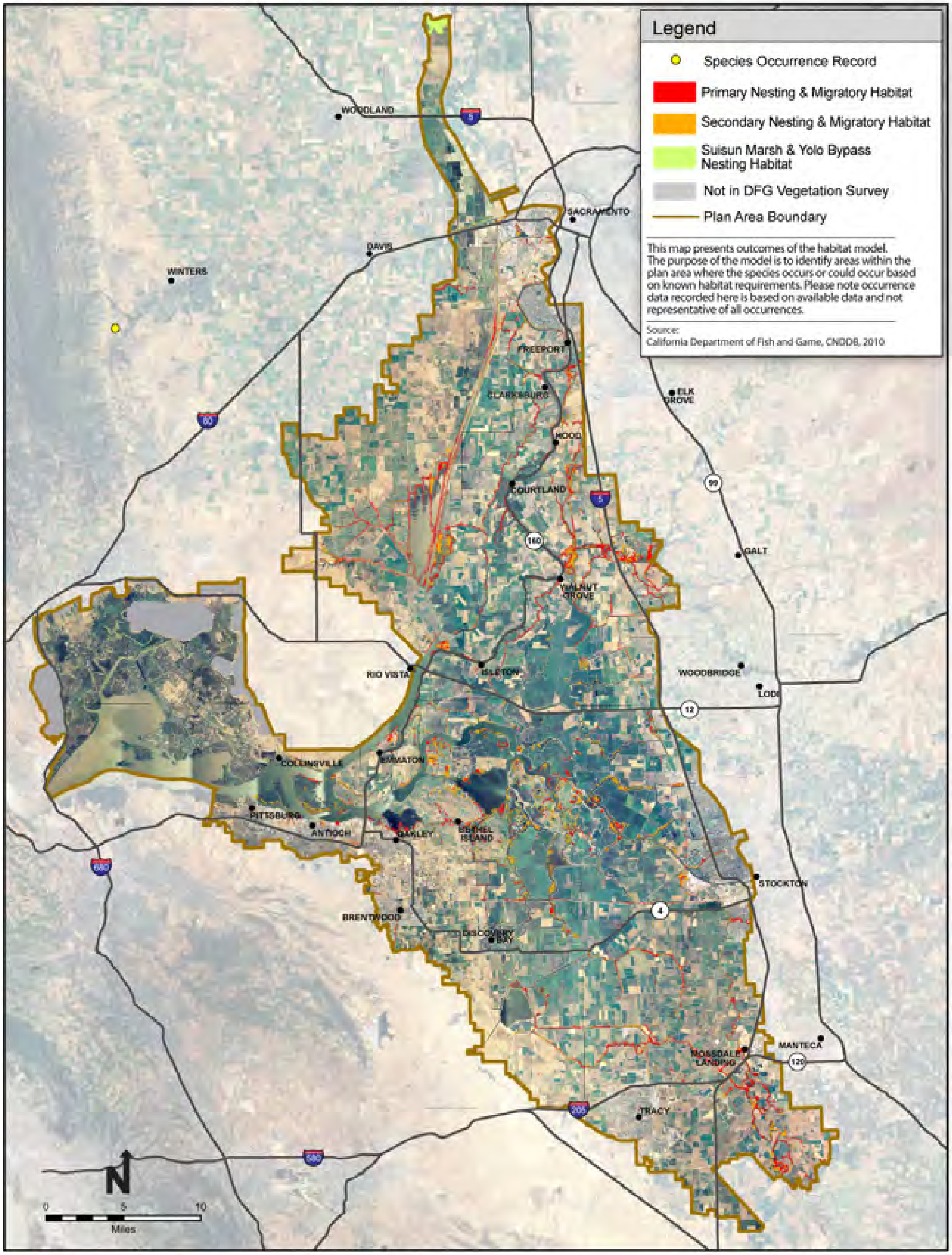

Figure A-20b. Yellow-Breasted Chat Habitat Model and Recorded Occurrences

A variety of trees and shrubs are used as nest substrate, including willow; alder; and several shrub species, including blackberry. At the Lower Clear Creek Floodway in Shasta County, Burnett and DeStaebler (2003) found that most chat nests were associated with Himalayan blackberry. Other species used for nesting include California blackberry, California wild rose *(Rosa californica),* and pipevine *(Aristolochia macrophylla)* (Ricketts and Kus 2000). Additionally, chats have been found to use saltcedar preferentially to native habitat (Hunter et al. 1988). During migration, yellow-breasted chats use habitat similar to their breeding habitat (Dunn and Garrett 1997).

A20.4 LIFE HISTORY

Description. The yellow-breasted chat is the largest of the North American warblers (average total length equals 13.3 centimeters [cm] [5.2 inches]; average wing length equals 17.8 cm [7.0 inches]; average weight equals 11 grams [0.39 ounces]). The sexes are similar, with plain olive-green to olive-gray upperparts, a deep yellow throat and breast, and a grayish face with black lores, white supercilium, and whitish spectacles contrasting with the surrounding feathers (Dunn and Garrett 1997, Eckerle and Thompson 2001).

Seasonal Patterns. Yellow-breasted chats are migratory and usually arrive at California breeding grounds in April from their wintering grounds in Mexico and Guatemala (Green 2005). Northern populations may arrive at breeding grounds from late April to early May (Ricketts and Kus 2000). In the Sierra Nevada, they may move upslope after breeding (Gaines 1992). Departure for wintering grounds occurs from August to September (Ricketts and Kus 2000). Spring migration occurs from March to May (Dunn and Garrett 1997).

Little information is available on juvenile dispersal. Banding studies in Indiana showed that many juveniles moved away from the forests where they were born. Data on post-breeding dispersal are also scarce. Data from the eastern United States indicate an extremely low fidelity to breeding sites between years; however, in southern California, the limited amount of available habitat may foster a higher level of breeding site fidelity (Eckerle and Thompson 2001).

Reproduction. Yellow-breasted chats breed from early May to early August, with peak breeding activity occurring in June (Green 2005). Males arrive at breeding grounds before females (Eckerle and Thompson 2001). Pairs are monogamous, although pairs may nest near one another in loose colonies (Ehrlich et al. 1988). Following arrival at the breeding grounds, nests are constructed and three to six eggs are laid from mid-May to mid-July (Thompson and Nolan 1973). Females incubate eggs for 11 to 15 days (Green 2005). Once eggs hatch, both sexes tend to the nestlings until they fledge (Harrison 1978). Approximately 8 to 11 days are required for fledging (Petrides 1938, Green 2005). They will occasionally produce a second brood in the season. Of 24 females nesting in southern Indiana for which all nesting attempts within a single year were known, only 2 (8 percent) had a second brood (Thompson and Nolan 1973). Survival rates of fledglings are unknown.

Foraging Behavior and Diet. Chats forage by foliage gleaning, consuming insects and berries about equally (Ehrlich et al. 1988, Green 2005). Adults feed on a variety of arthropods, including beetles and weevils, true bugs, ants, bees, caterpillars, and spiders. Nestlings are typically fed a diet of soft-bodied orthopterans (e.g., grasshoppers) and larval lepidopterans (Petrides 1938). In late summer and fall, chats feed largely on small fruits, such as the fruits of honeysuckle, wild strawberry, blackberry, mulberry, chokecherry, sumac, and nightshade (Dunn and Garrett 1997).

Home Range/Territory Size. Yellow-breasted chats typically nest in loose colonies, although males usually defend distinct territories (Ehrlich et al. 1988). Territorial defense appears to be less effective as population densities increase (Eckerle and Thompson 2001). Territory size ranges from 0.3 to 3.2 acres (0.1 to 1.3 hectares) (Zeiner et al. 1990). Thompson and Nolan (1973) reported 28 territories averaging 3.2 acres (1.3 hectares) in Indiana and reported that territory sizes decreased as more males arrived. Brewer (1955) reported territories averaging 0.3 acres (0.1 hectares) and varying from 0.1 to 0.7 acres (0.04 to 0.3 hectares) in Illinois. Dennis (1958) reported territory varying from 1.2 to 2.5 acres (0.5 to 1.0 hectares) in Virginia. Territory sizes have not been measured in California, but Gaines (1974) reported a breeding density from the Sacramento Valley of one chat per 10 acres (4 hectares). Although some known breeding sites are consistently active each year, some data suggest low site fidelity (Thompson and Nolan 1973).

A20.5 Threats and Stressors

Habitat Loss and Alteration. A major factor leading to declines in populations of yellow-breasted chats is the loss and degradation of riparian woodland habitat throughout the species' range (Remsen 1978, Rosenberg et al. 1991). Habitat loss and degradation can occur through clearing of vegetation for agriculture, timber harvest, development, or flood control.

Flood control and river channelization eliminates early successional riparian habitat (willow/alder shrub habitats with a dense understory) that chats (and many other riparian focal species) use for breeding.

Timber harvest may have initial negative impacts on nesting chats; however, Annand and Thompson (1997) noted that chats preferred clearcut areas, suggesting that timber harvest impacts may be temporary and could ultimately have a beneficial impact in some situations.

Grazing can also have a significant effect on riparian vegetation (Sedgwick and Knopf 1987). Cattle and other livestock can trample vegetation and eat seedlings, saplings, shrubs, and herbaceous plants. This can lead to a reduction in cover and nesting sites and affect insect prey populations.

Cowbird Parasitism. Brown-headed cowbirds *(Molothrus ater)* may also significantly impact yellow-breasted chats by laying eggs in chats' nests in a phenomenon called brood parasitism

(Gaines 1974, Remsen 1978). The chat is among the 17 hosts most parasitized by cowbirds (Ricketts and Kus 2000). In a 3-year study in Missouri, 31 percent of nests were parasitized by cowbirds (Burhans and Thompson 1999). While data are limited on the extent of cowbird parasitism on yellow-breasted chats in California, it could have a significant impact on local reproductive performance.

Predation. Yellow-breasted chats are also subject to occasional predation by accipiters, small mammals, and snakes (Green 2005). Potential nest predators in California include western scrub-jays *(Aphelocoma californica)*, American crows *(Corvus brachyrhynchos)*, common ravens *(Corvus corax)*, black rats *(Rattus rattus)*, dusky-footed woodrats *(Neotoma fuscipes)*, raccoons *(Procyon lotor)*, and several species of snakes (Ricketts and Kus 2000). Predation of nests may be intensified where insufficient riparian scrub cover or insufficient riparian width occurs, potentially reducing reproduction and recruitment.

A20.6 Relevant Conservation Efforts

There have been few conservation efforts directed toward yellow-breasted chats in California. Efforts to protect and restore riparian systems can potentially preserve or create habitat for this species. Some regional habitat conservation planning efforts may also protect the species, primarily through preserving existing occupied habitat. Neighboring HCP/NCCP finalized or in-progress plans that include the yellow-breasted chat as a covered species include the following: Yolo County Natural Heritage Program Plan, Solano County Multispecies Habitat Conservation Plan, San Joaquin County Multi-Species Habitat Conservation and Open Space Plan, the South Sacramento County Habitat Conservation Plan, and the Butte Regional Habitat Conservation Plan and Natural Community Conservation Plan.

A20.7 Species Habitat Suitability Model

Model Approach. BDCP Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which are incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and revise the vegetation input data as necessary.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements, and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate, as well as overestimate, the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small, isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; instead, the models indicate that non-habitat areas have a much lower probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percentage cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf (2007). Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers; connectivity between habitat types; and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified, and each vegetation type or association is identified, along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or underestimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The yellow-breasted chat model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), USDA 2005 aerial photography, and California Department of Water Resources 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable yellow-breasted chat nesting and migratory habitat in the Plan Area using two qualitative parameters, primary habitat and secondary habitat. Vegetation types were assigned based on the species requirements, as described above, and the assumptions described below.

Nesting and Migratory Habitat. Nesting and migratory habitat in the Delta consists of the following valley riparian types from the BDCP composite vegetation layer:

Primary Habitat

- White alder *(Alnus rhombifolia)*;
- *Alnus rhombifolia/Salix exigua (Rosa californica)*;
- *Acer negundo-Salix gooddingii*;
- Hinds walnut *(Juglans hindsii)*;
- Black willow *(Salix gooddingii)*;
- *Salix gooddingii-Populus fremontii (Quercus lobata-Salix exigua-Rubus discolor)*;
- *Salix gooddingii/Rubus discolor*;
- Coast live oak *(Quercus agrifolia)*;
- *Quercus lobata/Rosa californica (Rubus discolor-Salix lasiolepis/Carex* spp.*)*;
- *Quercus lobata – Acer negundo*;
- *Quercus lobata – Alnus rhombifolia (Salix lasiolepis-Populus fremontii-Quercus agrifolia)*;
- *Quercus lobata – Fraxinus latifolia*;
- *Salix lasiolepis* – Mixed brambles *(Rosa californica-Vitis californica-Rubus discolor)*; and
- *Salix exigua (Salix lasiolepis – Rubus discolor – Rosa californica)*.

Secondary Habitat

- *Alnus rhombifolia/Cornus sericea*;
- Oregon ash *(Fraxinus latifolia)*;
- Box elder *(Acer negundo)*;
- Fremont cottonwood *(Populus fremontii)*;
- *Salix gooddingii*/wetland herbs;
- *Salix gooddingii – Quercus lobata*/wetland herbs;
- Coyote bush *(Baccharis pilularis)*;
- Blackberry *(Rubus discolor)*;
- California wild rose *(Rosa californica)*;
- Mexican elderberry *(Sambucus mexicana)*;
- California dogwood *(Cornus sericea)*;

- *Cornus sericea – Salix exigua*;
- *Cornus sericea – Salix lasiolepis/(Phragmites australis)*;
- Arroyo willow *(Salix lasiolepis)*;
- *Salix lasiolepis – Cornus sericea/Scirpus*[1] spp. – complex unit;
- Shining willow *(Salix lucida)*; and
- Narrow-leaf willow *(Salix exiqua)*.

Nesting and migratory habitat in the Suisun Marsh and Yolo Basin consists of the following valley riparian types from the BDCP composite vegetation layer:

- *Fraxinus latifolia*;
- Fremont cottonwood-Valley oak-Willow riparian forest;
- Mixed Fremont cottonwood – Willow;
- Mixed willow super alliance;
- *Quercus agrifolia*;
- *Rosa californica*;
- *Rosa/Baccharis*;
- *Rubus discolor*;
- *Salix laevigata/S. lasiolepis*;
- *Salix lasiolepis/Quercus agrifolia*;
- Valley oak alliance – Riparian; and
- Willow trees.

Yellow-breasted chat nesting and migratory habitat consists of all valley riparian types with a shrub component that includes blackberry, California wild rose, dogwood, coyote bush, willow, and other shrub species, and an overstory component that includes valley oak, coast live oak, Fremont cottonwood, white alder, box elder, Oregon ash, willow, or walnut. Distinguishing primary from secondary habitat within the Delta was based on a qualitative assessment of the suitability of the understory and overstory layers within each type. Types that are classified as primary habitat support a greater percentage of cover of a suitable shrub layer, particularly blackberry and California wild rose, and also have an open to moderately dense overstory canopy. Determining whether a riparian habitat was considered primary or secondary habitat in the Delta was done through a review of the species associations and ranges of percentage cover from Hickson and Keeler-Wolf (2007). Because this information was not available in the Suisun

[1] Currently known as *Schoenoplectus*.

Marsh data set (Boul and Keeler-Wolf 2008), suitable habitat types were not similarly differentiated.

Assumptions. Yellow-breasted chats nest and forage in dense riparian thickets of willows, vines, and brush associated with streams and other wetland habitats (Small 1994). Population density is directly related to shrub density (Crawford et al. 1981), with a preference for blackberry noted in several studies (Kroodsma 1982, Burnett and DeStaebler 2003), although a variety of other shrubs and thickets are considered suitable, including wild grape, willows, and California wild rose (Melhop and Lynch 1986, Annand and Thompson 1997, Ricketts and Kus 2000, Comrack 2008). Some taller overstory trees are also required for song perches (Dunn and Garrett 1997), but the mature and dense overstory canopies are apparently avoided (Kroodsma 1982, Melhop and Lynch 1986, Annand and Thompson 1997, Comrack 2008).

While uncommon, there are historical and several relatively recent breeding records of chats within the Plan Area, and late spring and summer occurrences of chats have been confirmed by DHCCP surveys. Chats are known to migrate through the Plan Area. Vegetation types that are listed as primary habitat are considered to have a higher probability of breeding activity, and while chats generally use similar habitat during the breeding and non-breeding seasons, both the primary and secondary types are considered suitable migratory habitat.

The model does not distinguish suitability on the basis of riparian width or patch size. Zeiner et al. (1990) reported chat territory sizes from 0.3 to 3.2 acres (0.1 to 1.3 hectares). Because the minimum mapping unit (1 acre) is above the minimum territory size, the model is not restricted on the basis of patch size, but may in fact underestimate the extent of suitable habitat. Note however, that Gaines (1974) reported a breeding density from the Sacramento Valley of one chat per 10 acres, which suggests a possible overestimate of suitable habitat. Riparian width may be an important factor related to yellow-breasted chat occurrence. Narrow widths may make chats more susceptible to brown-headed cowbird parasitism (Gaines 1974, Ricketts and Kus 2000) and predation (Green 2005). The model may also overestimate suitable habitat for chats by not restricting the distribution of suitable habitat based on riparian width.

A20.8 Recovery Goals

A USFWS recovery plan has not been prepared for this species, and no recovery goals have been established.

A20.9 References

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APPENDIX A21. LEAST BELL'S VIREO (*VIREO BELLII PUSILLUS*)

A21.1 LEGAL STATUS

The least Bell's vireo (*Vireo bellii pusillus*) is state and federally listed as endangered. The species was listed by the California Fish and Game Commission pursuant to the California Endangered Species Act (Fish and Game Code, Sections 2050 et seq.) on October 2, 1989, and by the U.S. Fish and Wildlife Service (USFWS) pursuant to the federal Endangered Species Act on May 2, 1986 (51 FR 16474). Critical habitat was designated for this species pursuant to the federal Endangered Species Act on February 2, 1994 (59 FR 4845).

A21.2 SPECIES DISTRIBUTION AND STATUS

A21.2.1 Range and Status

The least Bell's vireo is one of four subspecies of Bell's vireo and is the only subspecies that breeds entirely in California and northern Baja California. Arizona Bell's vireo (*V. bellii arizonae*) is found along the Colorado River and may occur on the California side, but otherwise occurs throughout Arizona, Utah, Nevada, and Sonora, Mexico.

A riparian obligate, the historical distribution of the least Bell's vireo extended from coastal southern California through the San Joaquin and Sacramento valleys as far north as Tehama County near Red Bluff (Figure A-21a). The Sacramento and San Joaquin valleys were considered the center of the species' historical breeding range supporting 60-80 percent of the historical population (51 FR 16474). The species also occurred along western Sierra foothill streams and in riparian habitats of the Owens Valley, Death Valley, and Mojave Desert (Cooper 1861 and Belding 1878 in Kus 2002a, Grinnell and Miller 1944). The species was reported in Grinnell and Miller (1944) from elevations ranging from -175 feet in Death Valley to 4,100 feet at Bishop, Inyo County. These and other historical accounts described the species as common to abundant, but no reliable population estimates are available prior to the species' federal listing in 1986.

Coinciding with widespread loss of riparian vegetation throughout California (Katibah 1984), Grinnell and Miller (1944) began to detect population declines in the Sacramento and San Joaquin Valley region by the 1930s. Surveys conducted in late 1970s (Goldwasser et al. 1980) detected no least Bell's vireos in the Sacramento-San Joaquin Valleys, and the species was considered extirpated from the region. By 1986, the USFWS determined that least Bell's vireo had been extirpated from most of its historical range and numbered approximately 300 pairs statewide (51 FR 16474).

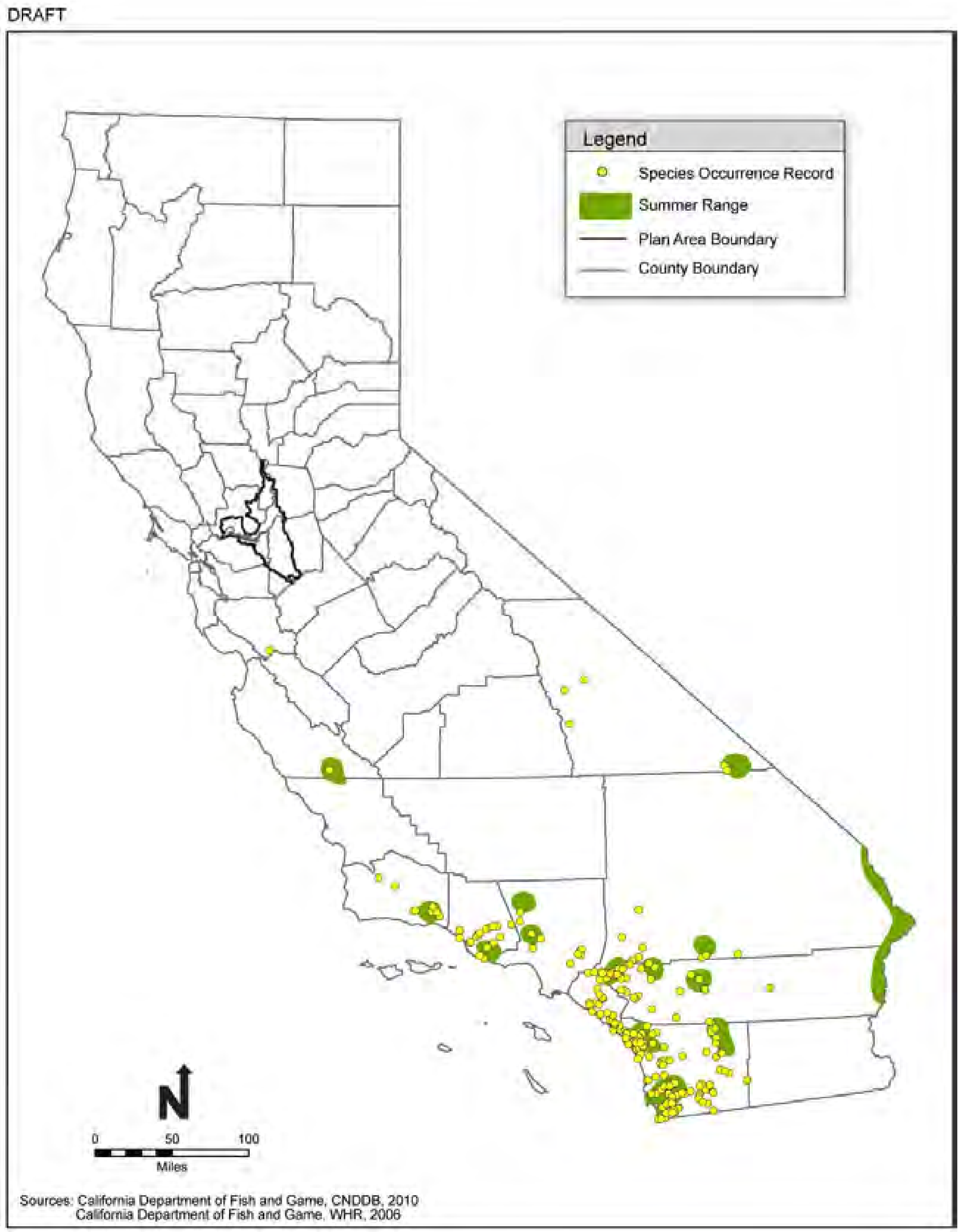

Figure A-21a. Least Bell's Vireo Statewide Range and Recorded Occurrences

The historical range was reduced to six California counties south of Santa Barbara, with the majority of breeding pairs in San Diego County (77 percent), Riverside County (10 percent), and Santa Barbara County (9 percent) (51 FR 16474).

Since federal listing in 1986, populations have gradually increased and the species has re-colonized portions of its historical range. Increases have been attributed primarily to riparian restoration and efforts to control the brood parasite brown-headed cowbird (Kus 1998 and Kus and Whitfield 2005 in Howell et al. in press). By 1998, the total population was estimated at 2,000 pairs and recolonization was reported along the Santa Clara River in Ventura County, the Mojave River in San Bernardino County, sites in Monterey and Inyo counties (Kus and Beck 1998, Kus 2002a, USFWS 2006), and a single nest reported from Santa Clara County near Gilroy in 1997 (Roberson et al. 1997). Still, the distribution remained largely restricted to San Diego County (76 percent) and Riverside County (16 percent) (USFWS 2006).

By 2005, the population had reached an estimated 2,968 breeding pairs (USFWS 2006) with increases in most Southern California counties and San Diego County (primarily Camp Pendleton Marine Corps Base) supporting roughly half of the current population (USFWS 2006).

Two singing least Bell's vireo males were detected, positively identified, and photographed in the southern portion of the Yolo Bypass Wildlife Area in Yolo County in mid-April 2010 (J. P. Galván pers. comm.). As of late-May the two males are still present and have been viewed by a large number of people. The next closest sighting occurred in June 2005 when least Bell's vireos were detected nesting at the San Joaquin River National Wildlife Refuge, west of Modesto in Stanislaus County, the first nesting record of the species in the Central Valley in over 50 years (Howell et al. in press). A single breeding pair nested at the refuge in 2005, 2006, and 2007. The pair successfully nested in 2005 and 2006. The nest was depredated in 2007. No least Bell's vireos were detected in 2008 or 2009 (Howell et al. in press).

A21.2.2 Distribution and Status in the Plan Area

There are no records of least Bell's vireos breeding in the Plan Area since at least the 1970's (Figure A-21b). Two singing males were detected in the Yolo Bypass Wildlife Area in mid-April 2010. The next-nearest most recent record (noted above) is approximately 7 miles south of the Plan Area at the San Joaquin River National Wildlife Refuge in the San Joaquin and Tuolumne River floodplain (Howell et al. in press). Because of the recent sighting of least Bell's vireo in the Plan Area and because the Plan Area may support suitable riparian habitat for a breeding pair, the species may potentially re-colonize the Plan Area.

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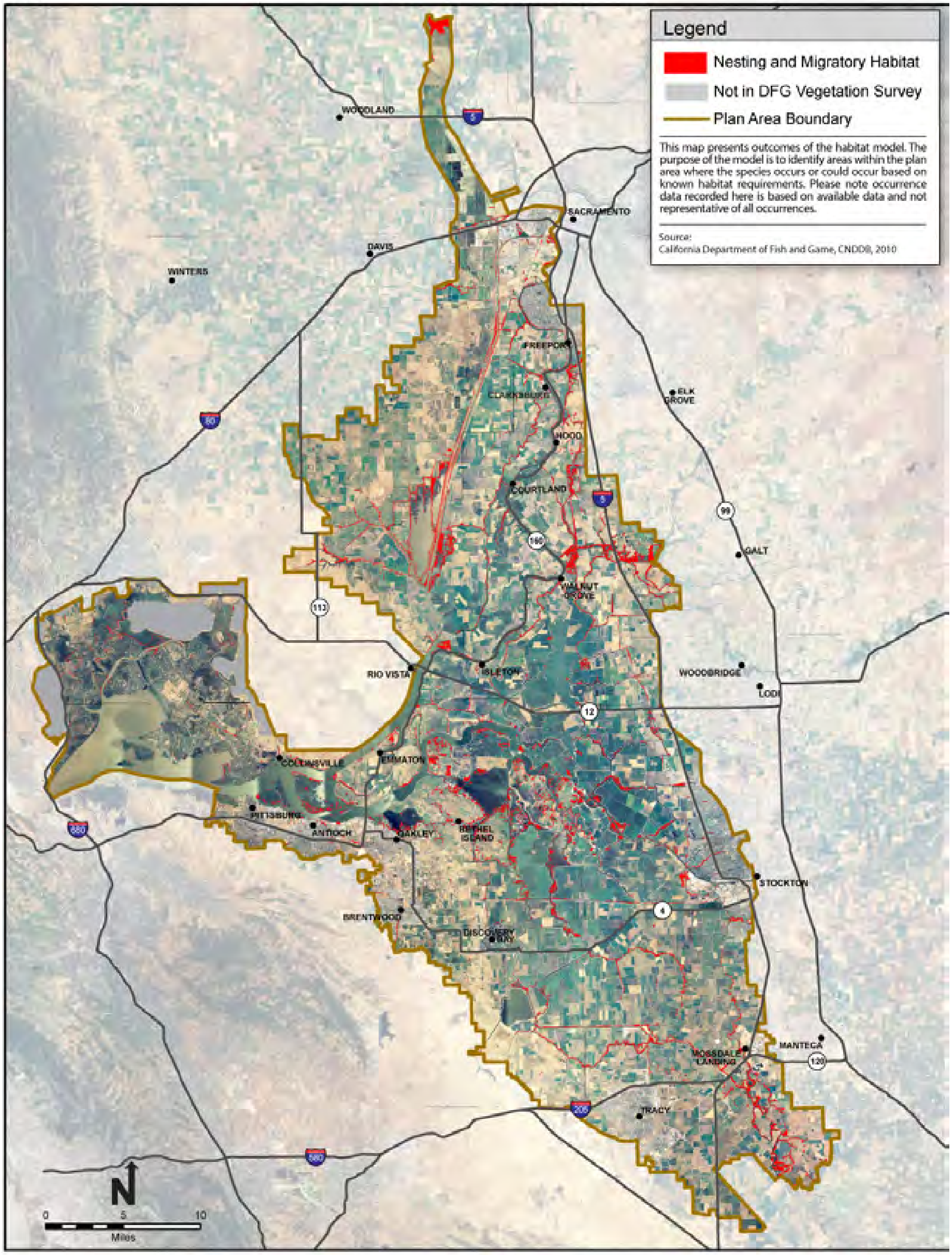

Figure A-21b. Least Bell's Vireo Habitat Model

A21.2.3 Habitat Requirements and Special Conditions

The least Bell's vireo is an obligate riparian breeder that typically inhabits structurally diverse woodlands, including cottonwood-willow woodlands/forests, oak woodlands, and mule fat scrub (USFWS 1998). Two features appear to be essential for breeding habitat: (1) the presence of dense cover within 3-6 feet (1-2 meters) of the ground, where nests are typically placed; and (2) a dense stratified canopy for foraging (Goldwasser 1981, Gray and Greaves 1981, Salata 1981 & 1983, RECON 1989). While least Bell's vireo typically nests in willow-dominated areas, plant species composition does not seem to be as important a factor as habitat structure.

Early successional riparian habitat typically supports the dense shrub cover required for nesting and a diverse canopy for foraging. While least Bell's vireo tends to prefer early successional habitat, breeding site selection does not appear to be limited to riparian stands of a specific age. If willows and other species are allowed to persist, within 5-10 years they form dense thickets and become suitable nesting habitat (Goldwasser 1981, Kus 1998). Tall canopy tends to shade out the shrub layer in mature stands, but least Bell's vireo will continue to use such areas if patches of understory exist. In mature habitat, understory vegetation consists of species such as California wild rose (*Rosa californica*), posion oak (*Toxicodendron diversiloba*), California blackberry (*Rubus ursinus*), grape (*Vitis californica*), and perennials that can conceal nests. Nest site characteristics are highly variable and no features have been identified that distinguish nest sites from the remainder of the territory (Hendricks and Rieger 1989, Olson and Gray 1989, RECON 1989).

Least Bell's vireo use upland habitat, in many cases coastal sage scrub, adjacent to riparian habitat. These areas provide migratory stopover grounds, foraging habitat, and dispersal corridors for non-breeding adults and juveniles (Kus and Miner 1989, RHJV 2004). Vireos along the edges of riparian corridors maintain territories that incorporate both habitat types, and a significant proportion of pairs with territories encompassing upland habitat place at least one nest there (Kus and Miner 1989).

Little is known about least Bell's vireo wintering habitat requirements. They are not exclusively associated with riparian habitat during winter, and can occur in mesquite scrub vegetation to a greater degree than riparian areas in winter (Kus unpubl. data in USFWS 2006). Least Bell's vireo may also occur in palm groves or along hedgerows associated with agriculture and rural residential areas.

A21.2.4 Life History

Description. Least Bell's vireo is the smallest subspecies of the Bell's vireo (*Vireo bellii*). The Bell's vireo can range from 4.3-4.7 inches (11-12 centimeters [cm]) in length and has a wingspan of 7.1 inches (18 cm). It weighs approximately 0.2-0.4 oz (7-10 g) (Brown 1993). It is drably colored and indistinctly marked. The least Bell's vireo is the grayest subspecies of Bell's vireo and has very little yellow or green in its plumage.

Seasonal Patterns. Least Bell's vireos are migratory and usually arrive to their California breeding grounds in mid-March to early April from their wintering grounds in Mexico. Observations of banded birds suggest that returning adult breeders may arrive earlier than first-year birds by a few weeks (Kus unpubl. data in USFWS 2006). Least Bell's vireos begin departing for their wintering grounds by late July but are generally present on their breeding grounds until late September (Garrett and Dunn 1981, Salata 1983).

Nest Site Selection. Nests are typically placed in the fork of a tree or shrub branch in dense cover within 3-6 feet (1-2 meters) of the ground. Both members of the pair construct the cup-shaped nest from leaves, bark, willow catkins, spider webs, and other material, in about 4-5 days. The female selects the nest site (Bent 1950, Barlow 1962). Nests are placed in a wide variety of plant species, but the majority are placed in willows (*Salix* spp.) and mule fat (*Baccharis glutinosa*). Nests tend to be placed in openings along the riparian edge, where exposure to sunlight allows the development of shrubs.

Reproduction. Egg-laying begins 1-2 days after nest completion. Typically 3-4 eggs are laid. Average clutch sizes of nonparasitized nests observed with complete clutches have ranged from 3.1-3.9 in recent years. Both parents share in incubation which takes approximately 14 days. After hatching, nestlings are fed by both parents for 10-12 days until fledging (USFWS 1998). Adults continue to care for the young at least two weeks after fledging when territorial boundaries may be relaxed as family groups range over larger areas. Fledglings usually remain in the territory or its vicinity for most of the season. Least Bell's vireo pairs may attempt up to five nests in a breeding season, although most fledge young from only one or two. Few nests are initiated after mid-July. Long term annual rates of hatching success (the percentage of eggs laid that hatch) have ranged from 53-83 percent in the major study populations at the San Luis Rey, Santa Margarita, and Tijuana Rivers. The annual average number of fledglings produced per pair has ranged from 0.9-4.5, with long term averages ranging between 1.8 and 3.2 (USFWS 1998).

Home Range/Territory Size. Territory size ranges from 0.5-7.5 acres (0.2-3 hectares), but on average are between 1.5 and 2.5 acres (0.6 and 1 hectares) in southern California (USFWS 1998). Newman (1992) investigated the relationship between territory size, vegetation characteristics, and reproductive success for populations in San Diego County, but found no significant factors that could account for the variability in territory size found at his sites. Spatial differences in riparian habitat structure, patch size, and numerous other factors result in differences in the density of territories within and between drainages. Embree (1992) concluded that patch size and crowding did not influence least Bell's vireo reproductive success, at least not through the mechanisms of singing rates and attraction of predators.

Foraging Behavior and Diet. Least Bell's vireos are insectivorous and prey on a wide variety of insects, including bugs, beetles, grasshoppers, moths, and especially caterpillars (Chapin 1925, Bent 1950). They obtain prey primarily by foliage gleaning (picking prey from leaf or bark substrates) and hovering (removing prey from vegetation surfaces while fluttering in the air). Foraging occurs at all levels of the canopy but appears to be concentrated in the lower to mid-strata, particularly when pairs have active nests (Grinnell and Miller 1944, Goldwasser 1981, Gray and Greaves 1981, Salata 1983, Miner 1989). Miner (1989) determined that least Bell's vireo foraging time across heights was not simply a function of the availability of vegetation at those heights, but rather represented an actual preference for the 3-6 m zone. Foraging occurs most frequently in willows (Salata 1983, Miner 1989), but occurs on a wide range of riparian species and even some non-riparian plants that may host relatively large proportions of large prey (Miner 1989).

A21.2.5 Threats and Stressors

Habitat Loss and Fragmentation. A major factor leading to declines in populations of least Bell's vireo is the loss and degradation of riparian woodland habitat throughout the species' range. Habitat loss and degradation can occur through clearing of vegetation for agriculture, timber harvest, development, or flood control.

Flood control and river channelization eliminates early successional riparian habitat that least Bell's vireo (and many other riparian focal species) use for breeding. Dams, levees and other flood control structures hinder riparian reestablishment, creating more "old-growth" conditions (dense canopy and open understory) that are unfavorable to breeding vireos. Finally, habitat degradation encourages nest predation and parasitism. Agricultural land uses and water projects not only directly destroy habitat, but may also reduce water tables to levels that inhibit the growth of the dense vegetation least Bell's vireo prefer (RJHV 2004).

Grazing can also have a significant effect on riparian vegetation (Sedgwick and Knopf 1987). Cattle and other livestock can trample vegetation and eat seedlings, saplings, shrubs, and herbaceous plants. This can lead to a reduction in cover and nesting sites, and affect insect prey populations.

Cowbird Parasitism. Brood parasitism from brown-headed cowbirds (*Molothrus ater*) has a major negative impact on least Bell's vireo. Livestock grazing has reduced and degraded the lower riparian vegetation favored by the Least Bell's Vireo (Overmire 1962) and provided foraging areas for the brown-headed cowbird. Sharp & Kus (2005) suggest that microhabitat cover around the nest is the most important habitat feature influencing brood parasitism of least Bell's vireo nests. They found unparasitized nests had fewer trees >8 cm (3 inches) diameter at breast height within 11.3 meters (37 feet) of the nest and had less canopy cover within 5 meters (16 feet) than parasitized nests. They also suggest that cover near the nest reduces the chance that a cowbird will observe nesting activity and later parasitize the nest.

Row crops and orchards also provide feeding grounds for the parasite. Young and Hutto (1997) found that distance to agriculture was the strongest predictor of cowbird presence and abundance. Riparian habitat that is fragmented by agriculture is therefore highly susceptible to cowbird brood parasitism. By as early as 1930, nearly every least Bell's vireo nest found in

California hosted at least one cowbird egg (USFWS 1998). Since a parasitized nest rarely fledges any vireo young, nest parasitism of least Bell's vireo results in drastically reduced nest success (Goldwasser 1978, Goldwasser et al. 1980, Franzreb 1989, Kus 1999, Kus 2002b).

Predation. Predation is a major cause of nest failure in areas where brown-headed cowbird nest parasitism is infrequent or has been reduced by cowbird trapping programs. Most predation occurs during the egg stage. Predators likely include western scrub jays (*Aphelocoma californica*), Cooper's hawks (*Accipiter cooperii*), gopher snakes (*Pituophis melanoleucus*) and other snake species, raccoons (*Procyon lotor*), opossums (*Didelphis virginiana*), coyotes (*Canis latrans*), long-tailed weasels (*Mustela frenata*), dusky-footed woodrats (*Neotoma fuscipes*), deer mice (*Peromyscus maniculatus*), rats (*Rattus* spp.), and domestic cats (*Felis domesticus*) (Franzreb 1989).

A21.3 Relevant Conservation Efforts

The least Bell's vireo is federally and state-listed as endangered. Critical habitat for the least Bell's vireo was designated in 1994, and a Draft Recovery Plan was published in 1998. Aside from the protections and regulations offered under these plans, the Clean Water Act, Migratory Bird Treaty Act of 1918, and a Memorandum of Understanding (MOU) between the USFWS and Camp Pendleton Marine Corps Base for the purpose and objective of managing and perpetuating the least Bell's vireo on Camp Pendleton, also offer the least Bell's vireo regulatory protection. The least Bell's vireo is also listed as a covered species in 16 Habitat Conservation Plans, including the Coachella Valley Multi-species Habitat Conservation Plan, San Diego Multi-Species Conservation Plan, Orange County Natural Community Conservation Plan / Habitat Conservation Plan, and Western Riverside Multi-Species Habitat Conservation Plan.

Riparian habitat creation and restoration is underway throughout California (RHJV 2004). The Santa Clara River Enhancement and Management Plan is an especially significant effort to protect the ecological integrity of the longest unchannelized river in the South Coast bioregion. Current efforts to develop along the Santa Clara and its tributaries may endanger the integrity of the plan.

Brown-headed cowbird trapping has proven to be an effective method of increasing the reproductive success of least Bell's vireo on a local scale. At Camp Pendleton, nest parasitism dropped from 47 percent to <1 percent in less than 10 years as a result of cowbird trapping efforts (USFWS 1998). However, cowbird trapping should be considered as a temporary and complementary aid to long-term restoration and habitat enhancement and preservation efforts.

Continued research and monitoring of key least Bell's vireo populations at Camp Pendleton and other southern California riparian areas provides important information on population trends and allows for the employment of appropriate adaptive conservation techniques. Point Reyes Bird Observatory's Geographic Information System (GIS) database of California Partners in Flight (CalPIF) riparian study sites is a useful tool in identifying where riparian research is occurring.

The Riparian Bird Conservation Plan (RHJV 2004) offers a comprehensive vision of conservation, education, and research activities necessary to conserve and restore the riparian habitats that least Bell's vireo requires.

A21.3.1 Species Habitat Suitability Model

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing GIS data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf 2007. Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers, connectivity between habitat types, and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The least Bell's vireo model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), and USDA 2005 aerial photography. Using these data sets, the model maps the distribution of suitable least Bell's vireo nesting and migratory habitat in the Plan Area. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Nesting and Migratory Habitat. Nesting and migratory habitat in the Delta includes the following valley riparian types from the BDCP composite vegetation layer:

- Black willow (*Salix gooddingii*);
- *Salix gooddingii-Populus fremontii* (*Quercus lobata-Salix exigua-Rubus discolor*);
- *Salix gooddingii/Rubus discolor;*
- *Salix lasiolepis* – Mixed brambles (*Rosa californica-Vitis californica-Rubus discolor*);
- *Salix exigua* – (*Salix lasiolepis* – *Rubus discolor* – *Rosa californica*);
- *Salix gooddingii*/wetland herbs;
- *Salix gooddingii* – *Quercus lobata*/wetland herbs;
- Arroyo willow (*Salix lasiolepis*);
- *Salix lasiolepis* – *Cornus sericea/Scirpus*[1] spp. – complex unit;
- Shining willow (*Salix lucida*);
- Narrow-leaf willow (*Salix exiqua*);
- Fremont cottonwood (*Populus fremontii*);
- White alder (*Alnus rhombifolia*);
- *Alnus rhombifolia/Salix exigua* (*Rosa californica*);
- Oregon ash (*Fraxinus latifolia*);
- Box elder (*Acer negundo*);
- *Acer negundo-Salix gooddingii;*
- Hinds walnut (*Juglans hindsii*);
- Coyotebush (*Baccharis pilularis*);

[1] Currently known as *Schoenoplectus*.;

- California wild rose (*Rosa californica*);
- *Cornus sericea – Salix exigua;*
- *Cornus sericea – Salix lasiolepis/(Phragmites australis*);
- Coast live oak (*Quercus agrifolia*);
- *Quercus lobata – Alnus rhombifolia* (*Salix lasiolepis-Populus fremontii-Quercus agrifolia*);
- *Quercus lobata/Rosa californica* (*Rubus discolor-Salix lasiolepis/Carex* spp.);
- *Quercus lobata – Acer negundo;*
- *Quercus lobata – Fraxinus latifolia;*
- Blackberry (*Rubus discolor*);
- Mexican elderberry (*Sambucus mexicana*); and
- California dogwood (*Cornus sericea*).

Nesting and migratory habitat in the Suisun Marsh and Yolo Basin includes the following valley riparian types from the BDCP composite vegetation layer:

- Fremont cottonwood-Valley oak-Willow riparian forest;
- Mixed Fremont cottonwood – Willow;
- Mixed willow super alliance;
- *Salix laevigata/S. lasiolepis;*
- *Salix lasiolepis/Quercus agrifolia;*
- *Rosa californica;*
- *Rosa/Baccharis;*
- *Fraxinus latifolia;*
- *Quercus agrifolia;*
- *Rosa californica;*
- *Rosa/Baccharis;*
- *Rubus discolor;*
- Valley oak alliance – Riparian; and
- Willow trees.

Assumptions. The least Bell's vireo is an obligate riparian breeder. While it can use adjacent non-riparian scrub habitats for foraging or dispersal (Kus and Miner 1989, RHJV 2004), suitable non-riparian habitats are largely absent from the Plan Area, which is primarily agricultural. Therefore, the habitat model is restricted to riparian vegetation. While least Bell's vireo typically nests in willow-dominated habitats, plant species composition does not seem to be as important a factor as habitat structure. Early successional riparian habitat typically supports the dense shrub cover required for nesting and a diverse canopy for foraging. While least Bell's vireo tends to prefer early successional habitat, breeding site selection does not appear to be limited to riparian stands of a specific age. Therefore, in addition to all willow-dominated types, all other riparian habitats that may consist of a dense shrub layer are included.

A21.3.2 Recovery Goals

The Draft Recovery Plan (USFWS 1998) includes the following criteria that constitute the recovery goals for this species:

Reclassification to Threatened may be considered when Criterion 1 has been met for a period of 5 consecutive years.

Criterion 1: Stable or increasing least Bell's vireo populations/metapopulations, each consisting of several hundred or more breeding pairs are protected and managed at the following sites: Tijuana River, Dalzura Creek/Jamul Creek/Otay River, Sweetwater River, San Diego River, San Luis Rey River, Camp Pendleton/Santa Margarita River, Santa Ana River, an Orange County/Los Angeles County metapopulation, Santa Clara River, Santa Inez River, and an Anzo Borrego Desert metapopulation.

Delisting may be considered when the species meets the criterion for downlisting and the following criteria have been met for 5 consecutive years:

Criterion 2: Stable or increasing least Bell's vireo populations/metapopulations, each consisting of several hundred or more breeding pairs, have become established and are protected and managed at the following sites: Salinas River, a San Joaquin Valley metapopulation, and a Sacramento Valley metapopulation.

Criterion 3: Threats are reduced or eliminated so that least Bell's vireo populations/metapopulations listed above are capable of persisting without significant human intervention, or perpetual endowments are secured for cowbird trapping and exotic plant control in riparian habitat occupied by least Bell's vireo.

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APPENDIX A22. WESTERN BURROWING OWL (*ATHENE CUNICULARIA HYPUGAEA*)

A22.1 LEGAL STATUS

The western burrowing owl (*Athene cunicularia hypugaea*) is designated as a state Bird Species of Special Concern (Shuford and Gardali 2008) by the California Department of Fish and Game (DFG). Nests are protected in California under Fish and Game Code Section 3503.5.

The burrowing owl has no federal regulatory status; however, the species is protected under the federal Migratory Bird Treaty Act and is designated as a Bird of Conservation Concern by the U.S. Fish and Wildlife Service (USFWS 2002).

A22.2 SPECIES DISTRIBUTION AND STATUS

A22.2.1 Range and Status

There are two subspecies of burrowing owls in North America (Clark 1997, Haug et al. 1993). The breeding range of *A. cunicularia floridana* is restricted to Florida and adjacent islands. The breeding range of *Athene cunicularia hypugaea* extends south from southern Canada throughout most of the western half of the United States and south to central Mexico. The winter range extends from Central California southeastward through Arizona, New Mexico, and Texas and south into northern and central Mexico and coincides with southern breeding range where the species is resident year-round (Haug et al. 1993).

Burrowing owls were once widespread and generally common over western North America in treeless, well-drained grasslands, steppes, deserts, prairies, and agricultural lands (Haug et al. 1993). The owl's range has contracted in recent decades, and populations have been generally diminished in some areas.

In California, burrowing owls are widely distributed in suitable habitat throughout the lowland portions of the state (Figure A-22a); however, occupied sites have ranged from 200 feet below sea level at Death Valley, to above 12,000 feet at Dana Plateau in Yosemite (DFG 2000). In southern California, the species is fairly common along the Colorado River Valley (Rosenberg et al. 1991) and in the agricultural region of the Imperial Valley. Only small, scattered populations are thought to occur in the Great Basin and the desert regions of southern California (DeSante et al. 2007). Burrowing owl breeding populations have greatly declined along the California coast, including the southern coast to Los Angeles, where these owls have been eliminated from virtually all private land and occur only in small populations on some federal lands (Garrett and Dunn 1981, DeSante et al. 2007, Kidd et al. 2007). Breeding populations in Central California include the southern San Francisco Bay between Alameda and Redwood City, the interior valleys and hills in the Livermore area, and the Central Valley (DeSante et al. 1997).

DRAFT

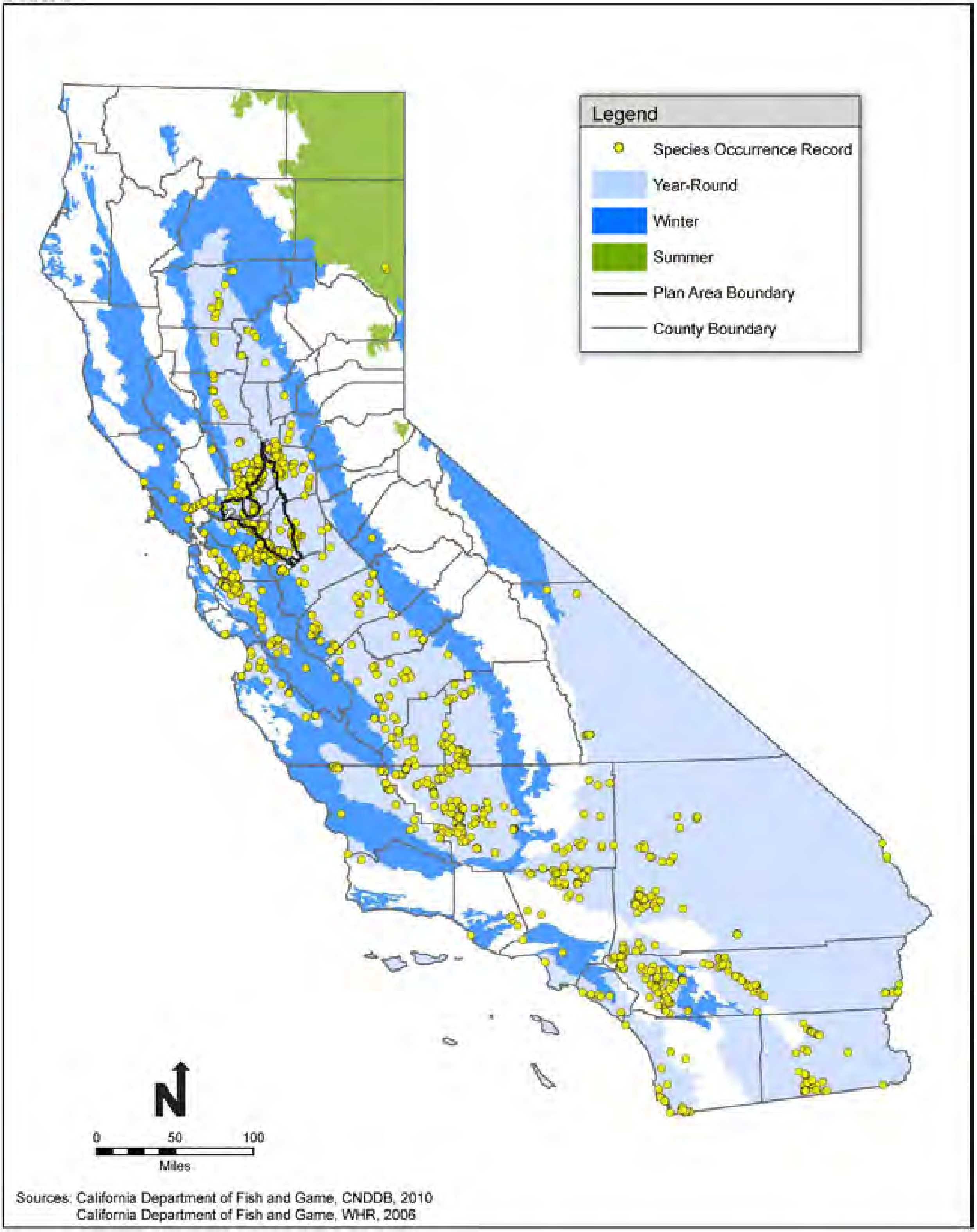

Figure A-22a. Western Burrowing Owl Statewide Range and Recorded Occurrences

1

Burrowing owls appear to be resident year-round throughout much of central and southern California; however, migratory patterns remain unclear (Haug et al. 1993).

Overall population trends throughout the western burrowing owl's North American range are reportedly declining (James and Espie 1997, Klute et al. 2003). James (1993) reports that 54 percent of the areas sampled reported declining burrowing owl populations. Breeding Bird Surveys conducted between 1980 and 1989 also report significant declines in many areas (Haug et al. 1993).

Burrowing owls were formerly common or abundant throughout much of California, but noticeable declines have been reported since the 1940s (Grinnell and Miller 1944) and continue to the present time (DeSante et al. 2007, Shuford and Gardali 2008). The decline has been almost universal throughout California. Conversion of grasslands and pasturelands to incompatible crop types and the destruction of ground squirrel colonies have been the main factors causing the decline of the burrowing owl population (Zarn 1974). Assimilation of poisons applied to ground squirrel colonies may also affect burrowing owl population levels (James et al. 1990).

Surveys in California in 1986-91 found population decreases of 23 to 52 percent in the number of breeding groups and 12 to 27 percent in the number of breeding pairs of owls (DeSante et al. 1997). Nearly 60 percent of burrowing owl colonies that existed in the 1980s reportedly disappeared by the early 1990s (DeSante and Ruhlen 1995, DeSante et al. 1997).

DeSante et al. (2007) estimated a statewide population of 9,266 breeding pairs, most occurring in four main population areas: the Imperial Valley, the Central Valley, the Southern California coast, and the San Francisco Bay area. An estimated 167 nesting pairs (1.8 percent of California's population) occur in the Bay area, where the species often uses burrows created by the California ground squirrel (*Spermophilus beecheyi*) and resides in undeveloped grassland remnants amid a rapidly expanding human population. In the southern California coastal population, burrowing owls have been almost entirely extirpated from private lands and were found only on a few undeveloped federal lands, where an estimated 260 nesting pairs (3 percent of California's population) persist (DeSante et al. 2007, Kidd et al. 2007). An estimated 2,224 nesting pairs exist in the Central Valley (24 percent of California's population), where the species is also subject to widespread habitat loss from urbanization. This population also often uses burrows created by the California ground squirrel and resides in remaining patches of grassland, along the grassland edges of canals and levees, and along the edges of pastures and some agricultural fields. An estimated 6,570 nesting pairs (71 percent of California's population) occur in the Imperial Valley, where burrowing owls are almost completely relegated to irrigation canal banks and where they most often use burrows created by the round-tailed ground squirrel (*Spermophilus tereticaudus*) (DeSante et al. 2007).

Although California has a significant burrowing owl population, development pressures and recent population trends suggest that the species may continue to be extirpated from large portions of its range in California during the next decade. Coastal areas, in particular, have experienced extirpations or near extirpations in recent years presumably from habitat loss (Desante et al. 2007). While burrowing owls in the Central Valley have exhibited strong site fidelity even with increasing habitat fragmentation, the species has been extirpated from many historically occupied areas due to increasing urbanization and related causes.

A22.2.2 Distribution and Status in the Plan Area

Reported occurrence data indicates that within the Plan Area, burrowing owls are concentrated mostly in the grassland/pastureland areas west of the Sacramento Deep Water Ship Channel in Yolo and Solano counties, and in the grassland habitats along the western edge of the Plan Area between roughly Brentwood/Antioch and Tracy (Figure A-22b). These mostly uncultivated areas support larger and more stable populations of California ground squirrels and are less likely to be disturbed by regular cultivation and other ground disturbances. The species is a year-round resident in the Plan Area; however, local migratory patterns and the extent to which migrants occupy the Plan Area during the non-breeding season are unclear.

Burrowing owls continue to persist locally in the vicinity of Stockton where they are typically found along levees, canals, field edges, and some ruderal habitats or idle fields. Burrowing owls are also known to occur in the grassland habitats in the vicinity of Stone Lakes. While relatively few burrowing owls have been reported from this area, the grassland habitats could potentially support a larger population. In recognition of this, enhancement of burrowing owl habitat, including the installation of 80 artificial nest boxes, reintroduction of the California ground squirrel, and adjustment of land management activities, is ongoing on the Stone Lakes National Wildlife Refuge. These activities are part of an agreement with the Sacramento Area Flood Control Agency and Sacramento County to use the refuge for purposes of burrowing owl mitigation because of impacts from the South Sacramento Streams Group Project (SAFCA, Resolution Number 07058).

Few burrowing owls have been reported from the central portion of the Delta and the northern Delta east of the Sacramento Deep Water Ship Channel (Figure A-22b), probably due to regular cultivation, lack of undisturbed habitats, and lack of ground squirrel populations. Active sites in this area are generally restricted to levee embankments and along irrigation canals.

Burrowing owls persist in low numbers in grassland habitats around the perimeter of Suisun Marsh. Gervais et al. (2008) note that populations in the vicinity of Suisun Marsh and San Pablo Bay are declining.

Remaining populations in the vicinity of Stockton, Brentwood/Antioch, and Tracy are subject to continued land use changes from urbanization and populations are likely to decline over time as suitable habitat is removed. Populations in Yolo and Solano counties west of the Deep Water Ship Channel are less subject to land use changes and thus may be more likely to persist.

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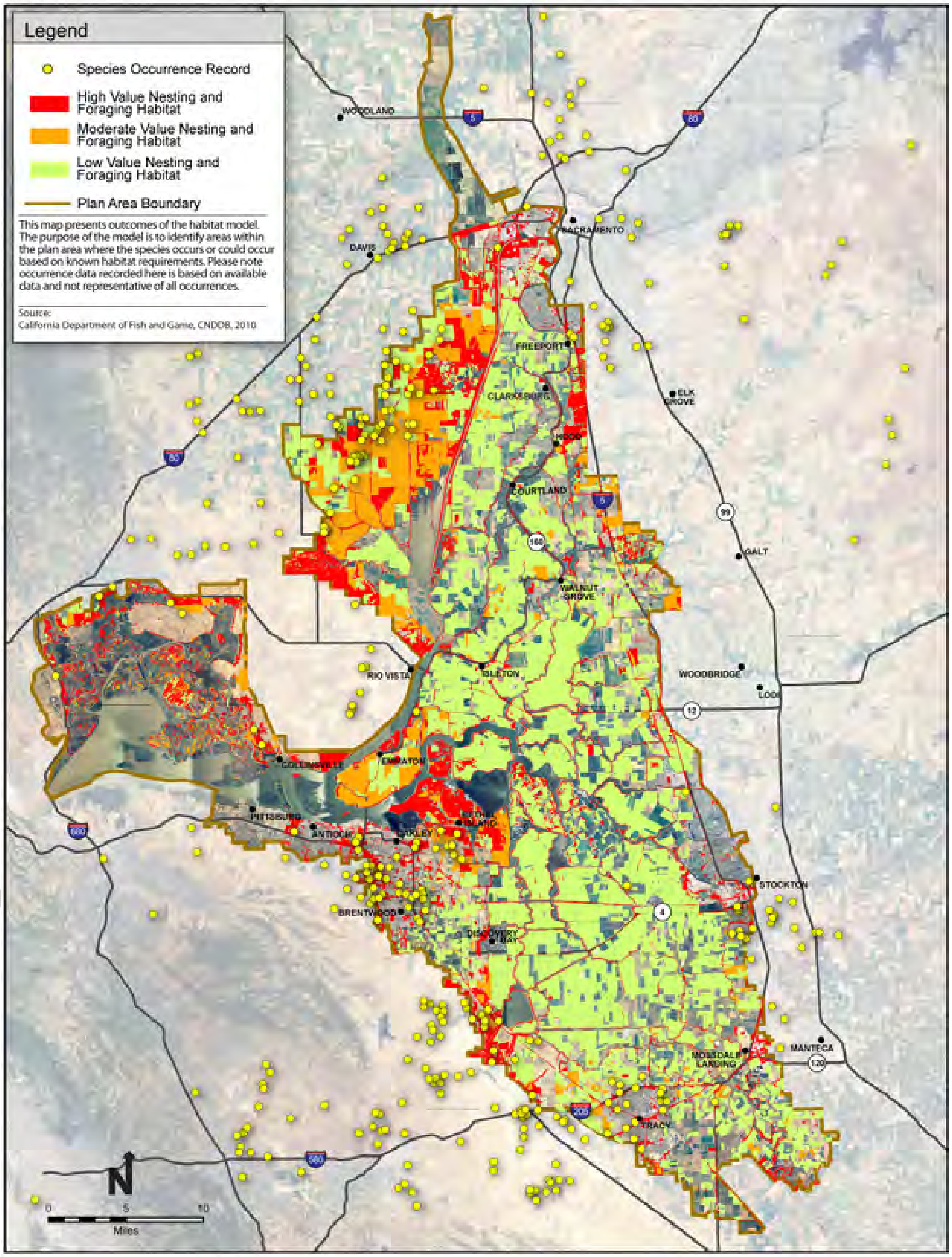

Figure A-22b. Western Burrowing Owl Habitat Model and Recorded Occurrences

A22.3 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

Burrowing owls are found in open, well-drained grasslands, agricultural and range lands, and desert habitats often associated with burrowing animals (Klute et al. 2003). They also occupy golf courses, airports, road and levee embankments, and other disturbed sites where there is sufficient friable soil for burrows (Haug et al. 1993). Because they typically use the burrows created by other species, particularly the California ground squirrel, presence of these species is usually a key indicator of potential occurrence of burrowing owl.

Nesting. In northern California, most reported nest sites occur in abandoned ground squirrel burrows; however, other mammal burrows and various burrow surrogates, such as culverts, pipes, rock piles, and artificially-constructed burrows are also used. Burrowing owls may select sites in habitats that allow for modification of burrows and maximize drainage. In addition to providing nesting, roosting, and escape burrows, ground squirrels improve habitats for burrowing owls in other ways. Burrowing owls favor areas with short, sparse vegetation, which is typical around active sciurid colonies (Coulombe 1971, Haug and Oliphant 1990, Plumpton and Lutz 1993b) to facilitate detection of predators and hunting. Additionally, burrowing owls may select areas with a high density of burrows (Plumpton and Lutz 1993b). Typical habitats are treeless, with minimal shrub cover and woody plant encroachment, and have low vertical density of vegetation and low foliage height diversity (Plumpton and Lutz 1993b). While occupied burrows are sometimes found in flat landscapes – often in elevated mounds created by burrowing activity – they are also commonly found on hillsides, levee slopes, or other steep cut banks, probably to facilitate drainage and maximize visibility. Nest sites are also often associated with nearby perches, including stand pipes, fences, or other low structures.

Burrowing owls are tolerant of human-altered open spaces, such as areas surrounding airports, golf courses, and military lands where burrows may be readily adopted (Thomsen 1971, Barclay 2007). Burrowing owls may use burrows in open areas adjacent to unimproved and improved roads (Brenckle 1936, Ratcliff 1986); a modest volume of vehicle traffic does not appear to significantly affect behaviors or reproductive success (Plumpton and Lutz 1993c), but presumably may also be a source of collision-related mortality. In the south San Francisco Bay region and in the Sacramento area, burrowing owls nest and winter in highly human-affected environments and can habituate to human activity if breeding and foraging habitat remains in a suitable condition.

The dimensions of the nest burrow vary with location, age of burrow, and the species that originally excavated it. Typical burrows constructed by ground squirrels are from 3 to 6 inches (7.6 to 15.2 centimeters [cm]) in diameter and extend underground at a gradual downward slope from 3 to 20 feet (0.9 to 6.1 meters) with an enlarged cavity at the end of a tunnel. Feathers, pellets, and white wash are often present at active burrow entrances. The burrow is often lined with grass or other material (Haug et al. 1993).

Burrowing owls may nest solitarily but many nest in loose colonies – usually from 4 to 10 pairs (Zarn 1974); however, larger colonies have been documented. Most pairs occupy a natal burrow, and several satellite burrows where available.

As semi-colonial raptors, colony size is indicative of habitat quality and quantity. Colony size is also positively correlated with annual site reuse by breeding burrowing owls; larger colonies (those with more than five nesting pairs) are more likely to persist over time than colonies containing fewer pairs or single nesting pairs (DeSante et al. 1997). Nest burrow reuse by burrowing owls has been well documented (Martin 1973, Gleason 1978, Rich 1984, Plumpton and Lutz 1993b, Lutz and Plumpton 1999). Former nest sites may be more important to continued reproductive success than are mates from previous nest attempts (Plumpton and Lutz 1994). Past reproductive success may influence future site re-occupancy by burrowing owls. Female burrowing owls with large broods tend to return to previously occupied nest sites; while females that fail to breed, or produced small broods, may change nest territories in subsequent years (Lutz and Plumpton 1999).

In general, burrowing owls show a high degree of nest site fidelity and reuse the same nesting burrows and satellite burrows for many years if left undisturbed.

Foraging. Burrowing owls forage in open grasslands, pasturelands, agricultural fields and field edges, fallow fields, and along the edges of roads and levees. Low vegetation aids in maximizing visibility and access. Short perches, such as fence posts are often used to enhance visibility. While they will defend the immediate vicinity of the nest, burrowing owls will often forage in common areas (Haug et al. 1993).

A22.4 LIFE HISTORY

Description. This small owl stands about 9 inches (23 cm) tall. The sexes are similar (although females are slightly smaller and often slightly darker than males) with distinct oval facial ruff, white supercilium, yellow eyes, and long legs. Wingspan is relatively broad (20 to 24 inches [51 to 61 cm]) and wings are somewhat rounded. The owl is sandy-colored with pale tan spots on the back and upperparts of the wings and white-to-cream with barring on the breast and belly (Haug et al. 1993).

Seasonal Patterns. Burrowing owls are resident in the Central Valley and other portions of central California. The breeding season (defined as from pair bonding to fledging) generally occurs from February to August with peak activity occurring from April through July (Haug et al. 1993). Pairs may be resident at breeding sites throughout the year or disperse out of the breeding area during the non-nesting season. Some individual birds only winter in the region. Burrowing owls have a strong affinity for previously occupied nesting and wintering habitats. They often return to burrows used in previous years, especially if they had been reproductively successful (Lutz and Plumpton 1999). Additionally, burrowing owls often return as breeding adults to the general area in which they were born. For these reasons, efforts that enhance productivity help to ensure continued use of burrows and territories.

Reproduction. Adults begin pair bonding and courtship in February through March. Following pair formation, a nest is established in the natal burrow and females lay a clutch of 6 to 11 eggs. Average clutch size is 7 to 9 eggs. Eggs are incubated entirely by the female for a period of between 28 and 30 days. Incubation begins prior to the clutch being complete, which causes asynchronous hatching. During this time, the female is provisioned with food by the male. Following hatching, the young remain in the natal burrow for 2 weeks after which they begin to emerge from the burrow and roost at the burrow entrance. The female begins hunting as soon as the young begin thermoregulation and no longer require continuous brooding. Adults and nestlings will also relocate to satellite burrows presumably to reduce the risk of predation (Desmond and Savidge 1998) and possibly to avoid nest parasites (Dechant et al. 2003). After approximately 44 days, young leave the natal burrow and by 49 to 56 days begin to hunt live insects. On average, three to five young fledge, but fledging rates can range from a single fledgling to as many as eight or nine (Lutz and Plumpton 1999). During this time, the juveniles expand their range and may find cover in satellite burrows. The juveniles continue to be provisioned by the adults until mid-August when they molt into adult plumage and begin to disperse (Landry 1979). King and Belthoff (2001) report that dispersing young use satellite burrows in the vicinity of their natal burrows for about two months after hatching before departing the natal area.

Home Range/Territory Size. Few valid measures of territory or home range size of burrowing owls have been published; home range has not often been measured directly (e.g., via telemetry studies) and is highly subject to observer bias or equipment effect. Accordingly, caution is warranted when interpreting home range estimates. Gervais et al. (unpublished 2000 report in Yolo Natural Heritage Program 2008) estimated that the mean minimum convex polygon (MCP) home range estimates for 22 burrowing owls in Fresno and Kings counties in California was 467 acres (189 hectares). Haug and Oliphant (1990) estimated that the mean MCP for six owls in Saskatchewan was 595 acres (241 hectares) (Yolo Natural Heritage Program 2008).

In Colorado, Plumpton and Lutz (D. Plumpton pers. comm. in Yolo Natural Heritage Program 2008) recorded densities of nesting burrowing owls that ranged from 21 to 34 pairs on roughly 2,240 acres (906 hectares) of available habitat (i.e., 106 and 65 acres [43 and 26 hectares]/pair, respectively). Thomsen (1971) estimated territory size based on nearest-neighbor distances between nest burrows, producing a result of six pairs of owls averaging 2 acres (0.8 hectares), with a range of between 0.1 to 4.0 acres (0.04 to 1.6 hectares). The preceding values demonstrate the disparity among studies, the different values attained when using different methods of estimating abundance, and the risk in relying on the results of a single study (Yolo Natural Heritage Program 2008).

Foraging Behavior and Diet. Although there are seasonal differences, burrowing owls are active during the day and night and will hunt throughout the 24-hour day, but are mainly crepuscular, hunting mostly at dusk and dawn, and are less active midday. During the fall and winter, they become more nocturnal, and during the breeding season they may hunt all times of the 24-hour day depending on the temperature, number of young, stage of breeding cycle, and other factors. They tend to hunt insects in daylight and small mammals at night. They usually hunt by walking, running, hopping along the ground, flying from a perch, hovering, and fly-catching in midair.

Burrowing owls tend to be opportunistic feeders. Large arthropods, mainly beetles and grasshoppers, comprise a large portion of their diet. In addition, small mammals, especially mice and voles (*Microtus*, *Peromyscus*, and *Mus* spp.) are also important food items. Other prey animals include reptiles and amphibians, young cottontail rabbits (*Sylvilagus audubonii*), bats, and birds, such as sparrows and horned larks (*Eremophila alpestris*). Consumption of insects increases during the breeding season (Zarn 1974, Tyler 1983, Thompson and Anderson 1988, Green et al. 1993, John and Romanow 1993, Plumpton and Lutz 1993a). Productivity may increase in proportion to the amount of mice and voles in the diet (D. Plumpton, unpublished data in Yolo Natural Heritage Program 2008).

As with most raptors, burrowing owls select foraging areas based on prey availability as well as prey abundance. Prey availability (the ability of a raptor to detect prey) decreases with increasing vegetation cover and thus foraging habitat suitability decreases with increasing grass height or vegetation density.

A22.5 THREATS AND STRESSORS

Urbanization/Habitat Fragmentation. Urbanization, including residential and commercial development and infrastructure development (roads and oil, water, gas, and electrical conveyance facilities) is one of the principal causes of habitat loss for burrowing owls and is a continuing threat to remaining northern California populations. Urbanization permanently removes habitat and has led to permanent abandonment of many burrowing owl colonies in the developing portions of the Central Valley, Bay Area, and throughout the state.

Interestingly, while urbanization is considered a key cause for population declines, burrowing owls are known to exhibit strong site fidelity (Johnson 1997). They have shown a relatively high level of tolerance for human encroachment, degradation of native habitats, and fragmentation of habitats (Schultz 1997, Trulio 1997). Active breeding colonies have been reported in small parcels or narrow strips of disturbed habitat along levees or utility corridors and surrounded by urban development. Colonies have also been reported along the edges of airport runways, around the perimeter fences of prisons, and in other urbanized or highly disturbed habitats (Thomsen 1971, Barclay 2007). Disturbances may depress reproductive potential in urban settings as compared with more natural habitats (Thomsen 1971). However, owls will often continue to occupy traditional sites as long as essential habitat elements remain present, until the disturbances force the owls out, or until the extent of available habitat is reduced below habitat requirements (Millsap and Bear 1988).

Agricultural Crop Conversion. Some burrowing owls nest on the edges of agricultural areas and forage in suitable agricultural fields (Gervais et al. 2003), such as recently harvested fields, alfalfa and other hay fields, irrigated pastures, and fallow fields. The conversion of these fields to incompatible crop types, such as orchards, vineyards, and other crops that are not conducive to burrowing owl foraging, reduce available foraging habitat and lead to abandonment of traditional nesting areas. Road and ditch maintenance in agricultural areas can also damage or destroy active nesting and wintering burrows.

Levee Maintenance. Many burrowing owl nests are known to occur along the outside slope of levees (Desante et al. 2004, Rosenburg and Haley 2004). Levee stability practices for flood control, including vegetation removal, grading, and reinforcing with rock can destroy burrowing owl nesting habitat (Catlin and Rosenburg 2006).

Rodent Control. Rodent control, particularly along levees and roadsides, can decimate ground squirrel populations and ultimately reduce available nesting and cover habitat for burrowing owls.

Other Human Disturbances. Although burrowing owls can exhibit a tolerance of some human activities, human-related impacts such as shooting and burrow destruction adversely affect this species (Zarn 1974, Haug et al. 1993). Artificially enhanced populations of native predators (e.g., gray foxes [*Urocyon cinereoargenteus*], coyotes [*Canis latrans*]) and introduced predators (e.g., red foxes [*Vulpes vulpes*], cats, dogs) near burrowing owl colonies can also be a significant local problem. Burrowing owls also get tangled in loose fences, abandoned wire, fishing line, rat traps, and other materials.

The overall effect of population-level threats (e.g., habitat conversion or ground squirrel eradication) is of much greater concern than sources of individual mortality (e.g., shooting or vehicle collisions), as these former forces operate at a population, regional, and/or range-wide level. As obligate burrow nesters that do not typically excavate their own burrows, burrowing owls are largely dependent on burrowing mammals that have no legal status or protection, and are commonly and purposefully eradicated by humans. Whereas, individual mortality cumulatively represents a significant number of individuals, a population that is stable and productive can offset these losses. Conversely, populations that are failing because of population-level effects cannot be sustained even in the absence of direct sources of individual mortality. In California, significant economic development pressures exist, and habitat conversion for human purposes continues to degrade the abundance and quality of owl nesting habitat (Barclay et al. 1998). Few provisions exist to protect habitats over time. As a result, burrowing owls appear to be declining throughout most of California.

A22.6 RELEVANT CONSERVATION EFFORTS

Few conservation efforts have been undertaken to conserve burrowing owl populations. The lack of state or federal listing, and the rejection of recent efforts to list the species at the state and federal levels, limits the extent of regulatory influence. There remain several significant data gaps regarding population status and trends, migration, dispersal from nesting sites, and other aspects of annual movements.

Protection typically occurs at the local project level through implementation of the guidelines prepared by DFG (1994). While the guidelines address protection of active sites and compensation for impacts, they do not address conservation or protection at a regional level. DFG is currently developing a statewide conservation strategy for the burrowing owl.

Regional conservation efforts have focused on the development and implementation of habitat conservation plans/natural community conservation plans. These regional conservation approaches can be an effective tool to manage and sustain burrowing owl populations if they protect sufficient suitable and occupied habitat. The majority of the Plan Area overlaps with other conservation planning efforts that are either currently being implemented or are in development. These include the San Joaquin County Multi-species Habitat Conservation and Open Space Plan, the East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan, the Natomas Basin Habitat Conservation Plan, the South Sacramento County Habitat Conservation Plan, the Solano County Multispecies Habitat Conservation Plan, the Yolo County Natural Heritage Program Plan, and the Butte Regional Conservation Plan. If effectively coordinated, these efforts can be a valuable tool in managing burrowing owl populations in the region.

A22.7 SPECIES HABITAT SUITABILITY MODEL

Model Approach. BDCP Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information systems (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided by Hickson and Keeler-Wolf (2007). Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include soils data, incorporating buffers, connectivity between habitat types, and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The western burrowing owl model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), USDA 2005 aerial photography, DWR Central Valley Levees 2001, DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3, and the Yolo County 1997 land use survey. Using these data sets, the model maps the distribution of suitable burrowing owl habitat in the Plan Area in three suitability categories: high, moderate, and low. Vegetation types were assigned to a suitability category based on the species requirements as described above and the assumptions described below.

Nesting and Foraging. Nesting and foraging habitat for burrowing owls has been split into three categories: high value, moderate value, and low value. Value is generally determined on the basis of major vegetation type (grasslands, pastures and seasonal wetlands, agricultural lands).

High value nesting and foraging habitat in the Delta includes the following types using the BDCP composite vegetation layer:

- Grasslands
  - California annual grasslands (California annual grassland/herbaceous alliance);
  - Ruderal herbaceous grasses and forbs (*Cynodon dactlyon* alliance and ruderal herbaceous [nonnative annual forbland]);
  - *Bromus diandrus – Bromus hordeaceus;*
  - Degraded vernal pool complex – California annual grasslands; and
  - Degraded vernal pool complex – Ruderal herbaceous grasses and forbs.
- Vernal pool complex
  - California annual grasslands; and
  - Ruderal herbaceous grasses and forbs.

High value habitat in the Suisun Marsh and Yolo Basin includes the following types using the BDCP composite vegetation layer:

- Annual grasses generic;
- Annual grasses/weeds; and
- Perennial grass.

Additional high value habitat also includes the following types using the DWR 2007 and Yolo County 1997 land use survey data:

- Native vegetation-Grassland

Moderate value nesting and foraging habitat in the Delta includes the following types using the BDCP composite vegetation layer:

- Grasslands
  - Italian rye-grass (*Lolium multiflorum* alliance); and
  - Degraded vernal pool complex – Italian rye-grass (*Lolium multiflorum*).
- Vernal pool complex
  - Italian rye-grass (*Lolium multiflorum* alliance)
- Alkali seasonal wetland complex
  - *Distichlis spicata* – annual grasses

Moderate value habitat in the Suisun Marsh and Yolo Basin includes the following types using the BDCP composite vegetation layer:

- Medium upland graminoids;
- Short upland graminoids;
- Bare ground;
- Pasture;
- Upland annual grasslands and forbs formation;
- Upland herbs; and
- Medium upland herbs.

Additional moderate value habitat also includes the following types using the DWR 2007 Survey data:

- Native pasture;
- Miscellaneous grasses; and
- Mixed pasture.

Levee slopes in managed and natural seasonal wetlands were also included as Moderate value habitat. DWR's Central Valley Levees data was buffered by 100 feet on either side; all managed wetland and natural seasonal wetland types from the BDCP composite vegetation layers situated within the buffered region were included as moderate value habitat.

Low value nesting and foraging habitat in the Delta includes the following types using the BDCP composite vegetation layer:

- Managed wetlands (when not flooded)
    - Temporarily flooded grasslands;
    - Rabbitsfoot grass;
    - Intermittently flooded perennial forbs;
    - Managed annual wetland vegetation (non-specific grasses and forbs);
    - Shallow flooding with minimal vegetation;
    - Seasonally flooded undifferentiated annual grasses and forbs;
    - Managed alkali wetland; and
    - Intermittently or temporarily flooded undifferentiated annual grasses and forbs.

- Alkali seasonal wetland complex and other seasonal wetlands (when not flooded)
  - Saltgrass (*Distichlis spicata*);
  - Seasonally flooded annual grasslands;
  - Vernal pools;
  - Degraded vernal pool complex-vernal pools; and
  - Temporarily flooded perennial forbs.

Low value habitat in the Suisun Marsh and Yolo Basin includes the following types using the BDCP composite vegetation layer:

- *Baccharis*/annual grasses;
- *Bromus* spp./*Hordeum;*
- Cultivated annual graminoid;
- *Cynodon dactylon;*
- *Hordeum*/*Lolium;*
- *Lolium* (generic);
- *Lolium*/*Rumex;*
- *Lotus corniculatus;* and
- Short wetland graminoids.

Low value nesting and foraging habitat also include the following agricultural types from the DWR 2007 Land Use survey and Yolo County 1997 Land use survey. These types represent the typical agricultural cover types in the Plan Area and Upper Yolo Bypass that are included in the DWR 2007 and 1997 Yolo County land use surveys. Rotational crop types that are not common to the Plan Area are not included here. Pasture types are mostly perennial; alfalfa is semi-perennial (3 to 7 years); and all other types are annually or seasonally rotated irrigated crops, only some of which provide suitable foraging habitat for burrowing owl.

- Grain and hay crops
  - Barley;
  - Wheat;
  - Oats; and
  - Miscellaneous and mixed grain and hay.
- Field crops

- Safflower;
- Sugar beets;
- Corn;
- Grain sorghum;
- Sudan;
- Beans;
- Miscellaneous field; and
- Sunflowers.

- Pasture
  - Alfalfa and alfalfa mixtures; and
  - Clover.
- Truck, nursery and berry crops
  - Asparagus;
  - Beans;
  - Onions and garlic;
  - Tomatoes; and
  - Peppers.
- Idle
  - Land not cropped the current or previous crop season, but cropped within the past three years; and
  - New lands being prepped for crop production.

Interior grassy slopes of levees surrounding central Delta islands were also considered low value habitat for burrowing owls. DWR's Central Valley Levees data was buffered by 100 feet on either side; BDCP composite vegetation layer for Agriculture and Valley/Foothill Riparian Natural Community types that fell within this buffer were included as low value habitat.

Assumptions. Western burrowing owls require habitat with three attributes: open, well-drained terrain; short, sparse vegetation; and underground burrows or burrow facsimiles (Klute et al. 2003). In Northern California, most nest sites occur in ground squirrel burrows; however, other mammal burrows and various artificial sites, such as culverts, pipes, and rock piles are also used (Haug et al. 1993). Optimal nesting locations are within an open landscape with level to gently sloping topography, sparse or low grassland or pasture cover, and a high density of burrows.

However, nest locations also include disturbed habitats within this landscape, including roadside berms, levee slopes, and debris piles.

Western burrowing owls occur primarily in open grassland habitats where vegetation is low to maximize visibility and access. Thus, open grassland habitats are ranked as high value for burrowing owls. Moderate value foraging and nesting habitat includes native and irrigated pasture types that maintain a relatively constant vegetation structure; and berms, road edges, and fence rows around the perimeter of fields; and levee slopes in managed and natural seasonal wetland types. Low value nesting and foraging habitat includes seasonal wetland types that are dry during the breeding season and types (e.g., irrigated crops) that exhibit periodic or seasonal foraging value due to management activities and changes in vegetation structure. A variety of irrigated crop types may be used; however, use is generally associated with low vegetation structure and thus occurs primarily during pre-planting or post-harvesting seasons. Because most irrigated crop types (Grain and hay; Field; and Truck, nursery and berry crop types listed above) are rotated seasonally or annually, the distribution of suitable types will also vary seasonally and annually. Thus, this model overestimates the extent of these lower value agricultural foraging habitats in any given year.

A22.8 RECOVERY GOALS

A USFWS recovery plan has not been prepared for this species and no recovery goals have been established.

A22.9 REFERENCES

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APPENDIX A23. WESTERN YELLOW-BILLED CUCKOO (COCCYZUS AMERICANUS OCCIDENTALIS)

A23.1 LEGAL STATUS

The western yellow-billed cuckoo (*Coccyzus americanus occidentalis*) is listed as an endangered species under the California Endangered Species Act. The western yellow-billed cuckoo (*C. americanus*) is currently a candidate for federal listing. Despite the evidence of population declines within the range of *C. a. occidentalis*, taxonomic debate related to the division of the two subspecies (*C. a. occidentalis* and *C. a. americanus*) contributed to the initial determination by the United States Fish and Wildlife Service (USFWS) that there was insufficient evidence to support federal listing. Following a second petition to list the species in 1998, the USFWS initially agreed that listing may be warranted and issued a 90-day Finding for Petition to list as endangered and commencement of a status review (65 FR 8104).

Additional information gathered during the status review suggested that there was insufficient differentiation to justify division into the two subspecies; thus, the USFWS determined that on the basis of the status of eastern populations, there was insufficient information to list the species. In 2001, however, the USFWS determined that there was sufficient information to consider the range of *C. a. occidentalis* as a distinct population segment (DPS), and thus found that there was sufficient evidence to list the yellow-billed cuckoo western DPS (66 FR 38611). The USFWS also determined, however, that the listing was precluded by higher priority listing actions and that the immediacy of the threat to the species was non-imminent. Thus, the species was added to the list of candidate species subject to future federal listing.

A23.2 SPECIES DISTRIBUTION AND STATUS

A23.2.1 Range and Status

There are two currently recognized subspecies, *C. a. occidentalis*, found west of the Rocky Mountains and *C. a. americanus*, found in deciduous forests east of the Rocky Mountains. There is a continuing debate over the taxonomic separation of the two subspecies, which is based primarily on morphological and plumage differences (Banks 1988, Franzreb and Laymon 1993), and more recently on genetics studies initiated by the USFWS during the status review for federal listing.

The range of western yellow-billed cuckoo historically extended from southern British Columbia to the Rio Grande River in northern Mexico, and east to the Rocky Mountains (Bent 1940). Currently, the only known populations of breeding western yellow-billed cuckoo are in several disjunct locations in California, Arizona, and western New Mexico (Halterman 1991). Yellow-billed cuckoos winter in South America from Venezuela to Argentina after a southern migration that extends from August to October (Laymon and Halterman 1985). They migrate north in late June and early July (de Schauensee 1970).

Studies conducted since the 1970s indicate that there may be fewer than 50 breeding pairs in California (Gaines 1974, Halterman 1991, Laymon et al. 1997). While a few occurrences have been detected elsewhere recently, including the Eel River, the only locations in California that currently sustain breeding populations include the Colorado River system in Southern California, the South Fork Kern River east of Bakersfield, and isolated sites along the Sacramento River in northern California (Figure A-23a) (Laymon and Halterman 1989, Laymon 1998).

Declines in numbers of the yellow-billed cuckoo in California are a result of “removal widely of essential habitat conditions,” as described by Grinnell and Miller (1944). These declines have continued primarily in the San Joaquin Valley, north coast, and central coast (where the populations had been extirpated by 1977) (Gaines and Laymon 1984), and the species was nearly extirpated in the Lower Colorado River Valley by 1999. In the Sacramento Valley, only 1 percent of the species’ historical habitat remains to support a small population estimated at only 50 pairs in 1987 and 19 pairs in 1989 (Laymon and Halterman 1989). Population estimates based on surveys conducted in 1999 are similar to those from the 1980s (USFWS 2001). Because no surveys have been conducted since 1999, the current status of the Sacramento Valley population is not known.

A23.2.2 Distribution and Status in the Plan Area

The historical distribution of yellow-billed cuckoo extended throughout the Central Valley, where the species was considered common (Belding 1890). In the mid-1940s, Grinnell and Miller (1944) still considered the Central Valley distribution to extend from Bakersfield to Redding. While there are few historical records from the Plan Area, presumably the species nested along the Sacramento, San Joaquin, and Mokelumne rivers and along smaller tributary drainages including Lost Slough, White Slough, and Disappointment Slough (Figure A-23b).

Gaines (1974) reports several sightings of cuckoos in the vicinity of the Plan Area between 1962 and 1973. The Yolo Audubon Society also reports several sightings from Yolo County, including one from the Putah Creek Sinks in 2005. All of these are presumed to be of migrating birds. There are no recently confirmed breeding locations from the Plan Area or vicinity. In summer 2009, DWR detected one and possibly two yellow-billed cuckoos in a remnant patch of riparian forest in the vicinity of Mandeville Island. Breeding status was not confirmed.

Most riparian corridors in the Plan Area do not support sufficiently large riparian patches for cuckoo breeding; however, the species likely continues to migrate along the Sacramento River and other drainages to northern breeding sites in the Sutter Basin and Butte County. The Plan Area supports several remnant riparian patches in the vicinity of Mandeville and Medford islands that provide suitable riparian vegetation for cuckoos, but may not provide sufficiently large patch size to support breeding cuckoos.

DRAFT

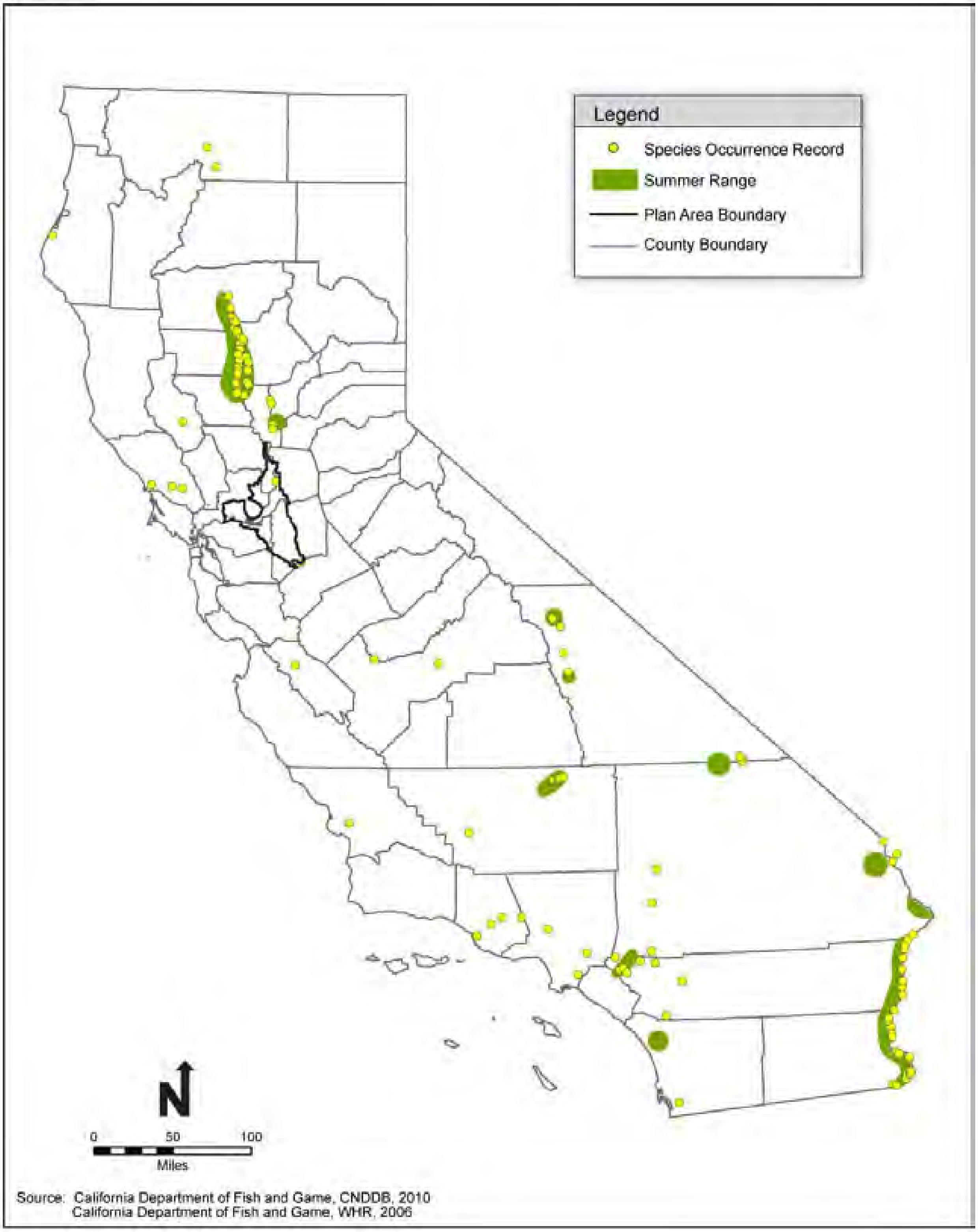

Figure A-23a. Western Yellow-Billed Cuckoo Statewide Range and Recorded Occurrences

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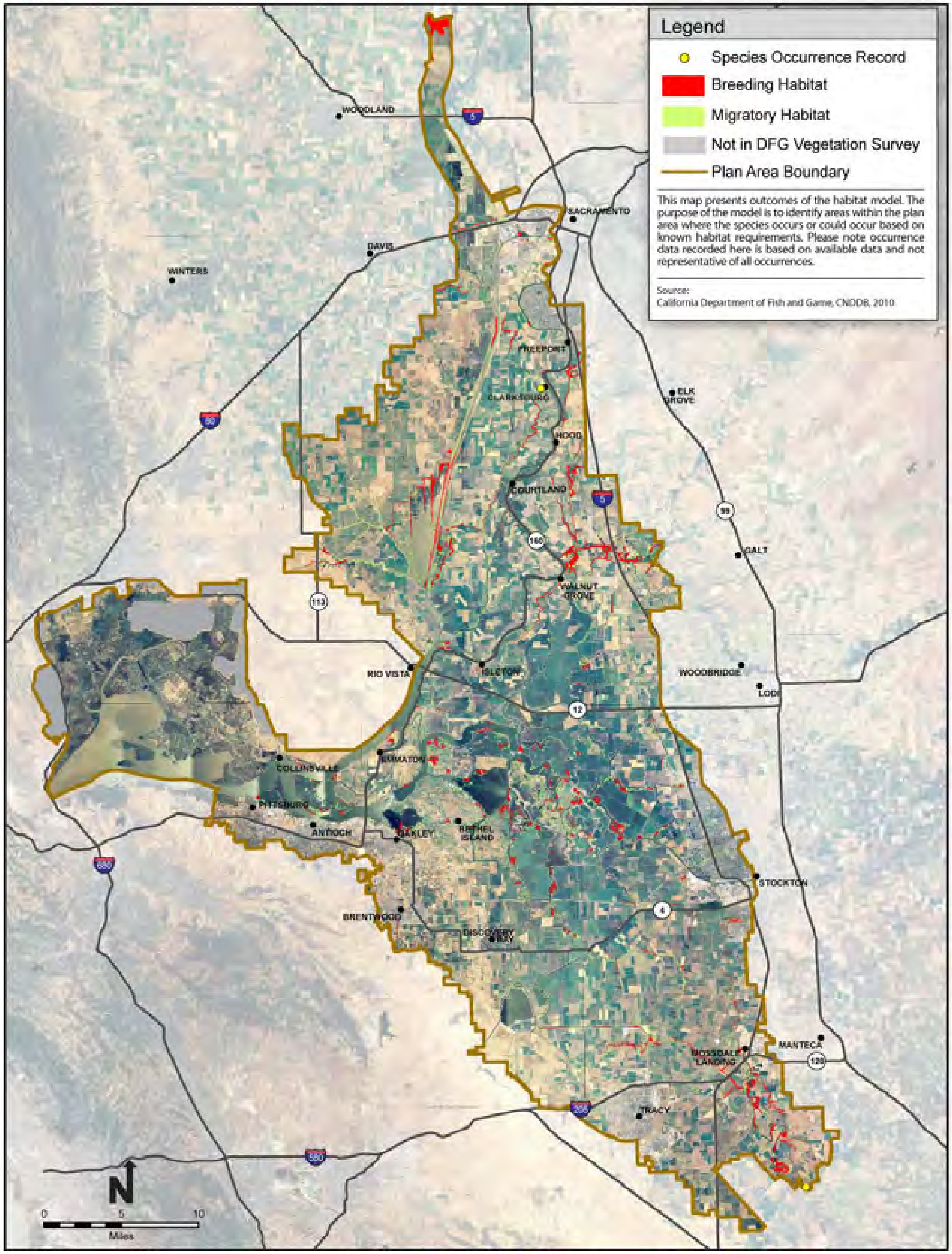

Figure A-23b. Western Yellow-Billed Cuckoo Habitat Model and Recorded Occurrences

1

A23.3 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

The yellow-billed cuckoo is a riparian obligate species. Its primary habitat association is willow-cottonwood riparian forest, but other species such as alder (*Alnus glutinosa*) and box elder (*Acer negundo*) may be an important habitat element in some areas, including occupied sites along the Sacramento River (Laymon 1998). Nests are primarily in willow (*Salix* spp.) trees; however, other tree species are occasionally used, including cottonwood (*Populus fremontii*) and alder. Along the Sacramento River, English walnut (*Juglans regia*) trees have also been reportedly used for nesting (Laymon 1980). Nest site height in willow trees average 14 feet (4.3 meters), but those in cottonwood trees have been reported at 100 feet (30.5 meters). Canopy cover is typically dense (averaging 96.8 percent at the nest), and large patch sizes (generally greater than 50 acres [20.23 hectares]) are typically required (Laymon 1998).

While yellow-billed cuckoos nest primarily in willow (*Salix* spp.) trees, cottonwood (*Populus fremontii*) trees are important foraging habitat, particularly as a source of insect prey. All studies indicate a highly significant association with relatively expansive stands of mature cottonwood-willow forests; however, yellow-billed cuckoos will occasionally occupy a variety of marginal habitats, particularly at the edges of their range (Laymon 1998). Continuing habitat succession has also been identified as important in sustaining breeding populations (Laymon 1998). Meandering streams that allow for constant erosional and depositional processes create habitat for new rapidly-growing young stands of willow, which create preferred nesting habitat conditions. Channelized streams or levied systems that do not allow for these natural processes become over-mature and, presumably, less optimal.

Occupied habitat in Butte County was described by Halterman (1991) as great valley cottonwood riparian forest and great valley mixed riparian forest, including willows, box elder, and white alder. On the Sacramento River, nests have been found in willows, cottonwoods, and box elders. Nests have also been found rarely in orchards including prune, English walnut, and almond. Several nests on the Sacramento River were draped with wild grape (Gaines and Laymon 1984, Laymon 1998). Potential habitat also occurs in valley marshland with willow riparian corridors, such as that found in the Llano Seco area of Butte County.

Primary factors influencing nest site selection in the Butte County population included the presence of cottonwood/willow riparian forest; patch size; and density of understory vegetation (Halterman 1991). Laymon and Halterman (1989) found a significant trend toward increased occupancy with increased patch size. In California, away from the Colorado River, cuckoos occupied 9.5 percent of 21 sites 20-40 hectares (49-99 acres) in extent, 58.8 percent of 17 sites 41-80 hectares (101-198 acres) in extent, and 100 percent of 7 sites greater than 80 hectares (198 acres) in extent (Laymon and Halterman 1989). On the Sacramento River, Halterman (1991) found that the extent of patch size was the most important variable in determining occupancy.

A habitat model developed by Gaines (1974) for the yellow-billed cuckoo in the Sacramento Valley includes the following: patch size of at least 25 acres, at least 100.5 meters (330 feet) wide and 302 meters (990 feet) long, within 100.5 meters (330 feet) of surface water, and dominated by cottonwood/willow gallery forest with high-humidity microclimate. Laymon and Halterman (1989) further refined the model by classifying habitat patch sizes for suitability. A willow-cottonwood forest patch greater than 604 meters (1,980 feet) wide and greater than 81 hectares (200 acres) is classified as optimum habitat; a patch 201-603.5 meters (660-1,980 feet) wide and 41.5-81 hectares (102.5-200 acres) is suitable; a patch 100.5-201 meters (330-660 feet) wide and 20 to 40 hectares (50-100 acres) is marginal, and smaller patches are unsuitable. Management objectives for the Sacramento Valley include six subpopulations of 25 pairs each to maintain viable populations sizes (Laymon 1998). To achieve this goal, it would be necessary to establish or preserve at least 6,070 hectares (15,000 acres) of optimum/suitable habitat. As of 1998, only 2,367 hectares (5,850 acres) of habitat were considered suitable (Laymon 1998).

A23.4 LIFE HISTORY

Description. The yellow-billed cuckoo is a medium-sized bird about 30 centimeters (cm) (11.8 inches) in length with a wingspan of 38-43 cm (15-17 inches). The species has a slender, long-tailed profile, with a fairly stout and slightly down-curved bill, which is blue-black with yellow on the base of the lower mandible. Plumage is grayish-brown above and white below, with red primary flight feathers. The tail feathers are boldly patterned with characteristic rows of large white spots on the underside. The legs are short and bluish-gray. Adults have a narrow, yellow eye ring. Juveniles resemble adults, except the tail patterning is less distinct, and the lower bill may have little or no yellow (Hughes 1999).

Seasonal Patterns. In northern California, birds typically arrive onto breeding territories and pair formation occurs from late June to mid-July following the northward migration from South America, which is followed by nest building and raising of young (Halterman 1991). The species is restricted to the mid-summer period for breeding, presumably due to a seasonal peak in large insect abundance (Rosenberg et al. 1982). To accommodate this, development of young is very rapid with a breeding cycle of 17 days from egg-laying to fledging. Following a relatively short period of post-fledging juvenile dependency, cuckoos migrate out of California from approximately mid-August to early September. The species migrates to South America during the non-breeding season and, thus, does not occur in California between approximately October and May.

Nest Site Selection. Primary factors influencing nest site selection include the presence of cottonwood/willow riparian forest, patch size, and density of understory vegetation. Little information is known about nesting density and spacing; however, along the Sacramento River, in an area of extensive foraging habitat (cottonwoods) and extremely restricted nesting habitat (willows and English walnuts), nests were placed as close as 200 feet apart, showing that they are capable of nesting in close proximity to one another (Laymon 1980).

Reproduction. The pair constructs a flimsy twig nest which is typically 5 to 40 feet above the ground in dense canopy cover. Clutch size is usually three to four eggs, rarely five (Bent 1940). Both the female and the male perform incubation of the eggs, which lasts for 10 to 11 days (Hamilton and Hamilton 1965). Both parents also share brooding duties and provision young with food. Young develop very rapidly and fledge from six to eight days post-hatching. Parental care continues for an additional three to four weeks before the southern migration begins (Halterman 1991).

In the well-studied Kern River population, it was found that 70 percent of yellow-billed cuckoo pairs were monogamous, while the remaining 30 percent included a helper at the nest (Laymon 1998). When prey is abundant, cuckoos increase clutch size and may lay eggs in nests of other yellow-billed cuckoo pairs and other nests of other species (Fleischer et al. 1985, Laymon 1998, Hughes 1999). Further, the Kern River studies determined that cuckoos tend to lay more eggs when they are able to feed nestlings a high percentage diet of katydids, and they tend to fledge more young when prey are easily and quickly captured (Laymon 1998).

Home Range/Territory Size. Limited information is available on home range and territory size. Territory size at the South Fork Kern River ranged from 8-40 hectares (20-100 acres) (Laymon and Halterman 1985), and on the Colorado River as small as 4 hectares (10 acres) (Laymon and Halterman 1989). Patch size, type and quality of habitat, and prey abundance largely determine the size of territories (Halterman 1991).

Yellow-billed cuckoos are loosely territorial and do not defend territories, but given uniform habitat they are regularly spaced throughout the landscape (Laymon 1998). Laymon (1980) found nests placed as close as 60 meters (197 feet) apart along the Sacramento River in an area where foraging habitat was abundant but nesting habitat was extremely limited. Breeding densities at the South Fork Kern River from 1985 to 1996 averaged 0.85 pairs/40 hectares and ranged from a low of 0.15 pairs/40 hectares in 1990 to a high of 1.4 pairs/40 hectares in 1993 (Laymon unpublished data *in* Laymon 1998).

Foraging Behavior and Diet. Food resources vary greatly from year to year and significantly affect reproductive success (Laymon et al. 1997). Cuckoos forage within the riparian canopy primarily on slow-moving insects. The principal food item is green caterpillar (primarily sphinx moth larvae) (44.9 percent), with lesser amounts of katydids (21.8 percent), tree frogs (23.8 percent), and grasshoppers (8.7 percent). The diet also includes cicadas, dragonflies, butterflies, moths, beetles, and spiders (Laymon et al. 1997). Primary food items, particularly sphinx moth larvae, are associated with cottonwood trees and likely explain high reported use of cottonwood trees as foraging habitat for cuckoos (Laymon and Halterman 1985).

Yellow-billed cuckoos are primarily foliage gleaners (Laymon 1998). The typical strategy is to slowly hop from limb to limb in the canopy searching for movement of prey. They also sally from perches to catch flying insects or drop to the ground to catch grasshoppers or tree frogs (Laymon 1998).

A23.5 Threats and Stressors

Habitat Loss and Fragmentation. Historical declines have been due primarily to the removal of riparian forests in California for agricultural and urban expansion. Habitat loss and degradation continues to be the most significant threat to remaining populations. Habitat loss continues as a result of bank stabilization and flood control projects, urbanization along edges of watercourses, agricultural activities, and river management that alter flow and sediment regimes. Nesting cuckoos are also sensitive to habitat fragmentation that reduces patch size (Hughes 1999).

Pesticides. Pesticide use associated with agricultural practices may also pose a long-term threat to cuckoos. Pesticides may affect behavior and cause death or potentially affect prey populations (Hughes 1999).

Predation. Predation is a significant source of nest failures, which have been recorded at 80 percent in some areas (Hughes 1999). Fragmentation of occupied habitats could make nest sites more accessible and more vulnerable to predation. Nestlings and eggs are vulnerable to predation by snakes, small mammals, and birds.

A23.6 Relevant Conservation Efforts

There have been few conservation efforts directed toward yellow-billed cuckoos in California. The most significant conservation and research efforts have occurred at Audubon California's Kern River Preserve and actions associated with the Lower Colorado River Multi-Species Conservation Program (MSCP). Efforts to protect and restore riparian systems can potentially preserve or create habitat for this species. Some regional habitat conservation planning efforts may also provide protections, primarily through protection of existing occupied habitat. Western yellow-billed cuckoo is also a covered species in other neighboring regional conservation plans including the approved San Joaquin County Multi-species Habitat Conservation and Open Space Plan and the in-progress Yolo County Natural Heritage Program Plan and Butte Regional Conservation Plan.

A23.7 Species Habitat Suitability Model

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models, and as necessary, revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements, and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf 2007. Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers, connectivity between habitat types, and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described, and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The yellow-billed cuckoo model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), USDA 2005 aerial photography, and DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable yellow-billed cuckoo nesting and migratory habitat in the Plan Area. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Breeding and Migratory Habitat. Breeding and migratory habitat in the Delta includes the following valley riparian types from the BDCP composite vegetation layer. Breeding habitat is restricted to patches greater than 10 ha (25 ac); migratory habitat has no size restriction.

Fremont cottonwood (*Populus fremontii*);

White alder (*Alnus rhombifolia*);

Oregon ash (*Fraxinus latifolia*);

Box elder (*Acer negundo*);

Hinds walnut (*Juglans hindsii*);

Black willow (*Salix gooddingii*);

Arroyo willow (*Salix lasiolepis*);

Shining willow (*Salix lucida*);

Narrow-leaf willow (*Salix exiqua*);

Alnus rhombifolia/*Salix exigua* (*Rosa californica*);

Alnus rhombifolia/*Cornus sericea*;

Acer negundo-Salix gooddingii;

Salix gooddingii-Populus fremontii (*Quercus lobata-Salix exigua-Rubus discolor*);

Salix gooddingii/*Rubus discolor*;

Salix lasiolepis – Mixed brambles (*Rosa californica-Vitis californica-Rubus discolor*);

Salix exigua – (*Salix lasiolepis – Rubus discolor – Rosa californica*);

Salix gooddingii/wetland herbs;

Salix goodingii – Quercus lobata/wetland herbs;

Salix lasiolepis – Cornus sericea/*Scirpus*[1] spp. – complex unit;

Cornus sericea – Salix exigua;

Cornus sericea – Salix lasiolepis/(*Phragmites australis*);

Quercus lobata/*Rosa californica* (*Rubus discolor-Salix lasiolepis*/*Carex* spp.);

Quercus lobata – Acer negundo; and

Quercus lobata – Alnus rhombifolia (*Salix lasiolepis-Populus fremontii-Quercus agrifolia*).

Nesting and migratory habitat in the Suisun Marsh and Yolo Basin includes the following valley riparian types from the BDCP composite vegetation layer:

Mixed Fremont cottonwood – willow;

Fremont cottonwood-valley oak-willow riparian forest;

Mixed willow super alliance;

Fraxinus latifolia;

Salix laevigata/*S. lasiolepis*;

Salix lasiolepis/*Quercus agrifolia*;

Valley oak alliance – Riparian; and

Willow trees.

Assumptions. The yellow-billed cuckoo is a riparian obligate species. Its primary habitat association is willow-cottonwood riparian forest, but other species such as alder (*Alnus rhombifolia*) and box elder (*Acer negundo*) may be an important habitat element in some areas, including occupied sites along the Sacramento River (Laymon 1998). Canopy cover is typically dense (averaging 96.8 percent at the nest) and large patch sizes (generally greater than 50 acres [20.23 ha]) are typically required (Laymon 1998). Cuckoos may also nest in smaller patches of habitat. Gaines (1974) reports a 25 acre (10 hectare) minimum patch size. Therefore, a patch size of at least 25 acres was selected based on values from Gaines (1974) and used for the Lower Colorado River Multi-Species Conservation Strategy (LCR MSCP 2004).

1 Currently known as *Schoenoplectus.*

A23.8 RECOVERY GOALS

A USFWS recovery plan has not been prepared for this species and no recovery goals have been established.

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APPENDIX A24. CALIFORNIA LEAST TERN (*STERNULA ANTILLARUM BROWNI*)

A24.1 LEGAL STATUS

The California least tern (*Sternula antillarum browni*) is state and federally listed as endangered. The species was listed by the California Fish and Game Commission pursuant to the California Endangered Species Act (Fish and Game Code, Sections 2050 et seq.) on June 27, 1971, and by the U.S. Fish and Wildlife Service (USFWS) pursuant to the federal Endangered Species Act on October 13, 1970 (35 FR 8491). Critical habitat has not been designated for this species.

A24.2 SPECIES DISTRIBUTION AND STATUS

A24.2.1 Range and Status

The California least tern, the smallest of the five recognized North American subspecies of *S. antillarum*, is the only subspecies that occurs in California (Thompson et al. 1997). The historical breeding range of the California least tern was described as extending along the Pacific Coast from approximately Moss Landing to the southern tip of Baja California (Grinnell and Miller 1944). However, since about 1970, colonies have been reported north to San Francisco Bay (USFWS 2006). The nesting range in California is somewhat discontinuous due to the availability of suitable estuarine shorelines, where California least terns often establish breeding colonies (Figure A-24a). Marschalek (2006) identifies six geographic population clusters along the Pacific Coast in California including San Diego, Camp Pendleton, Los Angeles/Orange County, Ventura County, San Luis Obispo/Monterey County, and San Francisco Bay. The majority of the California population is concentrated in three counties: San Diego, Orange, and Los Angeles.

There is little reliable historical information on breeding populations. The first statewide surveys were conducted in 1969-70 (Craig 1971). Annual breeding surveys began in 1973 (Bender 1974) and continue to present (Marschalek 2009). Recent statewide surveys estimated between 6,744 and 6,989 breeding pairs in California, with approximately 85 percent of the breeding colonies occurring in Southern California and only a small percentage (6.3 percent) occurring in the San Francisco Bay area (Marschalek 2009). Statewide, the trend in the breeding population has been dramatic since state and federal listing of the California least tern, from only several pairs in the late 1960s to a current estimate of 6,998 and 7,698 pairs (Marschalek 2009).

Marschalek (2009) monitored six active breeding colonies in the San Francisco Bay area in 2008 with a total number of breeding pairs estimated at approximately 443.

Figure A-24a. California Least Tern Statewide Range and Recorded Occurrences

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Colony sites included Alameda Point, Hayward Regional Landing, and Eden Landing on the western edge of Alameda County, Green Island at the southern tip of Napa County, the Pittsburg Power Plant in northern Contra Costa County, and the Montezuma Wetlands at the southern edge of Solano County. Approximately 73 percent (323) of the breeding pairs were documented at the Alameda Point site. The remaining sites included between 2 and 57 breeding pairs (Marschalek 2009).

A24.2.2 Distribution and Status in the Plan Area

Recently, several California least tern nesting sites have been reported from the vicinity of the Plan Area, two of which (Montezuma Hills and Pittsburg Power Plant) are within the Plan Area. California least terns have nested at the Montezuma Wetlands on the eastern edge of Suisun Marsh near Collinsville since 2006 (Figure A-24b). This colony site was unintentionally created as part of a wetlands restoration project that requires increasing the elevation of certain areas prior to flooding (Marschalek 2008). A pile of sand and shells, formed during excavation of the wetland restoration site, attracted terns to the site, which to date has prohibited completion of the restoration project. Marschalek (2009) reports 35 breeding pairs, 35 nests, and 11 to 18 fledglings from this breeding colony in 2008. California least terns also recently began nesting at the Pittsburg Power Plant in Pittsburg, although with less success. In 2008, Marschalek (2009) documented 10 breeding pairs, but no successful nests.

Two additional locations were recently reported from just outside the Plan Area, including Green Island on the Napa River east of the San Pablo Bay National Wildlife Refuge and northwest of American Canyon, where 19 least terns and two successful nests were reported in 2007 (Marschalek 2008); and along a gravel road between two treatment ponds at the Sacramento Regional Wastewater Treatment Plant (Bufferlands) east of Interstate-5, where a single unsuccessful nest was documented in 2008 (Marschalek 2009).

A24.3 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

California least terns nest in loose colonies on barren or sparsely vegetated sandy or gravelly substrates above the high tide line along the coastline and in lagoons and bays of the California coast. Coastal colonies are typically located on sandy shorelines that are kept free of vegetation from tidal action. Colonies are always near water that provides foraging opportunities. Foraging typically occurs in shallow estuaries or lagoons (Thompson et al. 1997, USFWS 2006).

In the San Francisco Bay area, nesting colonies are typically located in abandoned salt ponds and along estuarine shores, often using artificially or incidentally created habitat (Rigney and Granholm 2005, Marschalek 2008). Foraging occurs in the bay or large river estuaries.

California least terns roost on the ground. Prior to egg-laying, adults generally roost away from nest sites, from 0.25 miles at coastal sites to several miles at estuarine sites. This behavior is thought to be in response to predator avoidance (USFWS 2006).

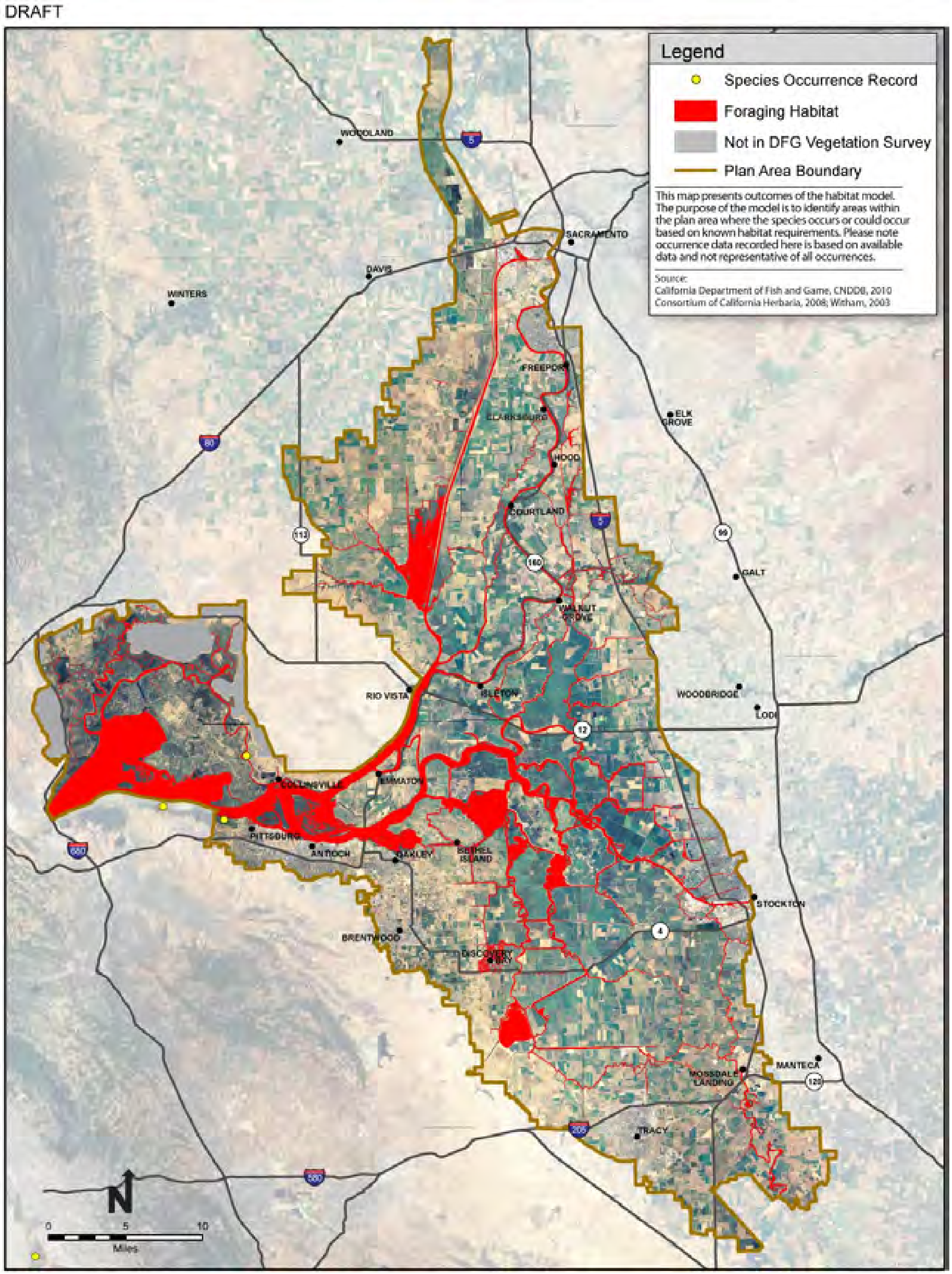

Figure A-24b. California Least Tem Habitat Model and Recorded Occurrences

California least terns are very gregarious and nest, feed, roost, and migrate in colonies. California least terns are highly sensitive to nest disturbance and will readily abandon nest sites if disturbed (Davis 1974).

A24.4 LIFE HISTORY

Description. The California least tern is a small seabird measuring approximately 10 inches (25 centimeters [cm]) in length with a 30-inch (76-cm) wingspan. It has long, tapered wings and a forked tail. Its distinctive black cap and black-tipped pale gray wings contrast with the white body. It has a white forehead, black-tipped yellow bill, and yellowish feet.

Seasonal Patterns. California least terns are migratory. Present at nesting areas from mid-April to late September (Massey 1974, Cogswell 1977, Anderson and Rigney 1980, Patton 2002). Wintering areas are largely unknown, but are suspected to be along the Pacific Coast of Central and South America (Massey 1977).

Nest Site Selection. Nesting colony sites are selected that are free of human or predatory disturbance. The availability of such sites is a limiting factor for the species. Nest sites are shallow depressions without nesting material, typically in barren sandy or gravelly substrate near water.

Reproduction. Courtship generally occurs during April-May and usually takes place away from the nesting area on exposed tidal flats or beaches. Nesting begins by mid-May (Massey 1974). Clutch size ranges from 1 to 4 eggs and is usually 2-3, with a single brood raised each year. Incubation is usually 20-25 days and young are fledged by 28 days, but continue to depend on adults for an additional two weeks (Rigney and Granholm 2005).

Home Range/Territory Size. No information is available on home range size. Nests are typically spaced 1 to 5 meters (3 to 16 feet) apart, and an approximately 1-meter radius area around the nest is defended by the adults (Thompson et al. 1997).

Foraging Behavior and Diet. The California least tern feeds in shallow estuaries and lagoons for small fish including anchovies (*Engraulis* spp.), silversides (*Atherinops* spp.), and shiner surfperch (*Cymatogaster aggregata*) (Rigney and Granholm 2005). It hovers above the water, then plunges, but does not completely submerge. It will also forage in the shallow tidal zone of the open ocean and in bays (Cogswell 1977, Rigney and Granholm 2005).

A24.5 THREATS AND STRESSORS

Habitat Loss and Fragmentation. The degradation and disturbance of suitable estuarine shoreline habitat is the primary reason for the historical reduction of California least tern populations. Most extant colonies occur on small patches of degraded nesting habitat surrounded on all sides by human activities. The majority of colony sites are in areas that were incidentally created during development projects. There is no other available natural habitat for expansion or dispersal other than artificial or incidentally created nesting habitat. Further expansion and recovery of the California least tern population may require the creation or restoration of habitat (USFWS 2006).

Human Disturbance. Human disturbance was noted as early as the mid-1920s as a factor in causing colony abandonment and population declines (Schneider 1926 in: Rigney and Granholm 2005), and is still considered a major threat to remaining colonies (Garrett and Dunn 1981, Marschalek 2009). There is no suitable natural habitat in California that is free of development, military, or recreation-related human disturbances; thus, opportunities for the species to develop new breeding territories are mostly restricted to artificially or incidentally created habitat. Fencing has been used to prohibit entry into colony sites, but this also restricts the movement of birds and has led to nesting failures (USFWS 2006).

Predation. Predation is regarded as the most significant threat to existing colonies. Marschalek (2009) reports 45 avian and mammalian predators or suspected predators of California least tern colonies in 2008. Most depredated terns were taken by American crow (*Corvus brachyrhynchos*), gull-billed tern (*Sterna nilotica*), common raven (*Corvus corax*), and coyote (*Canis latrans*). Peregrine falcon (*Falco peregrinus*), American kestrel (*Falco sparverius*), burrowing owl (*Athene cunicularia*), northern harrier (*Circus cyaneus*), and black skimmer (*Rynchops niger*) were also responsible for a significant proportion of predation events. Marschalek (2009) calculated that 1686-1693 eggs, 304-443 chicks, 73-100 fledglings, and 28 adults were lost to predation events in 2008.

A24.6 Relevant Conservation Efforts

In addition to the guidance provided by the federal recovery plan (USFWS 1985), which establishes 23 coastal management areas, and state and federal laws and regulations, conservation efforts include:

- U.S. Marine Corps, Camp Pendleton Integrated Natural Resources Management Plan. Provides specific direction regarding least tern protection and conservation on the military base.
- San Diego Unified Port District. Conducts monitoring and management of least tern colonies on their properties around San Diego Bay as well as public information programs.
- San Diego Multiple Species Conservation Program. Addresses conservation of California least tern within its planning area.
- Feeding ecology and monitoring studies at the Alameda Point colony by the Point Reyes Bird Observatory.

- Predator control programs – cooperative agreements and efforts by Navy, Marine Corps, and the USFWS and Animal Damage Control.
- California Coastal Management Program, administered by the California Coastal Commission in accordance with the Coastal Zone Management Act, requires a review, permit, and appeal process; implementation of local coastal programs; and a federal consistency review to guide development along the coast.
- Protection under the Migratory Bird Treaty Act of 1918.
- Audubon efforts to use decoys and recorded calls to lure terns to protected habitat that offer a better chance at breeding success.
- Los Angeles trash removal and invasive plant control at nesting sites by local community groups and government agencies.

A24.7 Species Habitat Suitability Model

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and revise the vegetation input data as necessary.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf 2007. Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers, connectivity between habitat types, and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association (i.e., breeding, foraging, or movement/dispersal habitat). Finally, the assumptions used in the formulation of the model are described, and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The California least tern model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta]; Boul and Keeler-Wolf 2008 [Suisun Marsh]; TAIC 2008 [Yolo Basin]); USDA 2005 aerial photography; and DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable California least tern nesting and migratory habitat in the Plan Area. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Breeding and Foraging Habitat. Foraging habitat includes all areas mapped as tidal perennial aquatic. Nesting habitat is not mapped but is assumed to potentially occur along the perimeter of tidal perennial aquatic habitat.

Assumptions. As evidenced by recent breeding occurrences at the Montezuma Wetlands, Pittsburg Power Plant, and the Bufferlands, California least tern has potential to nest in shoreline habitat adjacent to large permanent water bodies within the Plan Area. It is assumed that continued range expansion could occur in association with suitable tidal perennial aquatic habitat throughout the Plan Area. While most of the shoreline habitat has been modified or is artificial, nesting colonies are often in artificially or incidentally created habitat (Rigney and Granholm 2005, Marschalek 2008) such as gravel roads, debris piles, and other conditions that mimic a natural sandy or gravelly substrate. It is assumed that foraging can occur in large river estuaries, such as the Sacramento and San Joaquin rivers, and other tidal perennial aquatic habitat throughout the Plan Area and Restoration Opportunity Area (ROAs). However, because little if any natural nesting habitat occurs and future breeding occurrences may occur incidentally around these water bodies, it is not possible to accurately determine locations of suitable breeding habitat. Therefore, it is assumed that breeding sites could occur in the future adjacent to tidal perennial aquatic habitat.

A24.8 RECOVERY GOALS

A recovery plan for the California least tern was published in 1980 and revised in 1985 (USFWS 1985). Recovery criteria included (1) at least 1,200 breeding pairs distributed in at least 20 of 23 coastal management areas; (2) each of the 20 management areas must have at least 20 breeding pairs; (3) each of the 20 management areas must have a 5-year mean reproductive rate of at least 1.0 young fledged per breeding pair; and (4) San Francisco Bay, Mission Bay, and San Diego Bay must be included within the 20 secure management areas with 4, 6, and 6 secure colonies respectively.

The most recent 5-year review (USFWS) indicated that while the gross number of pairs was six times the number identified in the criteria, this was the only recovery goal that has been fully met (USFWS 2006). The review also indicated that substantial new information was available that should be used to revise the recovery plan. While the 5-year review recommends a downlisting of status to "threatened," it also recommends the following:

- Revisit and revise the California least tern recovery plan;
- Continued management of existing nest sites;
- Monitoring of nest sites; and
- Creation of new nest sites and site expansion at existing sites.

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APPENDIX A25. GREATER SANDHILL CRANE (*GRUS CANADENSIS TABIDA*)

A25.1 LEGAL STATUS

The greater sandhill crane (*Grus canadensis tabida*) is listed as a state-threatened species under the California Endangered Species Act (Fish and Game Code, Sections 2050 et seq.). The species was listed by the California Fish and Game Commission in 1983. The greater sandhill crane is also designated as a state Fully Protected species. The greater sandhill crane has no federal regulatory status.

A25.2 SPECIES DISTRIBUTION AND STATUS

A25.2.1 Range and Status

The greater sandhill crane is one of six subspecies of sandhill crane in North America; three of which are non-migratory and occupy ranges in the southeastern United States and Cuba (Littlefield and Ivey 2000). The remaining three are migratory and include the lesser and greater subspecies, both of which are further divided into distinct populations. The greater sandhill crane is divided into five migratory populations, all of which return to the same breeding territory and wintering sites each year. These include: the Eastern Population, the Prairie Population, the Rocky Mountain Population, the Lower Colorado River Population, and the Central Valley Population. The Central Valley Population breeds in northeastern California (Figure A-25a), central and eastern Oregon, southwestern Washington, and southern British Columbia; and winters in the Central Valley of California (Littlefield and Ivey 2000).

Breeding Range. There are an estimated 500,000 sandhill cranes in North America, of which an estimated 62,600 are greater sandhill cranes. An estimated 8,500 of these belong to the Central Valley Population (Littlefield and Ivey 2000). The most recent breeding surveys have recorded 1,151 breeding pairs in Oregon, 465 breeding pairs in California, 20 pairs in Washington, and 11 pairs in Nevada (Engler and Brady 2000 as cited in Ivey and Herziger 2001, Ivey and Herziger 2000). The exact number of breeding pairs in British Columbia remains unknown; however, Littlefield and Ivey (2000) estimate approximately 2,500 individuals.

Within California, the breeding distribution is restricted to a six-county area in the northeastern corner of the state, including Siskiyou, Modoc, Shasta, Lassen, Plumas, and Sierra counties (Figure A-25a) (Littlefield 1982, Littlefield 1989, Ivey and Herziger 2001). Ivey and Herziger (2001) conducted the most recent surveys and found that the greatest number of breeding pairs are in Modoc County (54 percent) followed by Lassen County (26 percent). A total of 91 percent of the breeding pairs were found in Modoc, Lassen, and Siskiyou counties (Ivey and Herziger 2001).

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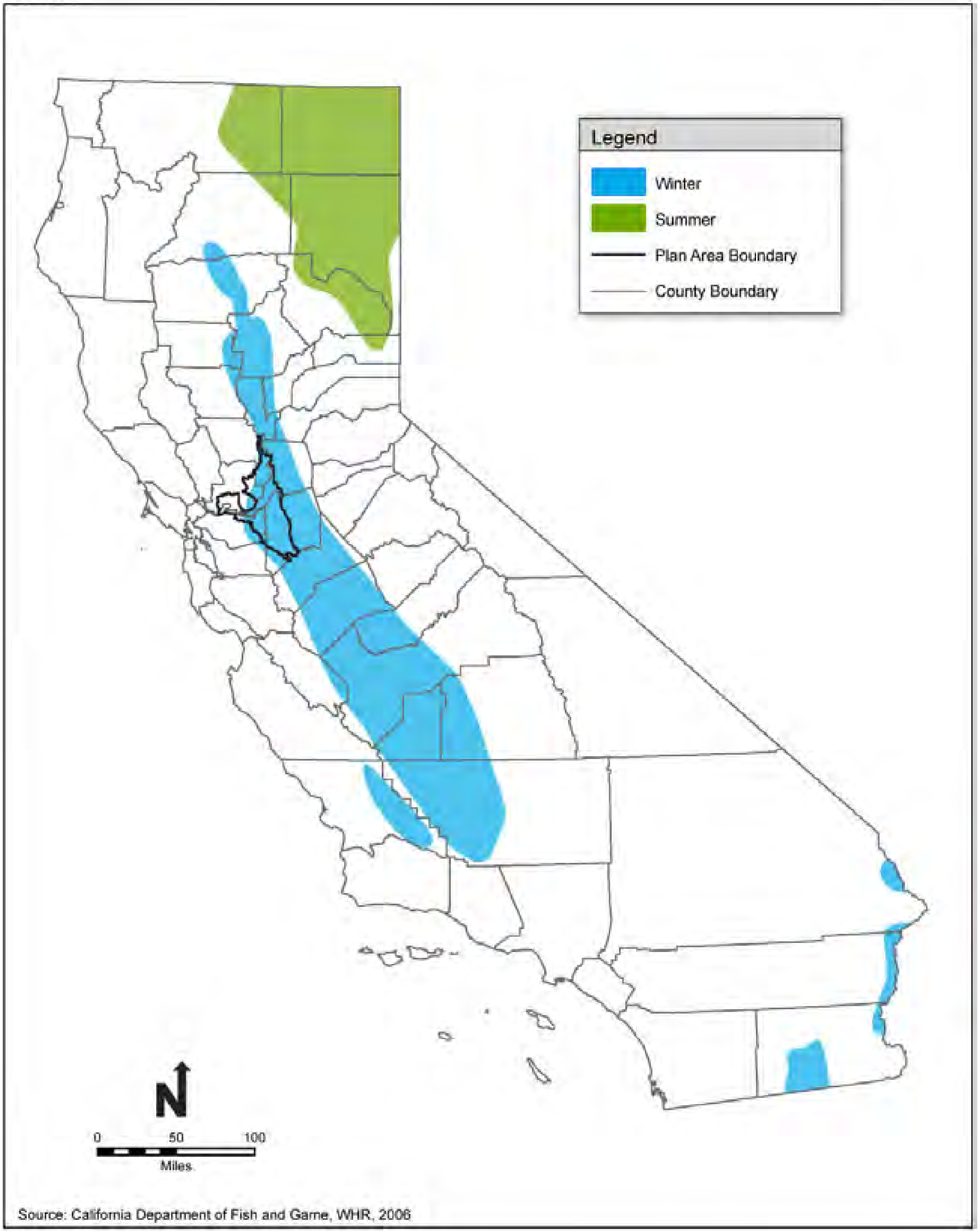

Figure A-25a. Greater Sandhill Crane Statewide Range and Recorded Occurrences

Prior to the early 1970s, survey efforts were insufficient to accurately estimate the breeding population of greater sandhill crane; however, major population declines have been noted and attributed to the widespread destruction of essential wetland habitats between 1870 and 1915 (Walkinshaw 1949). The first comprehensive surveys were conducted in 1971 (112 pairs), followed by surveys in 1981 (129 pairs) and 1988 (170 pairs), indicating a positive trend in the breeding population during that period (Littlefield 1982, Littlefield 1989). The next subsequent, and most recent, survey was conducted in 2000 (Ivey and Herziger 2001) when 465 pairs were reported, an increase of 68 percent since the 1988 survey. Much of this increase may be attributable to protection of traditional nesting areas on state and national wildlife refuges, lack of hunting, and a variety of management practices.

Wintering Range. Pogson and Lindstedt (1991) identified eight distinct wintering locations in the Central Valley from Chico/Butte Sink in the north to Pixley National Wildlife Refuge near Delano in the south, with over 95 percent occurring within the Sacramento Valley between Butte Sink and the Sacramento-San Joaquin River Delta (Figure A-25a). Use varies seasonally within this area probably as a function of the winter flooding regime and food resources. The Butte Sink has been reported to support a large segment of the population (>50 percent) during October and November. Use then shifts to the Delta and the Cosumnes River floodplain during December and January, where an estimated two-thirds of the population resides the remainder of the winter (Pogson and Lindstedt 1988, Littlefield and Ivey 2000).

The first exhaustive winter survey was conducted in the mid-1980s (Pogson and Lindstedt 1988), which estimated a wintering population of 6,000 birds. This was adjusted in the early 1990s to 8,500 birds as a result of additional follow-up survey work in the Sacramento Valley (Littlefield 1993). Although portions of the wintering population have been monitored periodically prior to and since the mid-1980s, no other comprehensive survey has been conducted and information has been insufficient to reliably detect trends.

A25.2.2 Distribution and Status in the Plan Area

Figure A-25b illustrates the distribution of the greater sandhill crane in the Plan Area. The entire Delta winter range of the species (defined here as including the Delta and Cosumnes River floodplain), as defined by Pogson and Lindstedt (1988), Littlefield and Ivey (2000), and most recently by Ivey (2010 pers. comm.) occurs within the Plan Area with the exception of the eastern portion of the Cosumnes River floodplain area. Greater sandhill cranes begin arriving in the Delta in October and from 3,000 to 4,000 cranes are in the Delta region in October and November. As noted above, the population peaks in December and January as cranes move into the Delta from the Butte Basin. An estimated two-thirds (from 5,000 to 6,000 cranes) of the population resides in the Delta the remainder of the winter (Pogson and Lindstedt 1988, Littlefield and Ivey 2000).

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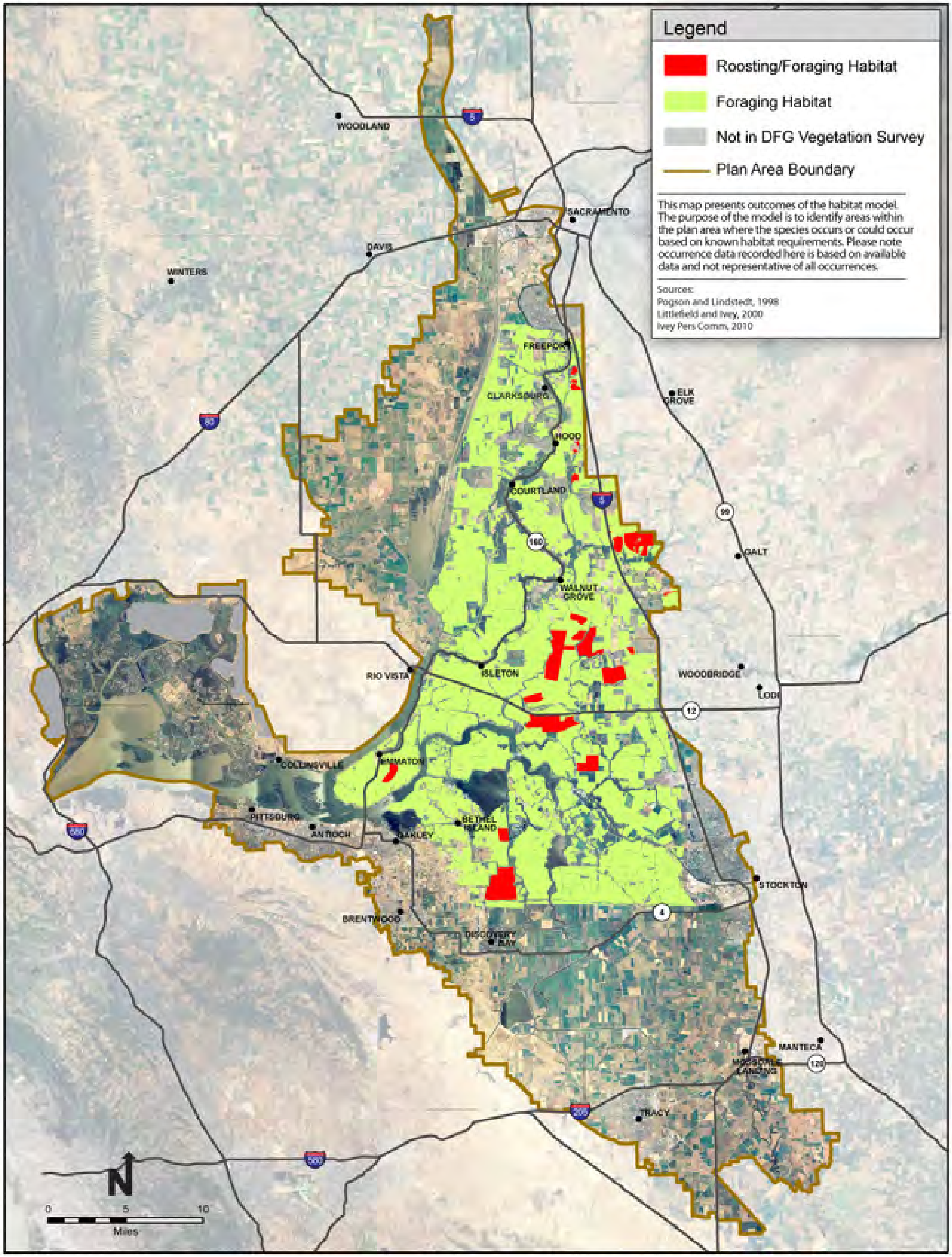

Figure A-25b. Greater Sandhill Crane Habitat Model

While populations have shifted over the years in response to changing agricultural patterns, particularly the increase of vineyards, the islands and tracts traditionally receiving the highest crane use include Staten Island, Terminous Island, Canal Ranch, and New Hope Tract. Other areas receive less and from occasional to regular use, including Bouldin Island, Empire Tract, King Island, Grand Island, Tyler Island, Ryer Island, Brannan Island, Twitchell Island, Bradford Island, Venice Island, Manderville Island, and Webb, Holland, and Palm tracts (Pogson 1990, Littlefield and Ivey 2000). More recently, greater sandhill cranes have also been found occasionally using Ridge, Bacon, and Roberts islands (Bradbury pers. comm.); and on lands west of the Sacramento River, in the west Delta in the vicinity of Sherman Island, and in the vicinity of the Stone Lakes National Wildlife Refuge (Ivey 2010 pers. comm.). Areas receiving the highest use are generally associated with the location of active roost sites. Highest levels of use are typically within approximately 2 miles of known roosts, and use (measured as a function of observed crane density) decreases beyond approximately 2 miles from roosts (Ivey 2010 pers. comm.).

The Cosumnes River floodplain, much of it protected within The Nature Conservancy's Cosumnes River Preserve, also supports significant winter crane use. Use may have increased in this area as continued conversion to vineyards on Delta Islands has reduced habitat availability in that area (Littlefield and Ivey 2000).

As noted, crane use is entirely dependent on agricultural crop patterns. Conversion to unsuitable crop types effectively eliminates crane habitat. Over the last two decades, a substantial amount of conversion to vineyards has occurred on Delta Islands and is considered among the most important conservation issues for greater sandhill crane (Littlefield and Ivey 2000). Several important traditionally used areas, such as portions of the Thompson-Folger Ranch along Peltier Road, have been converted to vineyards. Habitat loss from agricultural conversion and disturbances from increasing recreational activities in some areas threaten the long-term sustainability of key wintering areas for this species.

A25.3 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

Greater sandhill cranes are primarily birds of open freshwater wetlands. In California, nesting typically occurs in open grazed meadows. Most of these are bulrush or sedge meadows adjacent to grasslands or short vegetation uplands (Littlefield and Ryder 1968, Littlefield 1982). While breeding sites occur on state and federal refuges or U.S. Forest Service lands, more than 60 percent occur on private lands (Ivey and Herzinger 2001).

Wintering habitat is found almost entirely in agricultural fields and edges. Wintering habitat consists of three primary elements: foraging habitat, loafing habitat, and roosting habitat. There are two principal foraging habitat types used during winter. In the Delta, harvested corn fields are the most commonly used foraging habitat along with winter wheat, alfalfa, pasture, and fallow fields (Pogson and Lindstedt 1988). Ivey (pers. comm. in Sacramento County 2008) rated foraging habitat cover types in the Delta region in the following order of importance to greater sandhill cranes: harvested corn, winter wheat, irrigated pasture, and alfalfa fields. In the Butte Basin, harvested rice fields are the most commonly used foraging habitat along with winter wheat, harvested and unharvested corn, fallow fields, and grasslands (Pogson and Lindstedt 1988, Littlefield 2002).

Loafing generally occurs mid-day when birds loosely congregate along agricultural field borders, levees, rice-checks, ditches, or in alfalfa fields or pastures. Cranes will often loaf in rocky uplands or along gravel roads where they collect grit, which is important in the digestion of grain seeds. During the late afternoon and evening, cranes begin to congregate into large, dense communal groups where they remain until the following morning. Providing protection from predators during the night, roost sites are typically within two to three miles from foraging and loafing areas and thus available roosting sites are an essential component of winter habitat. Roosting habitat typically consists of shallowly flooded open fields of variable size (1 to 300 acres) or wetlands interspersed with uplands. Water depth is important and averages 4.5 inches. Littlefield (1993) reported cranes abandoning roosting sites when water depth reached 8 to 11 inches. He recommended roost sites be a minimum of 20 acres in size with water maintained from early September to mid-March. If properly managed, roost sites are often used for many years.

Greater sandhill cranes are considered intolerant of excessive human disturbances and the level of disturbance may play a role in habitat selection (Lovvorn and Kirkpatrick 1981).

Excessive disturbances have caused cranes to abandon foraging and roosting sites; and repeated disturbance may affect their ability to feed and store the energy needed for survival. Ivey and Herziger (2003) documented disturbances of greater sandhill cranes on Staten Island, a high use area, and found that aircraft, vehicles, hunting, and recreational activities (e.g., birding, walking, horseback riding, bicycling, boating) can cause cranes to run or fly away. Ivey (pers. comm. in Sacramento County 2008) found that cranes generally avoid suitable agricultural foraging habitat near occupied dwellings, and foraging areas within 100 yards of occupied dwellings should not be considered suitable (Sacramento County 2008).

A25.4 Life History

Description. The greater sandhill crane is the largest of the six sandhill crane subspecies. It stands up to 4.9 feet and has a wing span from 5.9 to 6.9 feet. Adult males and females are similar in appearance with gray plumage, whitish face, chin, and upper throat, and a bare red forehead and crown. Greater sandhill cranes sometimes preen iron-rich mud into their feathers leaving a rusty-brown hue that can last throughout the summer months and sometimes remains detectable during the early winter. Juveniles are easily detectable through their first winter by their smaller size and cinnamon-brown plumage, which changes to gray during their first year (Tacha et al. 1992).

Seasonal Patterns. Nesting generally begins in April and May and extends from July through August. By September, the Central Valley population begins their migration and arrives onto the wintering grounds by late September, where they remain until approximately late February to early March, when they begin their northward migration back to the breeding grounds (Pogson 1990, Tacha et al. 1992). Local winter movements continue throughout the winter season in response to changes in flooded habitat and available food resources. For example, Pogson and Lindstedt (1988) and Littlefield (2002) report extensive use of the Butte Basin during the early part of the winter season in October and November and movement of a large segment of the population into the Delta during December and January.

Nest Site Selection. Nesting areas are selected on the basis of meadow size, flooding regime, condition of meadow and presence of cattle, vegetation composition, available food resources, and proximity to human disturbances (Armbruster 1987). Nests are usually constructed as mounds in shallow water (generally less than 12 inches deep), typically in wetland vegetation. The nest is constructed by plucking and stacking the dominant vegetation in the nesting area to form a mound. These are often very large, 2 to 3 feet high and up to 6 feet in diameter. They often use all of the vegetation from several feet around the nest creating a distinctive circular unvegetated ring around the nest mound (Smith 1999). Nests are also constructed on dry ground.

Reproduction. Females usually lay two eggs. Both the male and female incubate the eggs; incubation lasts from 29 to 32 days. One or two young fledge from successful nests. Young fledge at 67 to 75 days. Juveniles remain with the adults during the first year in family groups and do not disperse until they return to the breeding areas the following year (Tacha et al. 1992).

Foraging Behavior and Diet. Sandhill cranes are omnivorous and primarily search for subsurface food items by probing soil with their bill. They also glean seeds and other foods on the surface (Walkinshaw 1973, Tacha 1987).

Sandhill crane diet consists of tubers, seeds, grains (particularly corn and rice), small vertebrates (e.g., mice and snakes) and a variety of invertebrates.

Home Range/Territory Size. Ivey and Herziger (2003) estimated average winter home range sizes of greater sandhill cranes in the Delta to be 0.66/square miles, varying from 0.07 to 2.12 square miles. Average distance between roost sites and feeding areas was estimated by Pogson (1990) to be 1.74 miles and by Ivey and Herziger (2003) to be 0.88 miles (range 0.17 to 1.89 miles).

A25.5 THREATS AND STRESSORS

On the breeding grounds, threats include changes in water regime that lowers the water table and eliminates nesting areas; cattle grazing that can degrade habitat, destroy nests, and disturb nesting birds; and mowing and haying operations that can kill young cranes.

Threats on the wintering grounds include changes in water availability; flooding fields for waterfowl, which reduces foraging habitat for cranes; conversion of cereal cropland to vineyards or other incompatible crop types; human disturbances; collision with power lines and other structures; disease; and urban encroachment (Littlefield and Ivey 2000).

Habitat Loss and Alteration. The most significant threat to wintering greater sandhill cranes is the loss of traditional winter habitat from urbanization and agricultural conversion. While relatively limited urbanization has occurred to date within key crane areas, surrounding development and increased levels of human disturbances may threaten the long-term sustainability of important wintering lands. In the Delta region, the conversion of suitable agricultural foraging and roosting habitats to unsuitable cover types, particularly orchards and vineyards, has removed key habitats and altered the distribution and behavior of wintering greater sandhill cranes.

Disturbance of Foraging and Roosting Areas. Greater sandhill cranes are sensitive to human presence and do not tolerate regular disturbances, including low-level recreational disturbances. Types of disturbances include hunting, birding, photography, operating equipment for habitat management, boating, and aircraft. Disturbances cause birds to abandon otherwise suitable habitats, and may cause birds to deplete important energy stores needed for survival during wintering and migration. Only one pre-dawn disruption is usually necessary before cranes abandon a site (Littlefield and Ivey 2000). Disturbance from hunting also poses a threat to cranes. Hunters accessing hunt areas during pre-dawn hours flush cranes from their roosts and hunter presence can keep cranes from roosting or foraging in an area (Ivey and Herziger 2003). Flooding of agricultural fields for waterfowl hunting also reduces available foraging habitat for wintering cranes.

A25.6 Relevant Conservation Efforts

Several significant efforts have been made to protect and enhance wintering habitat for greater sandhill cranes. In 1985, the California Department of Fish and Game (DFG) acquired and continues to manage the Woodbridge Ecological Reserve. Purchased specifically to manage as a crane roosting area, this site has been a traditional crane roost for decades and continues to be one of the most important crane roosts for this wintering population.

Management of Staten Island has also provided substantial benefit to greater sandhill cranes. The island has been managed for several decades to provide benefit to wildlife in conjunction with agricultural production. Crane use of the island has increased particularly since the 1980s and 1990s under the successful management of the private landowners and continues to be among the most significant crane use areas in the Delta (Littlefield and Ivey 2000). In 2002, The Nature Conservancy established the Conservation Farms and Ranches program to provide oversight management of Staten Island and to ensure long-term conservation of crane habitat on the island.

Beginning in 1984, a cooperative effort between The Nature Conservancy, the Bureau of Land Management, the California Department of Fish and Game, the Wildlife Conservation Board, and Ducks Unlimited also began acquiring lands that today encompass approximately 40,000 acres on the Cosumnes River Preserve. Portions of the preserve are managed specifically for winter crane use and have attracted up to 20 percent of the greater sandhill crane wintering population at certain times of the wintering season (Littlefield and Ivey 2000).

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designates the greater sandhill crane as a "Contribute to Recovery" species (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its control and within its scope that are necessary to contribute to the recovery of the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

Greater sandhill crane is a covered species under the approved San Joaquin County Multi-species Habitat Conservation and Open Space Plan. It is also proposed for coverage under the South Sacramento County Habitat Conservation Plan and the Butte Regional Conservation Plan.

A25.7 SPECIES HABITAT SUITABILITY MODEL

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf 2007. Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers, connectivity between habitat types, and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The greater sandhill crane model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), USDA 2005 aerial photography, and DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable winter roosting and foraging greater sandhill crane habitat in the Plan Area. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Winter Roosting and Foraging Habitat. Greater sandhill crane winter roosting and foraging habitat includes selected grasslands, managed seasonal wetlands, natural seasonal wetlands, rice lands, pasturelands, hay crops, and annually rotated agricultural crops that occur within the defined winter range. Natural vegetation types designated as species habitat in this model correspond to the mapped vegetation associations in the BDCP composite vegetation data layer. Agricultural crop types designated as species habitat correspond to DWR 2007 land use survey data.

The Delta winter range is defined by traditional use areas as described by Pogson and Lindstedt (1988, 1991) and most recently mapped by Littlefield and Ivey (2000) and Ivey (2010 pers. comm.), along with additional observations of occasional use areas (Bradbury pers. comm.).

Winter roosting and foraging habitat in the Delta includes the following types from the BDCP composite vegetation layer:

- Grassland
  - Ruderal herbaceous grasses and forbs;
  - California annual grasslands;
  - *Bromus diandrus-Bromus hordeaceus;*
  - Italian rye-grass (*Lolium multiflorum*);
  - *Lolium multiflorum-Convolvulus arvensis;*
  - Degraded vernal pool complex – California annual grasslands;
  - Degraded vernal pool complex – Ruderal herbaceous grasses and forbs; and
  - Degraded vernal pool complex – Italian rye-grass (*Lolium multiflorum*).
- Vernal pool complex
  - Ruderal herbaceous grasses *and forbs;*
  - *Califor*nia annual grasslands;
  - Italian rye-grass (*Lolium multiflorum*);
  - *Distichlis spicata* – annual grasses;
  - *Distichlis*/annual grasses;
  - Seasonally-flooded grasslands;
  - Vernal pools;
  - Annual grasses generic; and
  - Annual grasses/weeds.
- Managed wetland
  - Temporarily flooded grasslands;
  - Rabbitsfoot grass (*Polypogon monspeliensis*);
  - Intermittently flooded perennial forbs;
  - Managed annual wetland vegetation (non-specific grasses and forbs);
  - Shallow-flooding with minimal vegetation;
  - Seasonally flooded undifferentiated annual grasses and forbs;
  - Managed alkali wetland (*Crypsis*);
  - Intermittently or temporarily flooded undifferentiated annual grasses and forbs;

    - *Scirpus*[1] spp. in managed wetlands; and
    - Smartweed *Polygonum* spp. – mixed forbs.
- Alkali seasonal wetland complex and other seasonal wetlands
    - *Distichlis spicata* – annual grasses;
    - Seasonally-flooded grasslands;
    - Vernal pools;
    - Degraded vernal pool complex-vernal pools;
    - Temporarily flooded perennial forbs; and
    - *Juncus balticus* – Meadow vegetation.

Agriculture. The following DWR 2007 Land Use survey types are included as suitable agricultural roosting and foraging habitats. These types represent the typical agricultural cover types in the Plan Area that are included in the DWR 2007 land use survey. Rotational crop types that are not common to the Plan Area are not included here. Pasture types are mostly perennial; alfalfa is semi-perennial (3 to 7 years); and all other types are annually or seasonally rotated irrigated crops, only some of which (italicized) provide high value habitat for greater sandhill cranes.

- Grain and hay crops
    - Barley;
    - *Wheat;*
    - Oats; and
    - Miscellaneous and mixed grain and hay.
- Field crops
    - Safflower;
    - Sugar beets;
    - *Corn;*
    - Grain sorghum;
    - Sudan;
    - Beans;
    - Miscellaneous field; and

[1] Currently known as *Schoenoplectus*.

   - Sunflowers.
- Pasture
   - *Alfalfa and alfalfa mixtures;*
   - Clover;
   - *Mixed pasture;*
   - *Native pasture;*
   - Induced high water table native pasture; and
   - Miscellaneous grasses.
- Truck, nursery and berry crops
   - Asparagus;
   - Beans;
   - Onions and garlic;
   - Tomatoes; and
   - Peppers.
- Idle
   - Land not cropped the current or previous crop season, but cropped within the past three years; and
   - New lands being prepped for crop production.

Assumptions. Greater sandhill crane does not breed in the Plan Area, but the Plan Area contains one of the most important wintering areas of this state threatened species (Figure A-25b) (Pogson and Lindstedt 1988). The Delta winter range is defined by traditional use areas as described by Pogson and Lindstedt (1988, 1991) and most recently mapped by Littlefield and Ivey (2000) and supplemented with new information by Ivey (2010 pers. comm.). The Littlefield and Ivey (2000) and Ivey (2010 pers. comm.) map along with modifications based on recent crane use in the Stone Lakes area are used here to define the geographic winter range of the species within the Plan Area.

Throughout their wintering range in the Delta, cranes roost in shallowly flooding seasonal wetlands and forage primarily in harvested corn fields, winter wheat fields, alfalfa fields, seasonal wetlands, irrigated pastures, and grasslands (Pogson and Lindstedt 1988, 1991, Littlefield and Ivey 2000). Suitable foraging habitat is likely also a function of patch size. However, because there is insufficient data on winter habitat patch size and because, in general, field size within the Delta winter range are probably sufficiently large to support foraging cranes, all suitable cover types are considered suitable irrespective of patch size. Because annually rotated crop types could convert to a more suitable or less suitable cover type in any given year, all crop types that are or could potentially rotate into a suitable cover type (Grain and hay; Field; and Truck, nursery and berry crop types listed above) are included here as potentially suitable habitat. Therefore, these crop types are not differentiated based on their seasonal value and are instead combined into a category of seasonally rotated croplands. As a result, this model overestimates the extent of available agricultural roosting/foraging habitat in any given year.

It is assumed that under appropriate management, all cover types could function as roosting habitat. However, known roosting sites indicated on Figure A-25b are provided by Ivey (2010 pers. comm.).

The model also does not differentiate habitat value based on observed crane use patterns within the overall use area. The model only differentiates potential use based on the presence or absence of suitable cover types as defined above irrespective of geography within the overall use area. While the distance from roost sites is an important factor that influences use of surrounding foraging habitats, using this criterion to further define use patterns assumes knowledge of all roost sites in the crane use area and assumes the stability of roost site locations over time.

Habitat Units. As described, greater sandhill cranes are closely associated with agricultural lands in the Plan Area. Most of the land within the Delta use area consists of agricultural land, and much is considered to have some value as foraging habitat for greater sandhill cranes. While the species is traditional to winter use areas, the agricultural landscape throughout the crane's use area is dynamic and subject to seasonal and annual changes in crop types. Because the greater sandhill crane is closely associated with specific agricultural crop types and patterns, use areas are also subject to change as crop patterns change. Because of the dynamic nature of the agricultural landscape and the variability of crop patterns and conditions seasonally and annually, only a portion of the agricultural landscape is suitable or available for foraging in any given season. To account for this variability and to more accurately represent the value of Plan Area-wide foraging habitat, acres of greater sandhill crane foraging habitat can be converted to habitat units.

Sufficient information is available on the use of different agricultural crops to generally categorize crops based on their value as foraging habitat. By placing different crop types and other foraging habitats that traditionally occur in the Plan Area into crop value classes and assigning relative values to those classes (e.g., 0.1, 0.5, 0.75, and 1.0), the habitat acres can be converted to habitat units. Habitat units, in addition to acres, can then be used to describe and calculate impacts to crane foraging habitat using this index of habitat value. Table A-25a provides the rationale for assigning crop types and other agricultural land uses to habitat value categories. Figure A-25c displays the distribution of habitat and the assigned habitat values within the Plan Area.

Table A-25a. Greater Sandhill Crane Foraging/Roosting Habitat Suitability Model

Foraging Habitat Value Class	*Assigned Agricultural Crops/ Habitats*	*Rationale for Assignment of Agricultural Crop Class*	*Information Sources[1]*
1.0-Very High	Corn, managed wetland	The primary food of sandhill cranes in agricultural areas is waste grain. Within the Delta wintering area, waste corn from harvested fields is generally regarded as the highest value forage for cranes. Fields traditionally planted to corn in the central Delta and therefore considered to have the highest value ranking relative to other agricultural cover types. Managed wetlands also provide high value invertebrate prey and potential roosting sites if they meet crane roosting habitat needs (e.g., appropriate water depth, vegetation type, availability of berms and other adjacent uplands, and proximity to agricultural foraging habitats) and are thus also regarded as having the highest value ranking.	Reinecke and Krapu 1979, Pogson and Lindstedt (1991), Ivey (pers. comm.); Littlefield and Ivey (2000)
.75-High	Alfalfa, irrigated pasture, wheat	Alfalfa, irrigated pasture, and winter wheat also provide high value foraging habitat for cranes. However, these types are generally used on a more temporary basis based on crop growth, harvesting, irrigation, and grazing regimes. For example, use of alfalfa fields increases following cutting and during flood irrigation events. Wheat, while available during November and December following initial planting, decreases in value during January and February as the vegetation height increases.	Pogson and Lindstedt (1991), Ivey (pers. comm.); Littlefield and Ivey (2000)
.5-Medium	Other grain crops, grassland	Other grain crops including rice and barley also provide foraging value but are traditionally less abundant in the Delta (e.g., rice) or the growth/harvest regime is not optimal for crane foraging use (e.g., barley, oats).	Pogson and Lindstedt (1991), Ivey (pers. comm.); Littlefield and Ivey (2000)
.25-Low		There are a variety of other agricultural cover types in the Delta, many of which may be occasionally used by foraging cranes. However, in most cases they are regarded as having significantly lower value in terms of relative suitability/use than those noted in the Very High, High, and Medium categories, and are therefore placed in the Marginal category below.	
.10-Marginal	Other irrigated crops, natural seasonal wetland, idle cropland	A variety of other irrigated crops may receive occasional use by cranes during the winter if fields have been left idle following harvest or immediately following planting. Some types of natural seasonal wetland may also provide suitable foraging habitat for cranes. These types, however, are dependent on vegetation type and structure, flooding, and food availability (waste grain, invertebrates, etc.) and are considered less predictable than the types identified in the Very High, High, and Medium categories.	Pogson and Lindstedt (1991), Ivey (pers. comm.); Littlefield and Ivey (2000)

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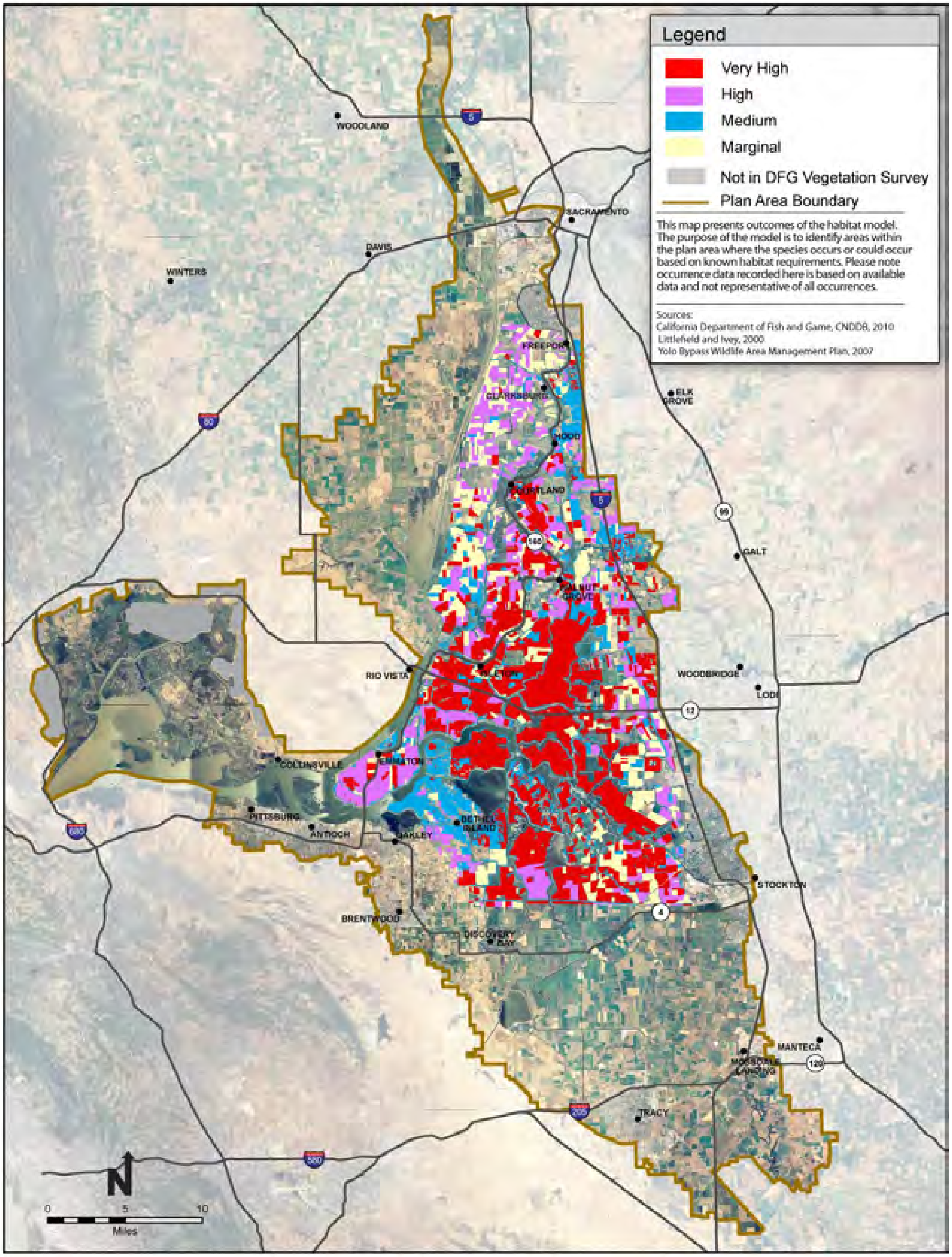

Figure A-25c. Greater Sandhill Crane Foraging Habitat and Associated Value Rankings

A25.8 Recovery Goals

In 1997 the California Endangered Species Act was amended, explicitly requiring the California Department of Fish and Game to develop a recovery strategy pilot program for the greater sandhill crane (DFG 2001). A recovery strategy team was assembled with representatives from state and federal agencies, local landowners, environmental groups, and species experts; and it produced a draft recovery strategy. The strategy included long-term recovery goals, and a range of alternative management goals and activities. The overall goal was to improve the status of the species through a variety of specific habitat protections and other actions so the protections of the California Endangered Species Act are no longer necessary, and therefore, delisting can be proposed (DFG 2005). The draft recovery strategy has not been finalized or implemented.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designates the greater sandhill crane as "Contribute to Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its control and within its scope that are necessary to contribute to the recovery of the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

A25.9 References

A25.9.1 Literature Cited

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APPENDIX A26. CALIFORNIA BLACK RAIL (*LATERALLUS JAMAICENSIS COTURNICULUS*)

A26.1 Legal Status

The California black rail (*Laterallus jamaicensis coturniculus*) is listed as a threatened species under the California Endangered Species Act. It was listed by the California Fish and Game Commission in 1971. It is also designated as a Fully Protected species in California.

Black rail has no federal regulatory status; however, it is on the U.S. Fish and Wildlife Service (USFWS) Region 1 list of Birds of Conservation Concern (BCC). BCC species are those that the USFWS considers potential candidates for federal listing.

A26.2 Species Distribution and Status

A26.2.1 Range and Status

The California black rail is one of two subspecies of black rail that inhabit North America. The range of the California black rail extends throughout portions of California and Arizona. The Eastern black rail (*Laterallus jamaicensis jamaicensis*) is found along the eastern seaboard, along the Gulf Coast, and rarely at inland sites in the Midwest (Eddleman et al. 1994).

The historical range of the California black rail extended from the San Francisco Bay, throughout the Sacramento-San Joaquin Delta, along the coast to northern Baja California, at other Southern California locales such as the Salton Sea, and along the lower Colorado River. Breeding records existed early in the century of black rail populations existing on coastal marshes in San Diego, Los Angeles, and Santa Barbara counties. Loss of tidal marsh habitat has extirpated populations from much of its coastal range, particularly in Southern California and much of the San Francisco Bay since the 1950s (Manolis 1978, Garrett and Dunn 1981 as cited in DWR 2001).

Figure A-26a illustrates documented occurrences of California black rail in California. The species persists in remaining tidal marshes in the northern San Francisco Bay estuary, Tomales Bay, Bolinas Lagoon, the Sacramento-San Joaquin Delta, Morro Bay, the Salton Sea, and the lower Colorado River (Manolis 1978, Evens et al. 1991, Eddleman et al. 1994). Several small, isolated populations also still exist in southeastern California and western Arizona (Evens et al. 1991). The species has also been found more recently at several inland freshwater sites in the Sierra Nevada foothills in Butte, Yuba, and Nevada counties (Aigner et al. 1995, Tecklin 1999), and most recently in Clover Valley (City of Rocklin) in southern Placer County (The California Black Rail Project 2006). Additional detections have been made recently at the Cosumnes River Preserve in South Sacramento County and Bidwell Park in Chico, Butte County (Central Valley Bird Club Site Guides).

DRAFT

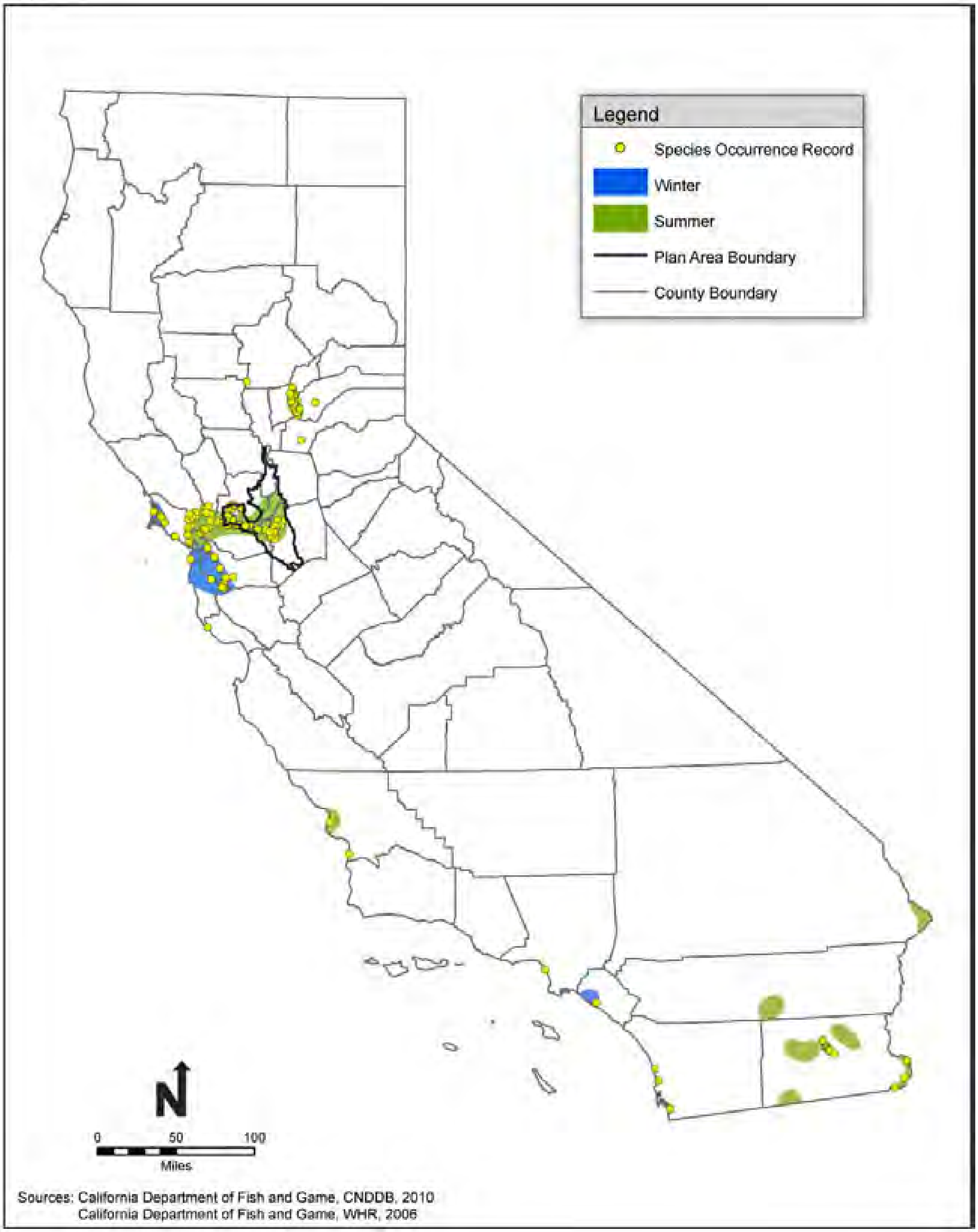

Figure A-26a. California Black Rail Statewide Range and Recorded Occurrences

1

Additional recent unconfirmed sightings from rice fields in the Butte Sink and Sutter County suggest that there may be down slope movement from the foothill breeding population.

Until 1994, the black rail was unknown from the Sacramento Valley except for a single winter record at the California Department of Fish and Game's (DFG) Gray Lodge Wildlife Area in Butte County. In 1994, a population of the rail was found occupying a freshwater marsh at the University of California's Sierra Field Station in Yuba County (Aigner et al. 1995). Further examination revealed that the species could be breeding at four separate freshwater marsh ponds within approximately 3.7 miles (6 kilometers) of each other. As a result, the DFG provided funding for a more regional survey effort that resulted in additional occurrences in Butte, Yuba, and Nevada Counties (Tecklin 1999). Since then, the University of California has continued with a study, the California Black Rail Study Project, that locates additional subpopulations in their Sierra Nevada foothill study area and examines how each of these isolated subpopulations are functioning as a metapopulation.

As of 2005, this ongoing study included 168 wetland sites in their sample, with 54 percent of these occupied by black rails (The California Black Rail Project 2005). These populations, and presumably others that remain undetected in the region, are considered to be year-round residents. Given the geographic extent of this metapopulation and the consistently high occupancy rate detected over the last five years, it is likely that additional subpopulations occur elsewhere in the Sacramento Valley and Sierra Nevada foothills.

Declines in populations of the black rail in California are a result of habitat loss and degradation along with an increase in exotic predators such as black rats and red foxes (Evens et al. 1991). However, because there were no estimates of historical population levels, the extent of population declines is not fully understood. Evens et al. (1991) examined relative abundance of rails at various locations within the species' range and determined that more than 80 percent of the remaining population is confined to the northern reaches of the San Francisco Bay estuary. They also determined that the species was subject to continuing and ongoing population decline due to habitat loss and/or degradation.

A26.2.2 Distribution and Status in the Plan Area

Within the San Francisco Bay and Sacramento-San Joaquin River Delta region, California black rail populations are restricted primarily to the remaining tidal marshlands of the northern San Francisco Bay estuary, and the vicinity of Suisun and Napa marshes (Figure A-26b). In Suisun Marsh, a high abundance of black rails have been found at east Mallard Island and moderate abundances at South Joice Island, Pacheco Creek, East Peyton Slough, Cutoff Island, Peytonia Slough, and Southampton Bay (Spautz et al. 2005). It is possible that a small population occurs in the vicinity of Little Honker Bay and on the north shore of Nurse Slough. In moderate abundances, black rails were found in the northern reaches of Suisun Bay in undiked marshes along the northern bank of Cutoff Slough from Beldonís Landing west to Suisun Slough.

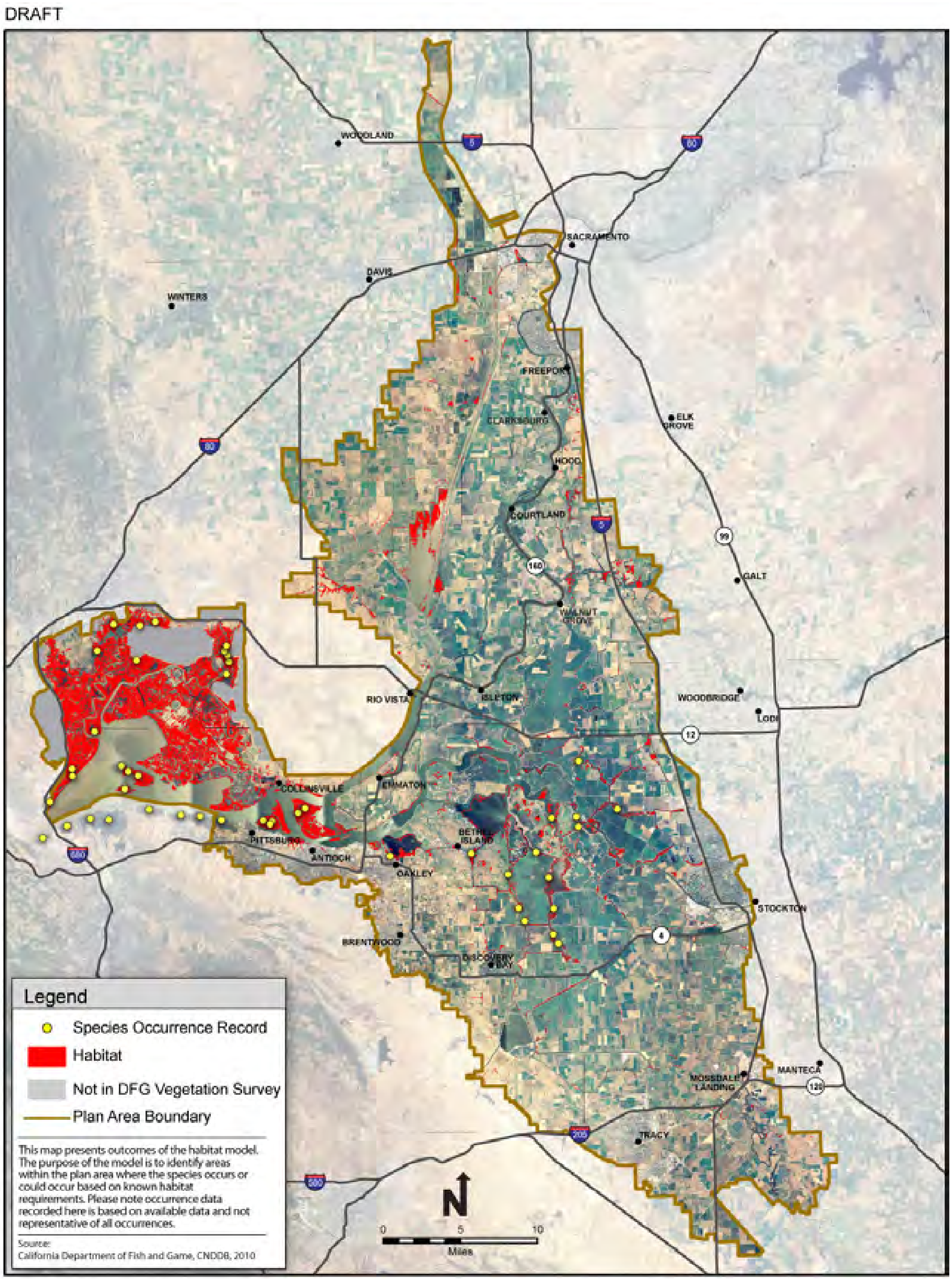

Figure A-26b. California Black Rail Habitat Model and Recorded Occurrences

Surveys conducted by DFG in the early 1990's found small numbers of black rails at several locations in the central Delta, including White, Little Potato, Disappointment, and Whiskey sloughs; mid-Channel Islands in Middle and San Joaquin rivers; Holland and Palm tracts; and Mildred, Bacon, and Mandeville islands (CNDDB 2008).

The National Audubon Society's Important Bird Areas Report for the Sacramento-San Joaquin Delta reports that California black rail occurs on most in-stream islands greater than 15 acres (6 hectares) that support marsh vegetation elevated above the high tide and wave line (National Audubon Society 2008).

Larger concentrations of black rail occur in the western portion of the Plan Area in the vicinity of Little Honker Bay and Kimble Island, and smaller concentrations on small in-channel islands, and other wetlands within the central Delta between State Route 12 (SR-12) and SR-4 (Figure A-26b). Overall, habitat availability is restricted to remnant wetland sites that are generally unavailable for agricultural uses. Insufficient data have been collected to estimate black rail populations within the Plan Area; however, the small populations found in the central Delta portion of the Plan Area likely represent a relatively small proportion of the San Francisco Bay/Sacramento-San Joaquin River Delta region. Regardless, these small populations that persist east of the Suisun Marsh are important relative to the overall range and dispersal capabilities of the species.

A26.3 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

California black rails inhabit tidal saltwater and brackish marshes, and freshwater marshes (Grinnell and Miller 1944, Manolis 1978, Spautz et al. 2005). A highly secretive and rarely observed bird, there appears to be a preference in coastal areas for tidal salt marshes dominated by dense pickleweed (*Sarcocornia*[1] spp.) with an open structure below. This provides a dense canopy for protective cover while providing nesting habitat and accessibility below the canopy (Evens and Page 1983). Rails are susceptible to predation by herons, egrets, northern harriers, short-eared owls, and several mammalian predators. A dense canopy that provides optimal cover is essential for survival.

Black rails tend to be associated with areas where *Schoenoplectus*[2] spp. and *Sarcocornia* border each other. Evens et al. (1991) found rails where there was a mosaic of *Juncus* (40 percent), *Schoenoplectus* (30 percent), *Triglochin* (10 percent), *Grindelia* (<10 percent), *Distichlis* (<10 percent), and *Typha* (<10 percent). In Suisun Marsh, presence of black rails occurs in conjunction with a pickleweed-alkali heath-American bulrush plant association in the high marsh zone. Data from Spautz et al. (2005) indicate that black rails prefer marshes that are close to water (bay or river), large, away from urban areas, and saline to brackish with a high proportion

[1]Formerly known as *Salicornia*.
[2]Formerly known as *Scirpus*.

of *Sarcocornia*, *Grindelia*, *Schoenoplectus maritimus*, *Juncus*, and *Typha*. Escape cover is critical to these birds. Rail nests consist of loosely-made, deep cups either at ground level or slightly elevated. Nests are concealed in dense marsh vegetation near the upper limits of tidal flooding (DWR 2001).

Away from coastal estuaries and salt marshes, black rails are restricted to breeding in freshwater marshes with stands of tule, cattail, bulrush, and sedge (*Carex* spp.) (Eddleman et al. 1994). These sites are very shallow (usually less than 3 centimeters [cm]), but require a perennial water source. A relatively narrow range of conditions is required for occupancy and successful breeding. Water depth is an important parameter for successful nest sites as rising water levels can prevent nesting or flood nests and reduce access to foraging habitat (Eddleman et al. 1994). Too little water will lead to abandonment of the site until the water source is reestablished. Primary factors determining their presence are annual fluctuations in water levels and shallow water depth (<3 cm) (Rosenberg et al. 1991, Eddleman et al. 1994, Conway et al. 2002). There is no information on minimum patch size for the California black rail in the Central Valley and Delta Region; however, in the foothills of the central Sierra Nevada, rails are in marshes ranging from 0.5 to 25 acres (0.2 to 10.1 hectares) in size, with 32 percent of occupied sites in wetlands less than 0.75 acres (0.3 hectares) (Tecklin 1999). The discovery of these Sierra Nevada populations suggest that the species is able to colonize isolated habitat patches (Aigner et al. 1995, Trulio and Evens 2000).

Black rails occur in marshland only, a habitat mostly destroyed or modified in the western United States since the mid-1800s (Atwater et al. 1979, Zedler 1982, Josselyn 1983, Nichols et al. 1986 as cited in DWR 2001). Populations and numbers have and will continue to decline as loss and alteration of habitat continues. Currently, the species is confined to mostly pristine remnants of historical tidal marshlands, mainly along the large tributaries and shoreline of northern San Pablo Bay, along the Carquinez Strait, and throughout parts of Suisun Bay (Evens et al. 1991, Spautz et al. 2005). The marshes of San Pablo and Suisun bays are important in that they are the last large refuge areas for a viable population. There is no evidence that black rails recolonize restored marshes for breeding (Evens et al. 1989).

A26.4 Life History

Description. The California black rail is a small (12- to 15-cm [4.7- to 5.9-inch]), secretive, marsh-associated species (Eddleman et al. 1994). They are black to gray in color with a small black bill, sides and back speckled with white, and a nape of deep chestnut brown (DFG 1999). Difficult to observe, rails are usually identified by their call.

Seasonal Patterns. Very little information is available on seasonal patterns, timing of reproduction, dispersal, or other activities. The breeding season begins as early as February with pair formation and extends through approximately early-to-mid June. Egg-laying peaks around May 1 (Eddleman et al. 1994). The species is generally known as a medium-distance migrant that winters in Mexico and Central America; however, recently discovered inland populations in California are thought to be year-round residents. At these locations, seasonal movements including juvenile dispersal and adult relocation to other wetland breeding sites occur each year sometime during the non-breeding season between approximately August and February (Tecklin 1999).

Reproduction. Black rails are monogamous birds. They build cup nests with a woven canopy in dead or new emergent vegetation over shallow water less than 3 cm (1.2 inches) in depth (Eddleman et al. 1994). They initiate egg-laying within a few days after nest construction is complete. Rails in California usually lay one single brood with an average clutch size of 6 eggs (range equals 3 to 8 eggs) (Eddleman et al. 1994). The incubation period ranges from 17 to 20 days and both adults apparently incubate the eggs (Flores and Eddleman 1993); however, there is very limited data. After hatching, the semi-precocial young leave the nest within a day, but at least one parent continues to brood the young for several additional days (Eddleman et al. 1994). There is limited information on length of brooding period, timing of fledging, parental care, or reproductive success.

Home Range/Territory Size. California black rails have small home ranges in the breeding season. In north San Francisco Bay tidal marshes, fixed-kernel home ranges (representing 95 percent utilization distribution) averaged 1.5 acres (0.6 hectare) and core use areas (representing the 50 percent utilization distribution) averaged 0.3 acre (0.1 hectare) (Tsao et al. in press). Using a different calculation method, Flores and Eddleman (1991) found that California black rail minimum convex polygon (MCP) home ranges in Arizona averaged 1.1 acres (0.4 hectare). For comparison, MCP home ranges for San Francisco Bay black rails averaged 0.6 acre (0.2 hectare) (Tsao et al. in press). Studies of other rail species showed increased home range sizes outside of the breeding season (Bookhout and Stenzel 1987, Conway 1990); however, black rails in Arizona, where water levels remain steady throughout the year, showed no difference in home range size across seasons (Flores and Eddleman 1991).

Foraging Behavior and Diet. Very little information is available on the foraging behavior of the black rail. The species is assumed to be an opportunistic daytime feeder that forages exclusively within the wetland habitat, presumably on or near the ground at the edges of emergent vegetation. Their diet consists of insects, small mollusks, amphipods, and other invertebrates, and seeds from bulrushes (*Schoenoplectus* spp.) and cattails (*Typha* spp.) (Eddleman et al. 1994).

A26.5 Threats and Stressors

Throughout its range, the primary threat to California black rail is the loss and fragmentation of habitat from urbanization, flood control projects, agricultural practices, and hydrologic changes that affect water regimes. The most significant historical threat was the draining of tidal marshes, which may be responsible for over 90 percent of the population declines of this species, and which is still occurring in some areas, albeit at a slower rate.

At inland sites, agricultural practices, livestock grazing, and urbanization may threaten individual subpopulations. Use of pesticides, including those used for mosquito control programs may also have unintended consequences for black rails. These isolated subpopulations are also susceptible to metapopulation dynamics and stochastic variables (Evens et al. 1991). Other potential threats include increased predation by domestic cats and by native predators as a result of hydrologic and vegetation changes that increase black rail susceptibility to predation; pollution and its effect on freshwater marshes; and collisions with automobiles and utility lines.

There are significant data gaps relating to many aspects of the ecology of the black rail. Data gaps include minimum patch size for successful breeding colonies, parameters of population sinks, sources of mortality, site fidelity and movement in winter, as well as winter diet and foraging ecology.

Since black rails reside year-round in tidal marshes throughout the San Francisco Bay-Delta region where sediment methylmercury (MeHg) production is high (Marvin-DiPasquale et al. 2003), they may be particularly vulnerable to MeHg contamination. Black rails at north San Francisco Bay tidal marshes had lower MeHg concentrations than other waterbirds at San Francisco Bay (Ackerman et al. 2007, Tsao et al. 2009), likely due to their low-trophic-level invertebrate diet (Eddleman et al. 1994) However, 78 percent of black rail feather samples were above levels associated with adverse reproductive effects in mallards and ring-necked pheasants (Heinz 1979, Eisler 2000); and 9 percent of blood samples fell within the range for moderate risk of reproductive effects in common loons (Evers et al. 2008). Since MeHg sensitivity varies widely among species, the effects of MeHg contamination on the San Francisco Bay black rail population are unclear.

A26.6 Relevant Conservation Efforts

The California black rail is a covered species in several neighboring regional habitat conservation plans/natural communities conservation plans, including the approved San Joaquin County Multi-species Habitat Conservation and Open Space Plan and the proposed Solano County Multispecies Habitat Conservation Plan, the Yolo County Natural Heritage Program Plan, and the Butte Regional Conservation Plan. Several management plans have outlined threats to California black rails and provided recommendations for conservation (Trulio and Evens 2000). Recommendations focus primarily on protection of high-quality habitats. However, few actual habitat protection or species conservation efforts specific to the California black rail have been undertaken to date.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designates the California black rail as "Contribute to Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its

control and within its scope that are necessary to contribute to the recovery of the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

A26.7 SPECIES HABITAT SUITABILITY MODEL

Model Approach. BDCP Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf 2007. Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers, connectivity between habitat types, and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The California black rail model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), USDA 2005 aerial photography, and DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable California black rail habitat in the Plan Area. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Habitat. In the central Delta portion of the Plan Area, California black rail may be found in remaining patches of tidal freshwater emergent wetland found along the perimeter of sloughs and on in-channel islands of larger watercourses. (Figure A-26b) (National Audubon Society 2008, Gifford pers. comm.). These are remnant wetland sites that are generally unavailable for agricultural uses. Primary habitat for this species in the Suisun Marsh is *Sarcocornia*-dominated tidal marshlands (Trulio and Evens 2000, Spautz and Nur 2002). However, the remaining patches of this habitat type within the Plan Area west of Sherman Island are considered too small and fragmented to support this species and are thus excluded from this model.

Potentially suitable habitat within the Plan Area includes all *Schoenoplectus* and *Typha*-dominated Tidal and Nontidal Freshwater Emergent Wetland in patches greater than 0.5 acres. Within the Suisun Marsh, suitable habitat includes all *Schoenoplectus* and *Typha*-dominated, and *Saarcornia*-dominated patches greater than 0.5 acres. Patches less than 5 acres that are within 100 feet of larger patches are also included.

Black rail habitat in the Delta includes the following types from the BDCP composite vegetation layer:

- Alkali seasonal wetland complex
  - *Distichlis spicata – Salicornia virginica;*[3]
  - Pickleweed (*Salicornia virginica*); and
  - *Salicornia virginica – Cotula coronopifoli.*

[3] Currently known as *Sarcocornia pacifica*.

- Nontidal freshwater perennial emergent wetlands
    - Broad-leaf cattail (*Typha latifolia*);
    - American bulrush (*Scirpus americanus*);
    - Hard-stem bulrush (*Scirpus acutus*);
    - Mixed *Scirpus*/floating aquatics (*Hydrocotyle – Eichhorinia*) complex;
    - Mixed *Scirpus*/submerged aquatics (*Egeria-Cabomba-Myriophyllum* spp.) complex;
    - Mixed *Scirpus* mapping unit;
    - Narrow-leaf cattail (*Typha angustifolia*);
    - *Salicornia*[4]/annual grasses;
    - *Scirpus acutus – Typha latifolia – Phragmites australis*;
    - *Scirpus acutus – Typha angustifolia*;
    - *Scirpus acutus* pure; and
    - *Scirpus acutus – Typha latifolia*.
- Tidal freshwater emergent wetland and tidal brackish emergent wetland
    - Mixed *Scirpus*[5] mapping unit;
    - Mixed *Scirpus*/floating aquatics complex;
    - Mixed *Scirpus*/submerged aquatics complex;
    - Hard-stem bulrush (*Scirpus acutus*);
    - *Scirpus acutus* pure;
    - *Scirpus acutus – Typha angustifolia;*
    - *Scirpus acutus – Typha latifolia;*
    - *Scirpus acutus* – (*Typha latifolia*) – *Phragmites australis;*
    - California bulrush (*Scirpus californicus*);
    - *Scirpus californicus – Eichhornia crassipes;*
    - *Scirpus californicus – Scirpus acutus;*
    - American bulrush (*Scirpus americanus*);
    - Narrow-leaf cattail (*Typha angustifolia*); and
    - *Typha angustifolia – Distichlis spicata.*

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[4] Currently known as *Sarcocornia*.
[5] Currently known as *Schoenoplectus*.

Black rail habitat in the Suisun Marsh and Yolo Basin includes the following types from the BDCP composite vegetation layer:

- *Scirpus* (*californicus or acutus*)*/Rosa;*
- *Scirpus* (*californicus or acutus*)/wetland herb;
- *Scirpus* (*californicus or acutus*)-*Typha* spp.;
- *Scirpus americanus* (generic);
- *Scirpus americanus/Lepidium;*
- *Scirpus americanus/Potentilla;*
- *Scirpus californicus/S. acutus;*
- *Scirpus maritimus;*
- *Scirpus maritimus/Salicornia*[6]*;*
- *Typha angustifolia/Distichlis;*
- *Typha angustifolia/S. americanus;*
- *Typha* species (generic);
- Bulrush - Cattail freshwater marsh NFD super alliance;
- *Scirpus americanus/S. Californicus-S. acutus;*
- *Scirpus maritimus/Sesuvium;*
- *Typha angustifolia;*
- *Typha angustifolia/Phragmites;*
- *Typha angustifolia/Polygonum-Xanthium-Echino;*
- *Typha angustifolia/S. americanus;*
- *Distichlis/Salicornia;*
- *Salicornia* (generic);
- *Salicornia virginica;*
- *Salicornia/Atriplex;*
- *Salicornia/Cotula;*
- *Salicornia*/annual grasses;
- *Salicornia/Crypsis;*

[6] Currently known as *Sarcocornia*.

- *Salicornia/Polygonum-Xanthium-Echinochloa;* and
- *Salicornia/Sesuvium.*

Assumptions. There is limited information available on minimum habitat patch size for black rail in the Delta region. Spautz and Nur (2002) and Spautz et al. (2005) determined that larger intact marshes in the San Francisco Bay estuary were required for occupancy; however, they did not establish a minimum patch size. Tsao et al. (in press) calculated an average home range size of 1.5 acres and average core use areas (representing the 50 percent utilization distribution) of 0.3 acres for the San Francisco Bay estuary. Recently discovered Sierra Nevada foothill populations occur in emergent marsh habitats as small as 0.5 acres (Tecklin 1999). However, the extent to which minimum habitat patch size corresponds to home range size is unknown. The California Department of Fish and Game conducted surveys for California black rail in the central Delta in the early 1990s and found occupancy on in-channel islands that were at least 15 acres and not subject to agricultural or other disturbances and that supported marsh vegetation elevated above the high tide and wave line (Gifford pers. comm.). However, while the occupied islands were at least 15 acres, suitable habitat may have covered only a portion of the islands. The extent to which habitat conditions or requirements in the San Francisco Bay estuary or the Sierra Nevada foothills may not be transferable to the rather unique habitat conditions in the Delta is unclear. However, for purposes of this model, a minimum patch size of 0.5 acres is used, relying on data from Tecklin (1999) and Tsao et al. (*in press*). However, this may result in an overestimate of potentially occupied habitat for black rails. To address habitats fragmented by roads or channels, we also assume that patches that are smaller than 5 acres but are within 100 feet of larger patches are potentially occupied.

Other important factors that determine occupancy include water depth and a perennial water source. Very shallow water (usually <1.2 inches) is required. In general, a relatively narrow range of conditions is required for occupancy and successful breeding (Eddleman et al. 1994). For purposes of this model, it is assumed that these conditions are met in all *Schoenoplectus* and *Typha*-dominated tidal freshwater emergent wetlands or tidal brackish emergent wetlands greater than 0.5 acres. This also likely results in an overestimate of potentially occupied habitat for this species.

A26.8 RECOVERY GOALS

A USFWS recovery plan has not been prepared for this species and no recovery goals have been established; however, the CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designates the California black rail as "Contribute to Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its control and within its scope that are necessary to contribute to the recovery of the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

A26.9 REFERENCES

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A26.9.2 Personal Communications

Dan Gifford (Wildlife Biologist, California Department of Fish and Game), telephone conversation with Jim Estep on October 22, 2008.

APPENDIX A27. CALIFORNIA CLAPPER RAIL (*RALLUS LONGIROSTRIS OBSOLETUS*)

A27.1 LEGAL STATUS

The California clapper rail (*Rallus longirostris obsoletus*) is state and federally listed as endangered. The species was listed by the California Fish and Game Commission pursuant to the California Endangered Species Act (Fish and Game Code, Sections 2050 et seq.) on June 27, 1971, and by the U.S. Fish and Wildlife Service (USFWS) pursuant to the federal Endangered Species Act on October 13, 1970 (35 FR 16047). The California clapper rail is also designated as a state Fully Protected species.

Critical habitat has not been designated for this species.

A27.2 SPECIES DISTRIBUTION AND STATUS

A27.2.1 Range and Status

The California clapper rail is one of three subspecies of clapper rail (including light-footed clapper rail [*R.l. levipes*] and Yuma clapper rail [*R.l. yumanensis*]) listed as endangered under both state and federal endangered species acts.

The historical range of the California clapper rail extended within the coastal California tidal marshes from Humboldt Bay southward to Elkhorn Slough and Morro Bay, and estuarine marshes of San Francisco Bay and San Pablo Bay to the Carquinez Strait. Historically, the highest densities of California clapper rails existed in south San Francisco Bay (DWR 1994, USFWS 1998, LSA 2007).

The current distribution is limited to San Francisco Bay, San Pablo Bay, Suisun Bay, and tidal marshes associated with estuarine sloughs draining into these bays (Figure A-27a) (USFWS 1998, Albertson and Evens 2000, DFG 2000). The USFWS reports that there are populations in all of the larger tidal marshes in South San Francisco Bay, and the distribution in the North Bay is patchy and discontinuous, primarily in small, isolated habitat fragments (USFWS 1998). Small populations are widely distributed throughout San Pablo Bay and at various locations throughout the Suisun Marsh Area (Carquinez Strait to Browns Island, including tidal marshes adjacent to Suisun, Honker, and Grizzly bays) (USFWS 1998).

California clapper rails were historically abundant throughout much of the San Francisco Bay estuary. Sport and market hunting significantly reduced populations in the late nineteenth and early twentieth centuries. Population levels recovered following passage of the Migratory Bird Treaty Act in 1913; however, with increasing loss and fragmentation of tidal marshes for salt ponds, agricultural land, and bayfill, available habitat continued to be reduced.

DRAFT

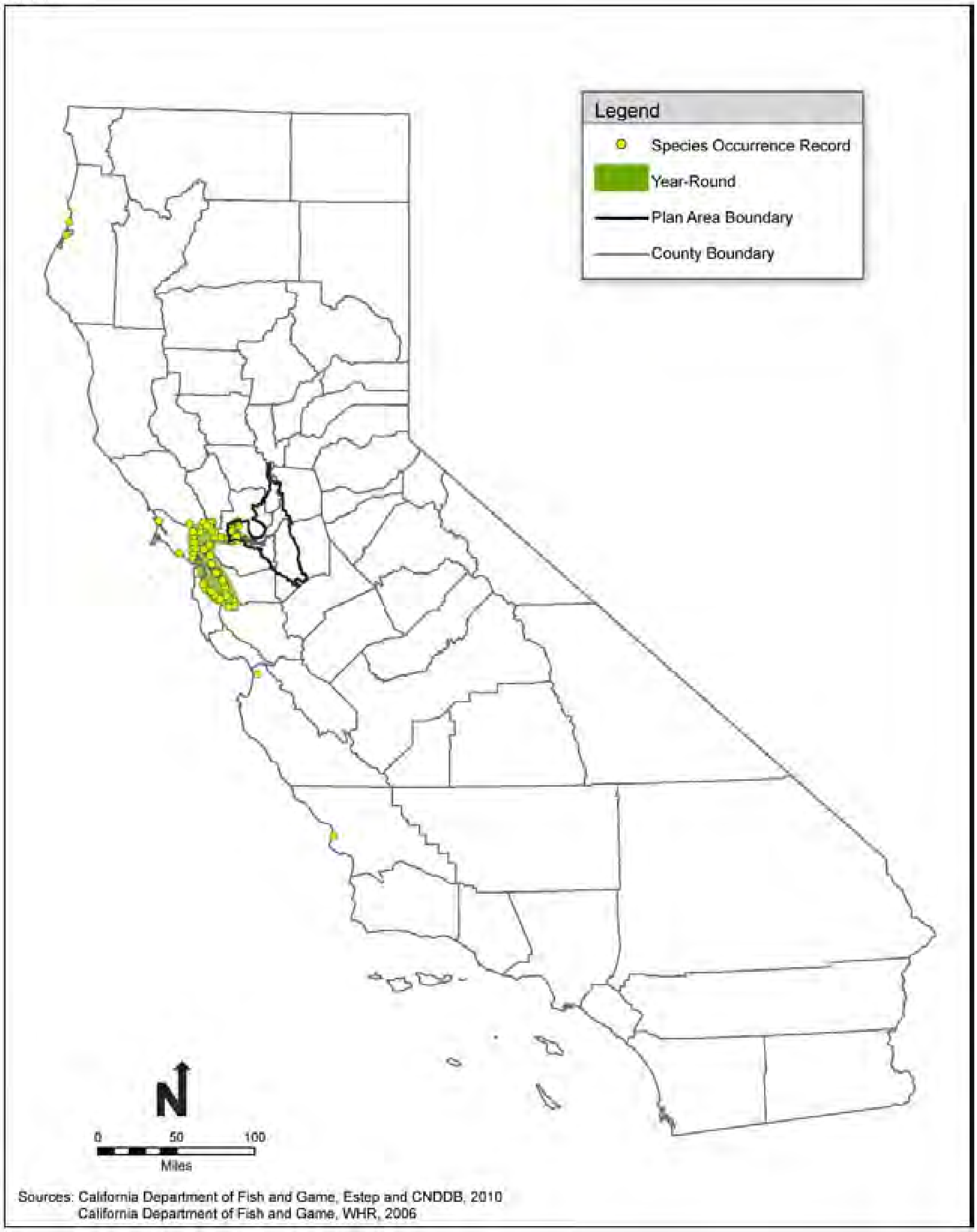

Figure A-27a. California Clapper Rail Statewide Range and Recorded Occurrences

1

Of the 193,800 acres of tidal marsh that bordered San Francisco Bay in 1850, about 30,100 acres currently remain (Dedrick 1989), representing an 84 percent reduction of available habitat.

In the early 1970s, California clapper rail populations were estimated at 4,200 to 6,000 individuals (Gill 1979). Loss and fragmentation of habitat continued over the following two decades resulting in a total rail population of approximately 500 birds in 1991, 300 of which are estimated to occur in the South San Francisco Bay (USFWS, unpubl. data).

Since then, management activities, including predator management, have resulted in population increases with the current estimate at approximately 450 to 600 pairs (USFWS unpubl. data). Of these, 195 to 282 pairs are estimated to occur in the North San Francisco Bay population, which includes the Suisun Marsh (Collins et al. 1994).

A27.2.2 Distribution and Status in the Plan Area

There are no reported occurrences of California clapper rail within the Plan Area (Figure A-27b); however, there are numerous reported occurrences in and around the Suisun Marsh Restoration Opportunity Area (ROA). Isolated patches of suitable habitat may occur within the Plan Area as far east as the western edge of Sherman Island.

Harvey (1980) reported the first California clapper rail in the Suisun Marsh at Cutoff Slough in 1978, which extended their range east of the San Francisco Bay area. A coordinated clapper rail survey was conducted by the San Francisco Bay Bird Observatory throughout the estuary between 1983 and 1986, resulting in two detections at the upper end of First Mallard Branch. Additional detections were made in 1986 at the Concord Naval Weapons Station (O'Neil 1988). Subsequent surveys, conducted by DFG and DWR, confirmed presence of the species in several locations in the Suisun Marsh including: Hill Slough, Cutoff Slough, First and Second Mallard branches, Suisun Slough from Goodyear Slough to Suisun Bay, Suisun Bay shoreline at the Suisun Marsh Reserve Fleet, Ryer Island, Point Edith Marsh, mouth of Boynton Slough, Union Creek, McCoy Creek and Suisun Slough at Morrow Island (DWR 1994).

A27.3 Habitat Requirements and Special Conditions

Throughout their distribution, California clapper rails occur within a range of salt and brackish marshes. In south and central San Francisco Bay and along the perimeter of San Pablo Bay, rails typically inhabit salt marshes dominated by pickleweed (*Sarcocornia pacifica*[1]) and Pacific cordgrass (*Spartina foliosa*). Pacific cordgrass dominates the middle marsh zone throughout the south and central Bay (USFWS 1998).

[1]Formerly known as *Salicornia virginica.*

DRAFT

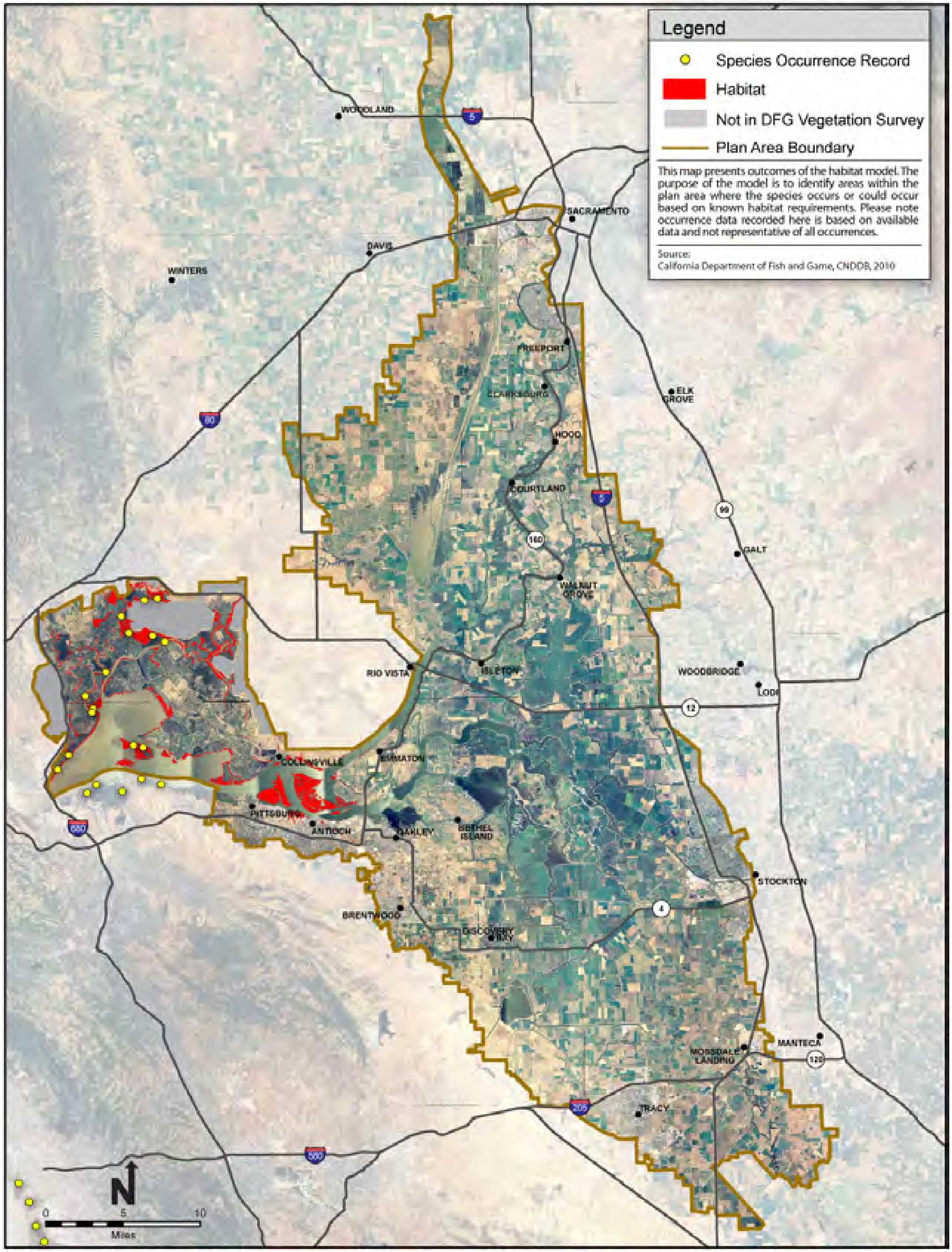

Figure A-27b. California Clapper Rail Habitat Model and Recorded Occurrences

1

In the North Bay (Petaluma Marsh, Napa-Sonoma Marshes, Suisun Marsh), clapper rails also live in tidal brackish marshes that vary significantly in vegetation structure and composition. Use of brackish marshes by clapper rails is largely restricted to major sloughs and rivers of San Pablo Bay and Suisun Marsh, and along Coyote Creek in South San Francisco Bay. Clapper rails have rarely been recorded in nontidal marsh areas (USFWS 1998).

Population density is higher in habitats that exceed 100 hectares (247 acres) in size. Other factors that affect density include proximity of suitable marsh habitats to each other, buffer areas between marsh and upland areas, marsh elevation, and hydrology (LSA 2007). Rail densities have shown to be lower in more brackish habitats resulting from freshwater outflows, possibly due to the resulting change in vegetation (Collins et al. 1994).

Nesting. In saline emergent wetlands, California clapper rails nest mostly in lower zones near tidal sloughs and where cordgrass (*Spartina foliosa*) is abundant (Harvey 1980, Zembal and Massey 1983, Eddleman and Conway 1998). Clapper rails build a platform concealed by a canopy of woven cordgrass stems or pickleweed and gumweed (Harvey 1980). Nests are constructed only as high as necessary to prevent inundation while preserving a natural cover of vegetation. Clapper rail nests are described as a mass or heap of vegetation, deeply cupped and securely woven to the surrounding vegetation that allows for flotation during extreme tidal events. Zucca (1954) discovered that although the nests are somewhat buoyant, they do not remain intact through a series of high tides. Clapper rails also use dead drift vegetation as a platform (Harvey 1990). The vegetation used to construct clapper rail nests is partly determined by the time of the nesting and the tidal influence (Zucca 1954). In fresh or brackish water, clapper rails construct nests in dense cattail or bulrush (Harvey 1980, LSA 2007).

Foraging. California clapper rails forage in higher marsh vegetation, along the vegetation and mudflat interface, and along tidal creeks.

A27.4 LIFE HISTORY

Description. The clapper rail is a coot-sized bird that is generally gray-brown above and buff-cinnamon below with brownish-gray cheeks and black-and-white barred flanks. It has a short neck, slightly down-curved bill, and a short tail cocked upward, revealing a white patch. Overall length ranges from 33 to 48 centimeters (cm) (13 to 19 inches), and bill length is greater than 5 cm (2 inches) (Lewis and Garrison 1983). The sexes differ only in size with males slightly larger than females. Juveniles have a paler bill and darker plumage, with a gray body, black flanks and sides, and indistinct light streaking on flanks and undertail coverts. California clapper rail is larger and of grayer plumage than light-footed clapper rail and Yuma clapper rail. Clapper rails are secretive, elusive, and difficult to observe in dense vegetation. Census data are usually taken by listening for vocal responses to recorded calls. When evading discovery, they typically freeze, hide in small sloughs or under overhangs, or run rapidly through vegetation or along slough bottoms. They prefer to walk or run over land rather than fly, and generally walk upright.

When flushed, they normally fly only a short distance before landing. They can swim well, although swimming is only used to cross sloughs or escape immediate threats at high tide (USFWS 1998, LSA 2007).

Seasonal Patterns. The California clapper rail is apparently non-migratory; however, some seasonal movements occur probably in response to seasonal hydrological changes and their effect on habitat availability and quality (Rozengurt et al. 1987, Collins et al. 1994). Post-breeding dispersal has also been recorded in late fall and early winter (Orr 1939, Wilbur and Tomlinson 1976, Harvey unpubl. data as cited in LSA 2007). In general, these findings indicate that while clapper rails tend to be more dispersed within the marsh following the nesting season, in general they appear to move very little between seasons and between nesting or core-use territories (Albertson 1995 as cited in LSA 2007).

Reproduction. The nesting season for California clapper rails begins mid-March and extends into August with peaks observed in early May and late June (Gill 1973, Harvey 1980). Clutch range is 6 to 10 eggs (Wilbur and Tomlinson 1976). Both the male and female incubate the eggs for approximately 18 to 29 days. Harvey (1980) reports hatching success of approximately 38 percent in the San Francisco Bay area.

Foraging Behavior and Diet. Clapper rails are most active in early morning and late evening, when they forage in marsh vegetation in and along creeks and mudflat edges. Most feeding is surface-gleaning and probing (Zembal and Fancher 1988), which occurs by walking a few steps, thrusting their beaks into the mud up to eye level, then walking a few more steps, then repeating the probing (Wilbur and Tomlinson 1976). Less frequent foraging behaviors include surface gleaning, fishing, and scavenging.

Moffitt (1941) examined the diet of California clapper rail by volumetric content of rail stomachs with the following results: ribbed horse mussels (56.5 percent), spiders (Lycosidae, 15 percent), seeds and hulls of cordgrass (14.6 percent), little macoma clam (*Macoma balthica*, 7.6 percent), mud crabs (3.2 percent), worn-out nassa (*Ilyanassa obsoletus*, 2 percent), insects, clam worms (*Nereis* spp.), and carrion (1.1 percent) (Eddleman and Conway 1998). Overall, the content included over 85 percent animal matter and 14.6 percent vegetable matter.

A27.5 THREATS AND STRESSORS

Habitat Degradation. Degradation of tidal marsh habitats continues to be the most significant threat to California clapper rail. Tidal marshes have been reduced by 84 percent since historical times (Dedrick 1989). While the loss of tidal marsh habitat through filling and diking has largely been curtailed, other current factors associated with declining populations include the conversion of salt marshes to brackish marshes due to freshwater discharges from sewage treatment plants, a progressive rise in sea level, invasion of runoff, industrial discharges, and sewage effluent (Williams 1985, Ohlendorf and Fleming 1988, Ohlendorf et al. 1989, Harvey 1990, Lonzarich et al. 1990, Foerster and Takekawa 1991, Leipsic-Baron 1992, DFG 2000 as cited in LSA 2007).

The suitability of many marshes for clapper rails is further limited, and in some cases precluded, by their small size, fragmentation, and lack of tidal channel systems and other micro-habitat features. These limitations render much of the remaining tidal marsh acreage unsuitable or of low value for the species. In addition, tidal amplitudes are much greater in South San Francisco Bay than in San Pablo or Suisun bays (Atwater et al. 1979). Consequently, many tidal marshes are completely submerged during high tides and lack sufficient escape habitat, likely resulting in nesting failures and high rates of predation. The reductions in carrying capacity in existing marshes necessitate the restoration of larger tracts of habitat throughout the current range of the species to maintain stable populations.

Predation. California clapper rails are subject to heavy predation from nonnative species such as red fox (*Vulpes vulpes*), feral cat (*Felis domesticus*) and Norway rat (*Rattus norvegicus*) as well as various native mammals and raptors (Foerster et al. 1990, Albertson 1995 as cited in LSA 2007, USFWS 1998, DFG 2000). The fragmentation of habitat through the construction of dikes and levees has increased and facilitated predation of clapper rails because terrestrial predators use these features as corridors to access clapper rail habitat (Foerster et al. 1990, Burkett and Lewis 1992). Urban development adjacent to marshland habitat has also increased predation by native predators such as raccoons, which thrive in urban areas, and raptors, which use electric power transmission lines as hunting perches (USFWS 1998). Red foxes, the predator that may pose the most serious threat to California clapper rails, have not yet been detected in the Suisun Marsh; however, river otters (*Lutra canadensis*) are common in the Suisun Marsh area and could also prey on eggs of clapper rails (Albertson and Evens 2000, LSA 2007).

Mercury Contamination. Mercury contamination has been detected in eggs and embryos in the South San Francisco Bay (Schwarzbach et al. 2006). Mortality and embryonic developmental issues associated with mercury contamination could potentially have long-term effects on reproduction and recruitment.

A27.6 RELEVANT CONSERVATION EFFORTS

The Suisun Marsh has been the subject of various conservation efforts for many years, particularly with respect to development and water quality-related issues within its boundaries. The following from the California Department of Water Resources Suisun Marsh Program (http://www.iep.water.ca.gov/suisun/program/index.html) summarizes the major agreements, management plans, and legislation that have directed management of the Suisun Marsh since the mid-1970s. These efforts focus on the preservation and restoration of tidal marsh habitats.

The Nejedly-Bagley-Z'Berg Suisun Marsh Preservation Act (1974). The California Legislature enacted the Suisun Marsh Preservation Act that protects the marsh from urban development. It required the San Francisco Bay Conservation and Development Commission (BCDC) to develop a plan for the marsh and provides for various restrictions on development within marsh boundaries.

Suisun Marsh Protection Plan (1976). This plan was developed by the BCDC and defines and limits development within primary and secondary management areas for the "future of the wildlife values of the area as threatened by potential residential, commercial and industrial development." It recommends that the State purchase 1,800 acres, and maintain water quality. While the focus of the plan is on maintaining waterfowl habitat, it also addresses the importance of tidal wetlands and recommends restoring historical marsh areas to wetland status (managed or tidal).

The Suisun Marsh Protection Act (1977). This bill adopts and calls for implementation of the Suisun Marsh Protection Plan. AB 1717 designates the BCDC as the state agency with regulatory jurisdiction of the marsh and calls for the Suisun Resource Conservation District to have responsibility for water management in the marsh. The bill identifies (and focuses on) actions for the preservation of waterfowl needs along with the retention of the diversity of wildlife. It states that land within the Suisun Marsh should be acquired for public use or resource management if it is suitable for restoration to tidal or managed marsh, but that such restoration cannot be required as a condition of private development.

State Water Resources Control Board (SWRCB) Water Rights Decision 1485 (1978). SWRCB adopted the Water Quality Control Plan for the Sacramento-San Joaquin Delta and issued Water Rights Decision 1485. The Decision includes: channel water salinity standards from October to May and preserves the area as brackish water tidal marsh. It set water quality standards in the Marsh as a condition of export pumping. These come from DFG's recommendations, which were based on (1) the relative value of marsh plants as duck food; (2) the influence of soil salinity and other factors on distribution and growth of marsh plants; and (3) the relationships between channel water salinity and soil salinity. DFG concluded that improved management practices, improved drainage, water control facilities, and adequate quality of water were needed to achieve desired soil salinity conditions for waterfowl food plants.

Plan of Protection for the Suisun Marsh (1984). DWR and the U.S. Bureau of Reclamation (USBR) developed and began implementing the Plan of Protection (POP) in accordance with D-1485. The POP implementation strategy was to construct large facilities and distribution systems to meet salinity standards (lower channel water salinity), in lieu of significant Central Valley Project/State Water Project (CVP/SWP) storage releases estimated as high as 2 million acre-feet in dry/critical water years. The six-phase POP was the programmatic blue print (required by the SWRCB and embodied in the original Suisun Marsh Preservation Agreement). Two of the six phases were completed including the Initial Facilities and the Suisun Marsh Salinity Control Gates.

1. **Suisun Marsh Preservation Agreement (1987)**. This contractual agreement between DWR, United States Bureau of Reclamation (USBR), DFG and Suisun Resource Conservation District (SRCD) contains provisions for DWR and USBR to mitigate the effects on Suisun Marsh channel water salinity from the SWP and CVP operations and

other upstream diversions. The Suisun Marsh Preservation Agreement requires DWR and USBR to meet salinity standards, sets a timeline for implementing the POP, and delineates monitoring and mitigation requirements. The Suisun Marsh Monitoring Agreement and the Suisun Marsh Mitigation Agreement were also signed at this time. The Suisun Marsh Mitigation Agreement defined habitat requirements to mitigate effects of facilities and operations and the Suisun Marsh Monitoring Agreement defines requirements for monitoring salinity and species in the Suisun Marsh.

Bay-Delta Accord (1994). On December 15, 1994, state and federal agencies, working with agricultural, environmental and urban stakeholders, reached agreement on water quality standards and related provisions that would remain in effect for three years. This agreement, known as the Bay-Delta Accord, was based on a proposal developed by the stakeholders. Elements of the agreement include:

- Springtime export limits expressed as a percentage of Delta inflow.
- Regulation of the salinity gradient in the estuary so that a salt concentration of two parts per thousand (X_2) is positioned where it may be more beneficial to aquatic life.
- Specified springtime flows on the lower San Joaquin River to benefit Chinook salmon.
- Intermittent closure of the Delta Cross Channel gates to reduce entrainment of fish into the Delta.

SWRCB Water Quality Control Plan (1995-1998). In 1994, wildlife and fishery agencies and urban water users expressed concerns about the appropriateness of western Suisun Marsh channel water salinity standards. The SWRCB, in the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, May 1995, modified the Suisun Marsh salinity objectives. Modeling analysis by the Suisun Marsh Planning Program showed that Suisun Marsh standards would be met most of the time at all Suisun Marsh compliance stations. Some standard exceedances would be expected in the western Suisun Marsh that participants to the Suisun Marsh Preservation Agreement (SMPA) agreed could be mitigated by more active water control by landowners.

SWRCB Water Rights Decision 1641 (1999). The SWRCB issued Decision 1641 in December 1999, which updated salinity standards for Suisun Marsh. Increased outflow and salinity requirements for the Bay-Delta provided indirect benefits to the Suisun Marsh. DWR proposed that the SWRCB adopt the Amendment Three actions for Suisun Marsh in this Decision. The SWRCB was unable to adopt Amendment Three actions because the Section 7 consultation with the USFWS had not concluded. However, the SWRCB did relieve USBR and DWR of its responsibility in meeting salinity objectives at S-35 and S-97 in the western Suisun Marsh.

Suisun Marsh Charter Implementation Plan (2001). The Suisun Marsh Charter was completed in 2001 and commenced development of an Implementation Plan. Charter participants collaborated on a joint presentation to the State of the Estuary Conference on the principles of the Charter Plan including coordinated water quality, endangered species, and heritage value protection in the Suisun Marsh.

Habitat Management, Preservation, and Restoration Plan (2003). The expansion of the Charter process to include additional federal and state agencies to develop a Suisun Marsh Plan that will balance the goals and objectives of the Bay-Delta Program, SMPA, and other management and restoration programs within the Suisun Marsh in a manner that is responsive to the concerns of all stakeholders and is based upon voluntary participation by private landowners.

In addition, several facilities have been constructed in the Suisun Marsh to protect and improve water quality and protect and enhance wildlife habitat including:

- Roaring River Distribution System (1979-80);
- Morrow Island Distribution System (1979-80);
- Goodyear Slough Outfall (1979-80);
- Suisun Marsh Salinity Control Gates (1988); and
- Cygnus and Lower Joyce Facilities (1991).

Several tidal marsh restoration projects are also planned or being implemented within the range of the California clapper rail. These projects, implemented through the direction or support of the San Francisco Bay National Wildlife Refuge (NWR), National Biological Service, East Bay Regional Park District, Regional Water Quality Control Board, DFG, and the City of San Jose include the following:

- Restoration of the 1,500-acre Napa Marsh Unit in the Napa River in the north bay;
- Restoration of the Knapp Property, a 452-acre former salt pond in the Alviso area, on the edge of the bay, between Alviso and Guadalupe Sloughs.
- Enhancement of the 325-acre Oro Loma Marsh, an area of diked salt marsh and adjacent uplands located along the shore of Hayward. The area will be restored to tidal marsh and seasonal wetland habitat.
- Restoration of the Baumberg Tract, an 835-acre inactive salt evaporator in Hayward to tidal marsh and seasonal wetlands.
- Restoration of the Moseley Tract located just north of the west approach to the Dumbarton Bridge from the Port of Oakland.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for California clapper rail is "Contribute to Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its

control and within its scope that are necessary to contribute to the recovery of the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

California clapper rail is also proposed for coverage under the Solano County Multi-species Habitat Conservation Plan.

A27.7 Species Habitat Suitability Model

Model Approach. Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf 2007. Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers, connectivity between habitat types, and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The California clapper rail model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), USDA 2005 aerial photography, and DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable California clapper rail habitat in the Plan Area. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Habitat. California clapper rail habitat includes all *Sarcornia*-dominated natural seasonal wetlands and *Schoenoplectus*[2]*/Tyhpa*-dominated tidal freshwater emergent wetlands located west of State Highway 160 on Sherman Island. Vegetation types designated as species habitat in this model correspond to the mapped vegetation associations in the BDCP GIS vegetation data layer.

California clapper rail habitat in the Delta includes the following types from the BDCP composite vegetation layer:

- Tidal freshwater emergent wetland and tidal brackish emergent wetland
    - Mixed *Scirpus*[3] mapping unit;
    - Mixed *Scirpus*/floating aquatics complex;
    - Mixed *Scirpus*/submerged aquatics complex;
    - Hard-stem bulrush (*Scirpus acutus*);
    - *Scirpus acutus* pure;
    - *Scirpus acutus – Typha angustifolia;*
    - *Scirpus acutus – Typha latifolia;*
    - *Scirpus acutus – (Typha latifolia) – Phragmites australis;*
    - California bulrush (*Scirpus californicus*);

[2] Formerly known as *Scirpus*.
[3] Currently known as *Schoenoplectus*.

  - *Scirpus californicus – Eichhornia crassipes;*
  - *Scirpus californicus – Scirpus acutus;*
  - American bulrush (*Scirpus americanus*);
  - Narrow-leaf cattail (*Typha angustifolia*); and
  - *Typha angustifolia – Distichlis spicata.*

California clapper rail habitat in the Suisun Marsh includes the following tidal brackish emergent wetland and tidal perennial aquatic types from the BDCP composite vegetation layer:

- *Scirpus (californicus* or *acutus)/Rosa;*
- *Scirpus (californicus* or *acutus*)/wetland herb;
- *Scirpus (californicus* or *acutus)-Typha* spp.;
- *Scirpus americanus* (generic);
- *Scirpus americanus/Lepidium;*
- *Scirpus americanus/Potentilla;*
- *Scirpus californicus/S. acutus;*
- *Scirpus maritimus;*
- *Scirpus maritimus/Salicornia*[4]*;*
- *Typha angustifolia/Distichlis;*
- *Typha angustifolia/S. americanus;*
- *Typha* species (generic);
- Bulrush - cattail freshwater marsh NFD super alliance;
- *Scirpus americanus/S. Californicus-S. acutus;*
- *Scirpus maritimus/Sesuvium;*
- *Typha angustifolia;*
- *Typha angustifolia/Phragmites;*
- *Typha angustifolia/Polygonum-Xanthium-Echino;*
- *Typha angustifolia/S. americanus;*
- *Distichlis/Salicornia;*
- *Salicornia* (generic);
- *Salicornia virginica;*

[4] Currently known as *Sarcocornia*.

- *Salicornia/Atriplex;*
- *Salicornia/Cotula;*
- *Salicornia*/annual grasses;
- *Salicornia/Crypsis;*
- *Salicornia/Polygonum-Xanthium-Echinochloa;* and
- *Salicornia/Sesuvium.*

Assumptions. Historical and current records of this species indicate that its known distribution extends eastward in the Suisun Marsh (Figure A-27b). Patches of suitable habitat extend into the Plan Area in the vicinity of Collinsville and Antioch, though no occurrences have been recorded there. For purposes of this model, the potential range of the California clapper rail occurs in suitable habitats west of the western edge of Sherman Island. California clapper rails are found within a range of salt and brackish marshes. Typical habitat consists of dense pickleweed (*Salicornia*) and cordgrass (*Spartina foliosa*)-dominated saline tidal marshes (Zucca 1954, Harvey 1980). There is also reported use of *Schoenoplectus/Typha*-dominated brackish marshes in the North Bay (Petaluma Marsh, Napa-Sonoma Marshes, Suisun Marsh) (USFWS 1998). Suitability of habitat may also be dependent on other factors, such as patch size, tidal connectivity (diked marshes), and proximity to other land uses. However, there is insufficient data on these issues relative to their effects on potential occupancy particularly with respect to determining minimum requirements, and thus potential habitat for the California clapper rail is not further restricted in this model on the basis of these factors. As a result, this model likely overestimates the extent of suitable habitat for California clapper rail in the Plan Area.

A27.8 Recovery Goals

The Salt Marsh Harvest Mouse and California Clapper Rail Recovery Plan was finalized in 1984. It is considered outdated and is under revision by the USFWS. Both species will be covered under the Tidal Marsh Ecosystem Recovery Plan.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designates the California clapper rail as "Contribute to Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its control and within its scope that are necessary to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

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APPENDIX A28. SWAINSON'S HAWK (*BUTEO SWAINSONI*)

A28.1 LEGAL STATUS

The Swainson's hawk (*Buteo swainsoni*) is listed as a threatened species under the California Endangered Species Act (Fish and Game Code, Sections 2050 et seq.). The species was listed by the California Fish and Game Commission in 1983.

The Swainson's hawk has no federal regulatory status. However, the species is included on the U.S. Fish and Wildlife Service (USFWS) list of Birds of Conservation Concern (BCC) for Region 1. BCC species are those that the USFWS considers potential candidates for federal listing.

A28.2 SPECIES DISTRIBUTION AND STATUS

A28.2.1 Range and Status

Swainson's hawks nest in the grassland plains and agricultural regions of western North America from southern Canada (and possibly in the northern provinces and territories, and Alaska) to northern Mexico. Other than a few documented small wintering populations in the United States (Herzog 1996, England et al. 1997), the majority of the species winters primarily in the Pampas region of Argentina. The Central Valley population winters mainly between Mexico and central South America (Bradbury et al. in preparation).

Early accounts described Swainson's hawk as one of the most common raptors in California, occurring throughout much of lowland California (Figure A-28a) including the Central Valley, coastal valleys, southern California deserts, and Great Basin deserts east of the Sierra Nevada (Sharp 1902). Since the mid-1800s, native grassland foraging habitats and woodland nesting habitats that supported the species have undergone a gradual conversion to agricultural uses and urban uses. Today, native grassland habitats are virtually nonexistent in the state, and only remnants of the once vast riparian forests and oak woodlands still exist (Katibah 1983). While the species has successfully adapted to certain agricultural landscapes, this habitat loss has caused a substantial reduction in the breeding range and in the size of the breeding population in California (Bloom 1980, England et al. 1997). Current breeding populations occur primarily in the Central Valley, but also in the Klamath Basin, the northeastern plateau, Owen's Valley, and rarely in the Antelope Valley (Grinnell and Miller 1944, Bloom 1980, Garrett and Dunn 1981, Anderson et al. 2007).

Swainson's hawk populations have declined in California, Utah, Nevada, and Oregon (England et al. 1997). Populations in other western states are considered stable. Bloom (1980) reported a statewide estimate of 375 breeding pairs.

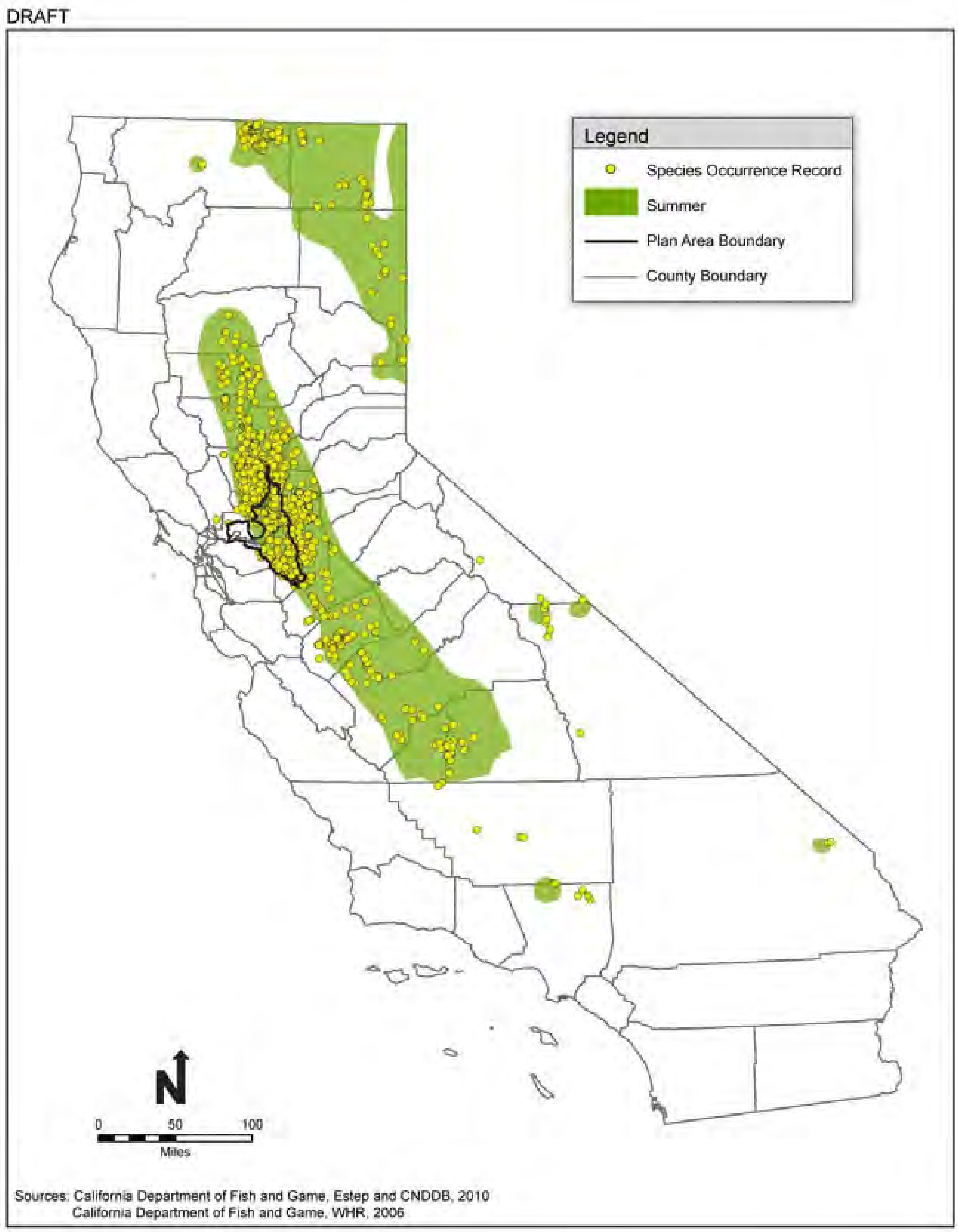

Figure A-28a. Swainson's Hawk Statewide Range and Recorded Occurrences

This was followed by estimates of 550 (DFG 1988) in the late 1980s, and 800 to 1,000 breeding pairs in the late 1990s (Swainson's Hawk Technical Advisory Committee). However, none of these estimates were generated using a statistically-based statewide survey effort and would be considered less credible than the results of a more statistically valid approach. The most recent statewide population estimate for California is 2,081 breeding pairs (Anderson et al. 2007) and is based on a statistically valid statewide survey effort conducted in 2005 and 2006. While this estimate is higher than the original statewide estimate that led to the state listing of the species (Bloom 1980) and subsequent estimates through the 1980s and 1990s, it cannot be reliably used to measure trends. It does, however, represent a substantial decline (50 to 90 percent) of the historical statewide breeding population in California (Bloom 1980).

Nearly 94 percent of nesting Swainson's hawks in California are found in the Central Valley (an estimated 1,948 nesting pairs) (Anderson et al. 2007) from Tehama County south to Kern County. The majority of these are found in the middle section of the Central Valley between approximately Butte County in the north to Merced County in the south, where foraging and nesting habitat conditions are optimized. Over 60 percent of the statewide population occurs within Yolo, Sacramento, Solano, and San Joaquin counties (Anderson et al. 2007). While intensively farmed for over 100 years, much of this area retains a relative abundance of nesting habitat – narrow riparian corridors along rivers and streams, remnant oak groves and trees, roadside trees – and an agricultural pattern that is conducive to Swainson's hawk foraging (Estep 2007, 2008, Anderson et al. 2007).

A28.2.2 Distribution and Status in the Plan Area

Figure A-28b illustrates the nesting distribution of Swainson's hawk in the Plan Area. These data are from recent survey efforts conducted in the Yolo and Sacramento County portions of the Plan Area (Estep 2007, 2008) and the most recent information from the CNDDB (2009). A total of 314 nesting sites are identified on Figure A-28b from within the Plan Area. While the majority of these represent independent nesting territories, a few of the CNDDB locations may represent the same nesting territory in subsequent years. There is, however, a fairly dense nesting population occurring in the northern (north of State Route 12 [SR-12]) and southern (south of SR-4) portions of the Plan Area. These are areas that support a relative abundance of potential nesting habitat and an agricultural landscape that is suitable for Swainson's hawk foraging.

In the northern portion of the Plan Area, nest sites are distributed mainly east of the Deep Water Ship Channel and along the western edge of the Plan Area. These are areas that support mainly annually-rotated irrigated agricultural, hayfield, and irrigated pasturelands, and an abundance of potential nesting habitat, including riparian woodlands, roadside trees, tree rows, and isolated trees.

DRAFT

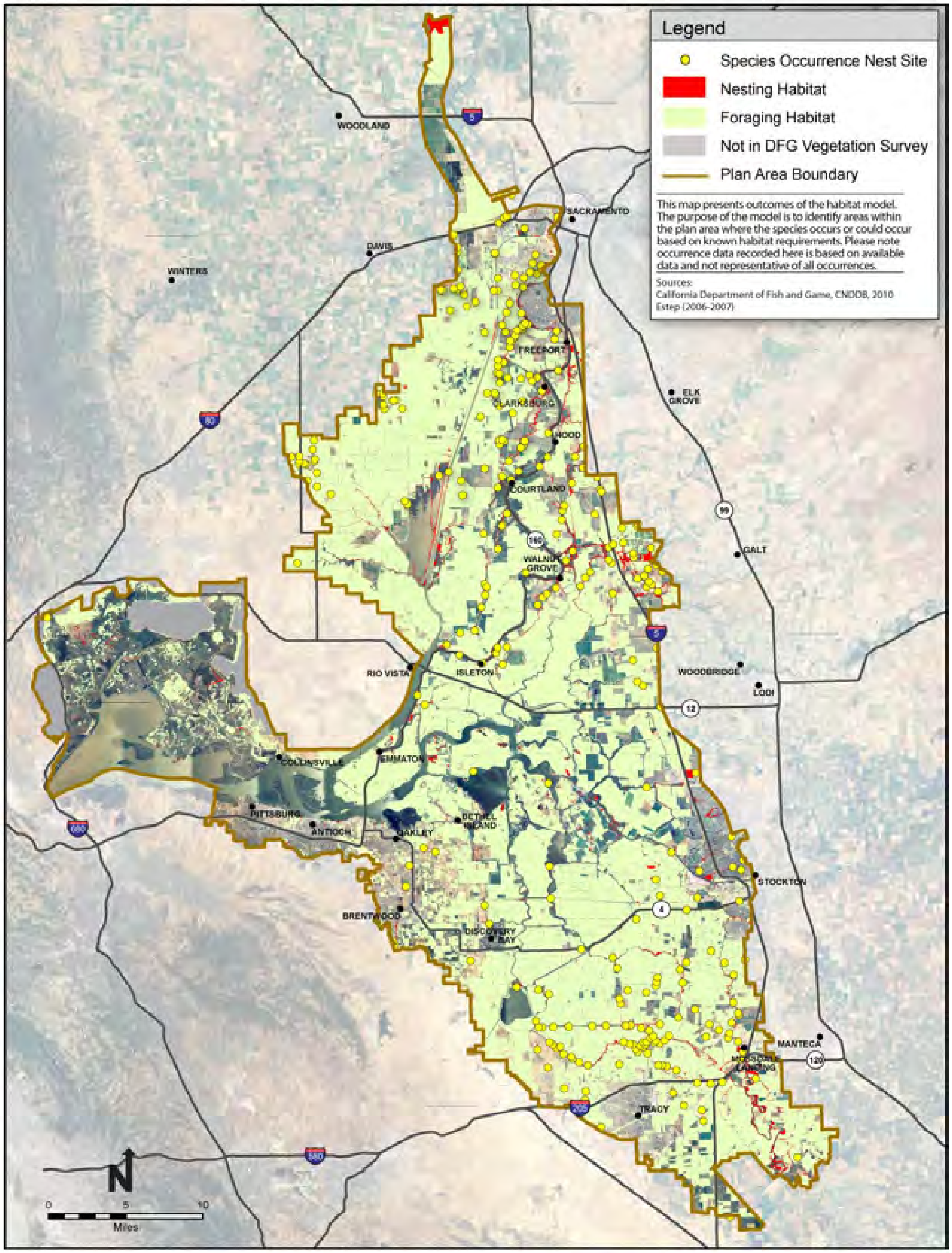

Figure A-28b. Swainson's Hawk Habitat Model and Recorded Occurrences

The area immediately west of the Deep Water Ship Channel (with the exception of the northern Yolo Bypass Wildlife Refuge) and the area immediately north of SR-12 support few potential nest trees and thus fewer known nest sites. However, a very dense nesting population occurs immediately west of the Plan Area boundary in Yolo and Solano counties. These birds likely forage throughout much of the northern Plan Area.

Similarly, the area south of SR-4 also supports a dense nesting population. The agricultural landscape in this area includes an abundance of alfalfa hay and annually rotated irrigated cropland and many potential nest trees, mostly along riparian corridors and roadside tree rows. Areas that lack nest sites, particularly the southernmost portion of the Plan Area south of Interstate 205, also lack sufficient nest trees to support many nesting pairs.

The central Delta, the region between SR-12 and SR-4, supports fewer Swainson's hawk nests compared with the northern and southern regions (Figure A-28b). The agricultural landscape in the central Delta provides generally suitable foraging habitat for Swainson's hawks, although probably less high value cover types; but the lack of nest sites is likely primarily associated with the lack of suitable nest trees in this area. However, it should also be noted that the survey effort in the central Delta has not been as extensive as elsewhere in the Plan Area, and this may contribute in part to the lack of reported nesting territories in that area. DWR 2009 survey data adds numerous additional active nest sites, primarily in the eastern and southern Plan Area, but also several within the central Delta.

A28.3 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

Nesting. Throughout much of its range, both in North and South America, the Swainson's hawk inhabits grasslands, prairies, shrub-steppes, and agricultural landscapes—including dry and irrigated row crops, alfalfa and hay fields, pastures, and rangelands. They nest in trees most often in riparian woodlands and farm shelterbelts (England et al. 1997), as well as in urban/suburban areas with large trees adjacent to suitable foraging habitat (James 1992, England et al. 1995). Suitable nest trees are usually deciduous and tall (up to 100 feet [30 meters]); however, in suburban/urban areas, most nest trees are conifers (England et al. 1995, 1997). Nests are built of sticks and are sometimes several feet in diameter. They are generally placed in the uppermost and outermost branches that will support the nest, often in mistletoe clumps (England et al. 1997).

In the Central Valley, Swainson's hawks usually nest in large native trees such as valley oak (*Quercus lobata*), cottonwood (*Populus fremontia*), walnut (*Juglans hindsii*), and willow (*Salix* spp.), and occasionally in nonnative trees, such as eucalyptus (*Eucalyptus* spp.). Nests occur in riparian woodlands, roadside trees, trees along field borders, isolated trees, small groves, and on the edges of remnant oak woodlands. Stringers of remnant riparian forest along drainages contain the majority of known nests in the Central Valley (Estep 1984, Schlorff and Bloom 1984, England et al. 1997). However, this appears to be a function of nest tree availability rather than dependence on riparian forest. Nests are usually constructed as high as possible in the tree, providing protection to the nest as well as better visibility from it.

Nesting pairs are highly traditional in their use of nesting territories and nesting trees. Many nest sites in the Central Valley are known to have been occupied annually since 1979 and banding studies conducted since 1986 confirm a high degree of nest and mate fidelity (Estep in preparation).

Nesting habitat results from the 2006 and 2007 baseline surveys of South Sacramento County and Yolo County (Estep 2007, 2008) indicate that riparian habitat was the most frequently used nesting habitat type. Isolated trees, roadside trees, tree rows, farmyard trees, and rural residential trees were also frequently used. Valley oak and Fremont cottonwood were the most frequently used nest trees, followed by walnut, willow, and eucalyptus trees.

Foraging. Swainson's hawks are essentially plains or open-country hunters, requiring large areas of open landscape for foraging. Historically, the species used the grasslands of the Central Valley and other inland valleys. With substantial conversion of these grasslands to farming operations, Swainson's hawks have shifted their nesting and foraging into those agricultural lands that provide low, open vegetation for hunting and high rodent prey populations.

Foraging habitat value is a function of: (1) patch size (i.e., Swainson's hawks are sensitive to fragmented landscapes; use will decline as suitable patch size decreases); (2) prey accessibility (i.e., the ability of hawks to access prey depending on vegetation structure and management activities); and (3) prey availability (i.e., the abundance of prey populations in a field). Data on minimum foraging patch size are largely anecdotal, but are generally thought to be between 2 and 10 hectares (5 and 25 acres) (Estep and Teresa 1992, DFG 1994). In the Central Valley, agricultural land use or specific crop type determine the foraging value of a field at any given time. Cover types were evaluated by Estep (1989) and ranked based on these factors. However, suitability ranking is based on a variety of site-specific issues and at a landscape level should be characterized only on a general basis. On a site-specific level—important for land management purposes to maximize foraging value—individual cover types can be assessed based on site-specific and management conditions.

Important land cover or agricultural crops for foraging are alfalfa and other hay, grain and row crops, bare fallow fields, dryland pasture, and annual grasslands. The matrix of these cover types across a large area creates a dynamic foraging landscape as temporal changes in vegetation results in changing foraging patterns and foraging ranges.

Hay crops, particularly alfalfa, provide the highest value because of the low vegetation structure (high prey accessibility), relatively large prey populations (high prey availability), and because farming operations (e.g., weekly irrigation and monthly mowing during the growing season) enhances prey accessibility. Most row and grain crops are planted in winter or spring and have foraging value while the vegetation remains low, but become less suitable as vegetation cover and density increases. During harvest, vegetation cover is eliminated while prey populations are highest, significantly enhancing their suitability during this period. Some crop types, such as rice, orchards, and vineyards, provide little to no value because of reduced accessibility and relatively low prey populations.

A28.4 LIFE HISTORY

Description. Swainson's hawk is a long-winged, medium-sized (19- to 22-inch [48- to 56-centimeter {cm}] and 1.5- to 3- pound [0.7- to 1.4-kilogram]) soaring raptor that nests and roosts in large trees in flat, open grassland or agricultural landscapes. Females, on average, are larger than males, but there are no distinguishing plumage characteristics for separating the sexes.

Swainson's hawk is characterized by its long, narrow, and tapered wings held in flight in a slight dihedral shape. The body size is somewhat smaller, thinner, and less robust than other buteos (broad-winged soaring hawks), although the wings are at least as long as other buteos. This body and wing shape allows for efficient soaring flight and aerial maneuverability. This is important for foraging, which Swainson's hawks do primarily from the wing, and during courtship and inter-specific territorial interactions.

There are three definitive plumage morphs: light, rufous, and dark. However, there are numerous intermediate variations between these plumage morphs. The two most distinguishing plumage characteristics are a dark breast band and the contrasting darker flight feathers and lighter wing lings on the underwings giving most individuals a distinctive bicolored underwing pattern. These characteristics are most pronounced in lighter morph birds and become less so as the plumage darkens, and are indistinguishable in the definitive dark morph, which is completely melanistic. All three definitive plumage morphs are present in the Central Valley with a relatively large proportion of the population categorized as intermediate morph, with varying amounts of streaking or coloration in the belly and wing linings.

Seasonal Patterns. Swainson's hawks arrive on their breeding grounds in the Central Valley from early March to early April. The breeding season extends through mid-to-late August, when most young have fledged and breeding territories are no longer defended. By late August pre-migratory groups begin to form. The fall migration begins early- to mid-September. By early October, most Swainson's hawks have migrated out of the Central Valley. Central Valley Swainson's hawks winter primarily in Central Mexico and, to a lesser extent, throughout portions of Central and South America (Bradbury et al. in preparation). This differs from what is known about the migratory pattern and wintering grounds of Swainson's hawk populations outside of the Central Valley, most of which take a different migratory route and winter entirely in southern South America, with the largest wintering populations known to occur in northern Argentina (England et al. 1997).

Reproduction. Swainson's hawks exhibit a high degree of nest site fidelity, using the same nests, nest trees, or nesting stands for many years (England et al. 1997). Pairs are monogamous and may maintain bonds for many years (England et al. 1997). Immediately upon arrival onto breeding territories, breeding pairs begin constructing new nests or repairing old ones. One to four eggs are laid in mid- to late-April followed by a 30- to 34-day incubation period. Nestlings begin to hatch by mid-May followed by an approximately 20-day brooding period. The young remain in the nest until they fledge in 38 to 42 days after hatching (England et al. 1997). Studies conducted in the Sacramento Valley indicate that one or two—and occasionally three—young typically fledge from successful nests (Estep in preparation). The rate of young fledged per nest in the Central Valley is among the lowest recorded in the entire species range. This geographic difference in reproductive success may be related to the reliance on small voles that may not meet the high energetic demands of breeding adults and developing young compared to the diets that include a higher proportion of gophers, rabbits, ground squirrels, and other larger mammals consumed in other locations. It may also be due to the energetic demands of foraging in a dynamic agricultural landscape that causes birds to travel long distances to forage during times when vegetation growth in agricultural fields reduces available foraging habitat near the nest. In Yolo County, fledging rates ranged from 1.15 to 1.96 young per successful nest from 1988 to 2000 (Estep in prep.).

After fledging, young remain near the nest and are dependent on the adults for about 4 weeks, after which they permanently leave the breeding territory (Anderson et al. in preparation).

Home Range/Territory Size. Home ranges are highly variable depending on cover type, and fluctuate seasonally and annually with changes in vegetation structure (e.g., growth and harvest) (Estep 1989, Woodbridge 1991, Babcock 1995). Smaller home ranges consist of high percentages of alfalfa, fallow fields, and dry pastures (Estep 1989, Woodbridge 1991, Babcock 1995). Larger home ranges were associated with higher proportions of cover types with reduced prey accessibility, such as orchards and vineyards, or reduced prey abundance, such as flooded rice fields. Swainson's hawks regularly forage across a very large landscape compared with most raptor species. Data from Estep (1989) and England et al. (1995) indicate that it remains energetically feasible for Swainson's hawks to successfully reproduce when food resources are limited around the nest and large foraging ranges are required. Radio-telemetry studies indicate that breeding adults in the Central Valley routinely forage as far as 18.6 miles from the nest (Estep 1989, Babcock 1995).

Home ranges (calculated as minimum convex polygons) for 12 Swainson's hawks in the Central Valley averaged 10.7 square miles (mi^2) (range: 1.3 to 33.7 mi^2) (27.7 kilometers [km^2] [range: 3.4 to 87.3 km^2]) (Estep 1989). Using similar methods, four Swainson's hawks in West Sacramento averaged 15.6 mi^2 (range: 2.8 to 29.6 mi^2) (40.4 km^2 [range: 7.3 to 76.7 km^2]), and included fields planted in grain, alfalfa, tomatoes, and safflower, as well as fallow fields (Babcock 1995).

Swainson's hawks in the central region of the Central Valley had the shortest distances between nests of those reported in England et al. (1997); on average, nests were 0.7 miles (1.1 km) apart

(Estep 1989). Results from a 2006 baseline survey of South Sacramento County indicate a nesting density of 37 pairs/100 mi^2 (259 km^2); and from a 2007 baseline survey of nesting Swainson's hawks in Yolo County, a nesting density within the survey area of 38 pairs/100 mi^2, the highest nesting density reported for this species (Estep 2008). This high nest density was attributed to widely available, uniformly distributed optimal foraging habitat and relatively abundant nesting sites along narrow riparian corridors, farm shelterbelts, roadside trees, remnant groves, and isolated trees.

Foraging Behavior and Diet. Swainson's hawks hunt primarily from the wing, searching for prey from a low altitude soaring flight, 98 to 295 feet (30 to 90 meters) above the ground and attack prey by stooping toward the ground (Estep 1989). This species is also highly responsive to farming and seasonal wetland management activities that expose and concentrate prey, such as cultivating, harvesting, and disking. During these activities, particularly late in the season, Swainson's hawks will hunt behind tractors searching for exposed prey. Other activities, such as flood irrigation and burning, also expose prey and attract foraging Swainson's hawks.

In the Central Valley, Swainson's hawks feed primarily on small rodents, usually in large fields that support low vegetation cover (to provide access to the ground) and high densities of prey (Bechard 1982, Estep 1989). These habitats include hay fields, grain crops, certain row crops, and lightly grazed pasturelands. Fields lacking adequate prey populations (e.g., flooded rice fields) or those that are inaccessible to foraging birds (e.g., vineyards and orchards) are rarely used (Estep 1989, Babcock 1995, Swolgaard 2003).

Meadow vole (*Microtus californicus*) is the principal prey item taken by Swainson's Hawks in the Central Valley (Estep 1989). Pocket gopher (*Thomomys bottae*) is also an important prey item. Other small rodents, including deer mouse (*Peromyscus californicus*) and house mouse (*Mus musculus*), are also taken along with a variety of small birds, reptiles, and insects.

A28.5 Threats and Stressors

Swainson's hawks face different threats in different portions of their range. In California, causes of population decline are thought to be loss of nesting habitat (Schlorff and Bloom 1984) and loss of foraging habitat to urban development and to conversion to unsuitable agriculture, such as orchards and vineyards (England et al. 1995, 1997).

Conversion of agricultural lands to urban uses continues at a high rate throughout the range of the Swainson's hawk. Urbanization results in permanent loss of habitat and fragmentation of landscapes, which both result in a reduction of available foraging habitat for the Swainson's hawk.

Conversion from compatible to incompatible crop patterns also reduces available foraging habitat and influences the distribution of nesting Swainson's hawks. Large regions of the Central Valley that have been converted to rice, vineyards, orchards, cotton, and other incompatible crop types support few nesting Swainson's hawks. The continued conversion of suitable agricultural landscapes (e.g., annually rotated irrigated cropland, hayfields, and pasturelands) to vineyards and other unsuitable cover types continues to reduce available foraging habitat on a local and regional basis. Spring and summer inundation of agricultural lands or seasonal wetland habitats also reduces available foraging habitat.

Loss of riparian and other nesting habitat continues throughout the Central Valley from levee projects, agricultural practices, and local development along watercourses. A related issue is the loss and lack of regeneration of valley oak and other native trees. This is an ongoing problem in areas that have continued to support remnant valley oaks and oak groves. Nesting habitat continues to decline as these trees and small groves die off or are removed and are not replaced through natural regeneration or replanting.

Nestlings are vulnerable to starvation and fratricide (i.e., the larger nestling killing the smaller nestling in times of food-stress), and predation from crows, ravens, and other raptors. Natural population cycles of voles in central California may be a major factor in reproductive success where vole population crashes suppress Swainson's hawk reproduction or lead to increased starvation rates of nestlings. In addition, insecticides and rodenticides may contribute to food scarcity by reducing prey abundance. There is little evidence that adult Swainson's hawks are killed by natural predators, but collisions with moving vehicles and illegal shooting and trapping have been identified as sources of mortality (England et al. 1997).

Well documented mass poisoning of hundreds or thousands of Swainson's hawks wintering in Argentina (Woodbridge et al. 1995, Goldstein et al. 1996) have led to that country's ban of an insecticide (organophosphate monocrotophos) used on alfalfa and sunflower fields to control grasshopper populations. Levels of dichlorodiphenyldichloroethylene (DDE) (a toxic degradation product of DDT [dichlorodiphenyltrichloroethane], a pesticide used extensively until 1972 when it was banned in the U.S.) in Swainson's Hawks from the Central Valley may have been high enough to negatively affect reproductive success during the decades when DDT was used extensively in the United States. However, levels of DDE measured in eggs collected in 1982–1983 were not considered high enough to indicate a health threat (Risebrough et al. 1989).

A28.6 Relevant Conservation Efforts

Conservation efforts have focused on the development and implementation of habitat conservation plans/natural community conservation plans. These regional conservation approaches can be an effective tool to managing and sustaining Swainson's hawk populations if sufficient suitable landscape is preserved (Estep and Teresa 1992). Much of the Plan Area overlaps with or is near other conservation planning efforts that are either currently being implemented or are in development. Swainson's hawk is a covered species under the approved San Joaquin County Multi-species Habitat Conservation and Open Space Plan, the East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan, and the

Natomas Basin Habitat Conservation Plan. It is also proposed for coverage under the South Sacramento County Habitat Conservation Plan, the Solano County Multi-species Habitat Conservation Plan, the Yolo County Natural Heritage Program Plan, and the Butte Regional Habitat Conservation Plan and Natural Community Conservation Plan.

DFG is currently finalizing a management strategy for the Swainson's hawk that is designed to coordinate conservation planning efforts to facilitate a comprehensive and consistent approach to managing landscapes to sustain Swainson's hawk populations in the Central Valley (DFG in preparation).

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designates the Swainson's hawk as "Contribute to Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its control and within its scope that are necessary in order to contribute to the recovery of the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

A28.7 SPECIES HABITAT SUITABILITY MODEL

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf 2007. Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers, connectivity between habitat types, and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The Swainson's hawk model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), U.S. Department of Agriculture (USDA) 2005 aerial photography, and DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable Swainson's hawk habitat in the Plan Area according to the species' two primary life requisite parameters, nesting habitat and foraging habitat. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Nesting Habitat. Nesting habitat in the Delta includes the following types using the BDCP composite vegetation layer:

- Valley/foothill riparian
    - White alder (*Alnus rhombifolia*);
    - *Alnus rhombifolia/Salix exigua;*
    - *Alnus rhombifolia/Cornus sericea;*
    - Oregon ash (*Fraxinus latifolia*);
    - Box elder (*Acer negundo*);
    - *Acer negundo-Salix gooddingii;*

- Hinds walnut (*Juglans hindsii*);
- Fremont cottonwood (*Populus fremontii*);
- Black willow (*Salix gooddingii*);
- *Salix gooddingii*/wetland herbs;
- *Salix gooddingii-Populus fremontii* (*Quercus lobata-Salix exigua-Rubus discolor*);
- *Quercus lobata-Salix exigua-Rubus discolor;*
- *Salix goodingii – Quercus lobata*/wetland herbs;
- *Salix gooddingii/Rubus discolor;*
- Coast live oak (*Quercus agrifolia*);
- Valley oak (*Quercus lobata*);
- *Quercus lobata/Rosa californica;*
- *Quercus lobata – Acer negundo;*
- *Quercus lobata – Alnus rhombifolia;*
- *Quercus lobata – Fraxinus latifolia;*
- Black willow (*Salix gooddingii*)-valley oak (*Quercus lobata*) restoration;
- Valley oak (*Quercus lobata*) restoration; and
- White alder (*Alnus rhombifolia*) arroyo willow (*Salix lasiolepis*) restoration.

Nesting habitat in the Suisun Marsh and Yolo Basin includes the following types using the BDCP composite vegetation layer:

- Eucalyptus;
- *Eucalyptus globules;*
- *Fraxinus latifolia;*
- Fremont cottonwood-valley oak-willow riparian forest ;
- Landscape trees;
- Mixed Fremont cottonwood – willow;
- Mixed willow super alliance;
- Oaks;
- *Quercus agrifolia;*
- *Salix lasiolepis/Quercus agrifolia;*

- Valley oak alliance – riparian; and
- Willow trees.

While valley oak and/or cottonwood-dominated riparian forests are considered optimal nesting habitat for this species, the model does not distinguish habitat quality according to overstory composition, tree density, structure, or patch size. For purposes of this model, all overstory riparian and other mature trees are considered potential Swainson's hawk nesting habitat. Natural vegetation types designated as species habitat in this model correspond to the mapped vegetation associations in the BDCP composite vegetation data layer.

Assumptions. In the Central Valley, Swainson's hawks typically nest in large native trees such as cottonwood, valley oak, walnut, and black willow (Figure A-28b). These trees (and thus most nest sites) are most often found along stringers of valley riparian forest (Estep 1984, Schlorff and Bloom 1984, England et al. 1997). Because the age or structure of the overstory trees is not considered here, this model may overestimate the extent of suitable riparian nesting habitat. However, Swainson's hawks also nest in a variety of other native (e.g., Oregon ash, box elder, white alder) and nonnative trees (e.g., eucalyptus) and habitats such as roadside trees, windbreaks, oak groves, isolated trees, and trees around rural residences. These nesting habitat types are not sufficiently captured by this model primarily due to the small mapping units that would be required, and thus potential non-riparian nesting habitat is underestimated here (Figure A-28b). While the model focuses on riparian habitats, to address this issue, impact assessments will include all potential nesting habitat types where they occur in association with suitable foraging habitat.

Foraging Habitat. Foraging habitat in the Delta includes the following types from the BDCP composite vegetation layer using a 5-acre minimum patch size:

- Grasslands
  - Ruderal herbaceous grasses and forbs;
  - California annual grasslands;
  - *Bromus diandrus-Bromus hordeaceus;*
  - Italian rye-grass (*Lolium multiflorum*);
  - *Lolium multiflorum-Convolvulus arvensis;*
  - Degraded vernal pool complex – California annual grasslands;
  - Degraded vernal pool complex – Ruderal herbaceous grasses and forbs; and
  - Degraded vernal pool complex – Italian rye-grass (*Lolium multiflorum*).
- Managed Wetlands
  - Temporarily flooded grasslands;

    - Rabbitsfoot grass (*Polypogon monspeliensis*);
    - Intermittently flooded perennial forbs;
    - Managed annual wetland vegetation (non-specific grasses and forbs);
    - Shallow-flooding with minimal vegetation;
    - Seasonally flooded undifferentiated annual grasses and forbs;
    - Managed alkali wetland (*Crypsis*); and
    - Intermittently or temporarily flooded undifferentiated annual grasses and forbs.
- Alkali seasonal wetland complex and other natural seasonal wetlands
    - *Distichlis spicata* – Annual grasses;
    - Seasonally-flooded grasslands;
    - Vernal pools;
    - Degraded vernal pool complex-vernal pools;
    - Temporarily flooded perennial forbs;
    - Alkaline vegetation mapping unit;
    - *Allenrolfea occidentalis* mapping unit;
    - *Suaeda moquinii* mapping unit; and
    - Salt scalds and associated sparse vegetation.
- Vernal pool complex
    - *Allenrolfea occidentalis* mapping unit;
    - Annual grasses generic;
    - Annual grasses/weeds;
    - California annual grasslands;
    - *Distichlis*/annual grasses;
    - *Distichlis spicata* – Annual grasses;
    - Italian rye-grass (*Lolium multiflorum*);
    - Ruderal herbaceous grasses and forbs;
    - Salt scalds and associated sparse vegetation;
    - Seasonally-flooded grasslands;
    - *Suaeda moquinii* mapping unit; and

  - Vernal pools.

Foraging habitat in the Suisun Marsh and Yolo Basin includes the following types from the BDCP composite vegetation layer:

- Annual grasses generic;
- Annual grasses/weeds;
- *Baccharis*/annual grasses;
- *Bromus* spp./*Hordeum;*
- *Crypsis schoenoides;*
- *Crypsis* spp. – Wetland grasses – Wetland forbs;
- Cultivated annual graminoid;
- *Cynodon dactylon;*
- *Distichlis*/annual grasses;
- Fallow disced field;
- Field crops;
- *Hordeum/Lolium;*
- *Lolium* (generic);
- *Lolium/Rumex;*
- *Lotus corniculatus;*
- Medium upland herbs;
- Medium wetland graminoids;
- Medium wetland herbs;
- Pasture;
- Perennial grass;
- Short upland graminoids;
- Short wetland graminoids;
- Tall wetland graminoids;
- Truck/nursery/berry crops;
- Upland annual grasslands and forbs formation;
- Upland herbs; and

- Agriculture.

The following DWR 2007 Land Use survey types are included as suitable agricultural foraging habitats for Swainson's hawk. These types represent the typical agricultural cover types in the Plan Area that are included in the DWR 2007 land use survey. Rotational crop types that are not common to the Plan Area are not included here. Pasture types are mostly perennial; alfalfa is semi-perennial (3 to 7 years); and all other types are annually or seasonally rotated irrigated crops, only some of which provide suitable foraging habitat for Swainson's hawk.

- Grain and hay crops
  - Barley;
  - Wheat;
  - Oats; and
  - Miscellaneous and mixed grain and hay.
- Field crops
  - Safflower;
  - Sugar beets;
  - Corn;
  - Grain sorghum;
  - Sudan;
  - Beans;
  - Miscellaneous field; and
  - Sunflowers.
- Pasture
  - Alfalfa and alfalfa mixtures;
  - Clover;
  - Mixed pasture;
  - Native pasture;
  - Induced high water table native pasture; and
  - Miscellaneous grasses.
- Truck, nursery and berry crops
  - Asparagus;
  - Beans;
  - Onions and garlic;

  - o Tomatoes; and
  - o Peppers.
- Idle
  - o Land not cropped the current or previous crop season, but cropped within the past three years; and
  - o New lands being prepped for crop production.

The model includes all grassland types, many managed and natural seasonal wetland types, all irrigated pastures and hays, and all seasonally rotated croplands. The model excludes suitable habitat fragments less than 40 acres in size if they are fragmented by urbanization. Suitable habitat fragmented by unsuitable agricultural crop types is not excluded. Agricultural crop types designated as species habitat correspond to DWR 2007 land use database categories.

Assumptions. In the Central Valley, foraging habitat consists primarily of irrigated croplands and pasturelands. Swainson's hawk also forage in annual grasslands and during the summer will use non-inundated seasonal wetlands. Swainson's hawks feed primarily on small rodents, usually in large fields that support low vegetation cover (to provide access to the ground) and high densities of prey (Bechard 1982, Estep 1989). These habitats include hay fields, grain crops, certain row crops, and lightly grazed pasturelands. Fields lacking adequate prey populations (e.g., flooded rice fields) or those that are inaccessible to foraging birds (e.g., vineyards and orchards) are rarely used (Estep 1989, Babcock 1995, Swolgaard 2003) and are excluded here. Because foraging Swainson's hawks must have access to the ground, vegetation structure influences foraging use, which varies according to the crop type and seasonal planting and harvesting regime (Estep 2009). However, because the Grain and Hay, Field, and Truck, Nursery and Berry Crop types listed above are seasonally rotated, the value of individual fields changes each year. Therefore, these crop types are not differentiated based on their seasonal value and are instead combined into a category of seasonally rotated croplands. As a result, this model overestimates the extent of available agricultural foraging habitat in any given year. Foraging use is also a function of patch size. Foraging use generally decreases as suitable foraging patch size decreases below approximately 40 acres. However, this is usually based on fragmentation of foraging habitat due to urbanization, and not necessarily by unsuitable crop types. To maintain consistency with DFG guidance, a minimum foraging patch size of 5 acres is used.

Habitat Units. As described, the Swainson's hawk is closely associated with agricultural lands. Most of the Plan Area consists of agricultural land and most is considered to have some value as foraging habitat for Swainson's hawks. However, the value of crop types differ widely due to their growth and structure, which influences accessibility by foraging hawks, and in prey abundance, which influences the availability of prey to foraging hawks. Because of the dynamic nature of the agricultural landscape and the variability of crop patterns and conditions seasonally and annually, only a proportion of the agricultural landscape is suitable or available for foraging in any given season or year. To account for this variability and to more accurately represent the value of Plan Area-wide foraging habitat, acres of Swainson's hawk foraging habitat can be converted to habitat units.

Sufficient information is available on the growth and structure of different agricultural crops (Estep 1989, 2009) and the prey abundance and use of different crop types to generally categorize crops based on their value as foraging habitat. By placing different crop types and other foraging habitats that traditionally occur in the Plan Area into crop value classes and assigning relative values to those classes (e.g., 0.1, 0.25, 0.5, 0.75, and 1.0), the habitat acres can be converted to habitat units. Habitat units, rather than acres, can then used to describe and calculate impacts to Swainson's hawk foraging habitat using this index of habitat value. Table A-28a provides the rationale for assigning crop types and other agricultural land uses to habitat value categories. Figure A-28c displays the distribution of foraging habitat and the assigned habitat values within the Plan Area.

Table A-28a. Swainson's Hawk Agricultural Foraging Habitat Value Classes

Foraging Habitat Value Class	*Assigned Agricultural Crops/Habitats*	*Rationale for Assignment of Agricultural Crop Class*	*Information Sources[1]*
1.0-Very High	Alfalfa	Alfalfa has the highest value because it is semi-perennial (up to 5 years before rotation), which increases prey abundance; has a relatively low profile such that prey are accessible season-long; and has a management regime (mowing and irrigation) which further increases prey accessibility.	J. Estep, pers. comm., T. Beedy, pers. comm., Estep 1989, Estep 2009, Swolgaard et al. 2008.
.75-High	Native Pasture, Undifferentiated Pasture, Mixed Pasture, Clover, Miscellaneous Grasses (grown for seed)	These pasture types provide a relatively consistent vegetation structure and rodent prey populations. There is less seasonal variability with respect to prey abundance and accessibility compared with grain and vegetable crops, but they lack the management practices that enhance prey accessibility found in alfalfa.	J. Estep, pers. comm., T. Beedy, pers. comm., Estep 1989, Estep 2009, Swolgaard et al. 2008.
.5-Medium	Sugar Beets, Tomatoes, Grain and Hay, annual grasslands, vernal pool grasslands, alkali grasslands	Certain row crops, such as beets and tomatoes also have relatively high value because they support large rodent prey populations, are accessible season-long because of their relatively low vegetation profile, and they are harvested prior to migration, when an abundance of prey becomes available. Most grain crops (primarily wheat in Yolo County) provide value during and following harvesting, when prey become accessible. Grasslands are generally available season-long but provide lower prey abundance compared with higher value agricultural habitats, don't provide a peak period of high value abundance and accessibility like some agricultural crops (e.g., tomatoes), and in some cases grass height reduces prey accessibility during a portion of the breeding season.	J. Estep, pers. comm., T. Beedy, pers. comm., Estep 1989, Estep 2009, Swolgaard et al. 2008.
.25-Low	Broccoli, Sudan, Dry Beans, Undifferentiated Field Crops, Asparagus, Green Beans, Cole Crops, Carrots, Melons/Squash/Cucumbers,	The truck and berry/field crop agriculture types are suitable for a portion of the breeding season depending on their structure and planting/harvesting regime. But in general, they produce less prey abundance and less prey	J. Estep, pers. comm., T. Beedy, pers. comm., Estep 1989, Estep 2008, Swolgaard et al.

Table A-28a. Swainson's Hawk Agricultural Foraging Habitat Value Classes

Foraging Habitat Value Class	*Assigned Agricultural Crops/Habitats*	*Rationale for Assignment of Agricultural Crop Class*	*Information Sources[1]*
	Onions/Garlic, Peppers, Cabbage, Undifferentiated Truck and Berry Crops, Artichokes, Lettuce (all types), Spinach, Mixed Truck and Berry	availability than the other agriculture types listed above.	2008.
.10-Marginal	Safflower, corn, grain sorghum, sunflower	These types are available for a brief time during the breeding season and have particularly low prey accessibility.	J. Estep, pers. comm., T. Beedy, pers. comm., Estep 1989, Estep 2009, Swolgaard et al. 2008.

[1]Literature cited or other information sources:

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A28.8 Recovery Goals

A USFWS recovery plan has not been prepared for this species and no recovery goals have been established; however, the CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy (MSCS) designates the Swainson's hawk as "Contribute to Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its control and within its scope that are necessary in order to contribute to the recovery of the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

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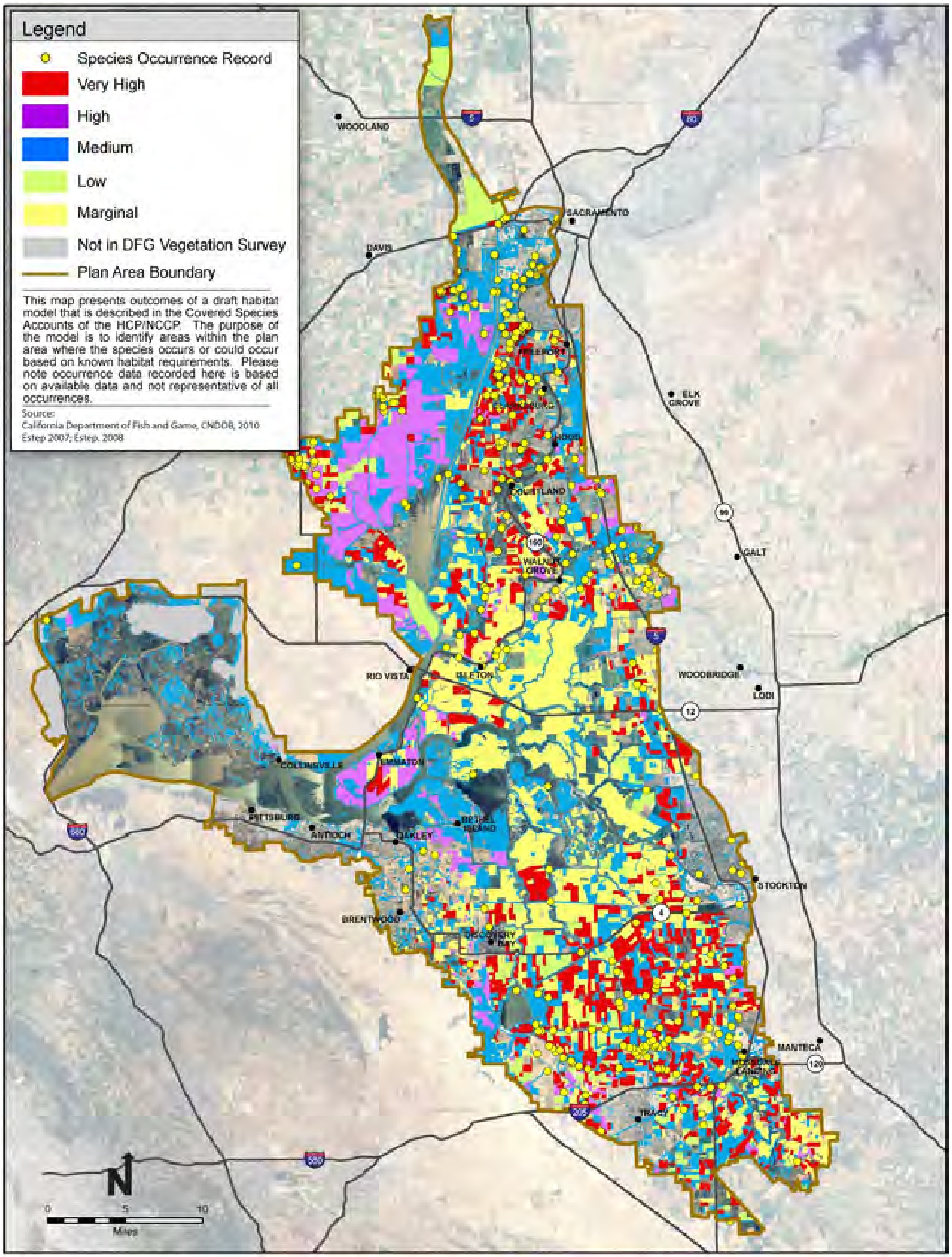

Figure A-28c. Swainson's Hawk Foraging Habitat and Associated Value Rankings

A28.9 REFERENCES

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APPENDIX A29. WHITE-TAILED KITE (*ELANUS LEUCURUS*)

A29.1 LEGAL STATUS

The white-tailed kite is designated as a state Fully Protected species pursuant to California Department of Fish and Game Code Section 3511. Nests are protected in California under Fish and Game Code Sections 3503.5.

White-tailed kite has no federal regulatory status; however, the species is protected under the federal Migratory Bird Treaty Act.

A29.2 SPECIES DISTRIBUTION AND STATUS

A29.2.1 Range and Status

The white-tailed kite was threatened with extinction in North America during the early twentieth century (Eisenmann 1971). Until the 1960s, the species was considered declining throughout its North American range, but since then has recovered in some areas. Currently, the distribution of the species includes the east coast and southeast United States, the southwest United States from Texas to California, and north to Washington State, and from Mexico to South America (Dunk 1995). Relatively stable resident populations occur in California, portions of coastal Oregon and Washington, southern Florida, southern Texas, and portions of northern Mexico. The species is considered rare in remaining portions of its North American range. Range expansion has also been noted in some Central American locales (Eisenmann 1971).

California populations were also thought to be seriously declining prior to the 1960s likely due to habitat loss, shooting, and possible egg collecting (Pickwell 1930, Waian and Stendell 1970). From the 1940s to the 1970s, populations and distribution increased (Fry 1966, Waian and Stendall 1970, Eisenmann 1971), due to protection from shooting and possibly due to increasing agricultural development, which may have increased rodent habitat and expanded the foraging range of white-tailed kite (Eisenmann 1971, Small 1994). In the Sacramento Valley, the kite has increased predominantly in irrigated agricultural areas where meadow vole (*Microtus californicus*) populations are found (Warner and Rudd 1975).

California is currently considered the breeding range stronghold for white-tailed kite in North America (Figure A-29a), with nearly all areas up to the western Sierra Nevada foothills and southeastern deserts occupied (Small 1994, Dunk 1995). It is common to uncommon and a year-round resident in the Central Valley, other lowland valleys, and along the entire length of the coast (Dunk 1995).

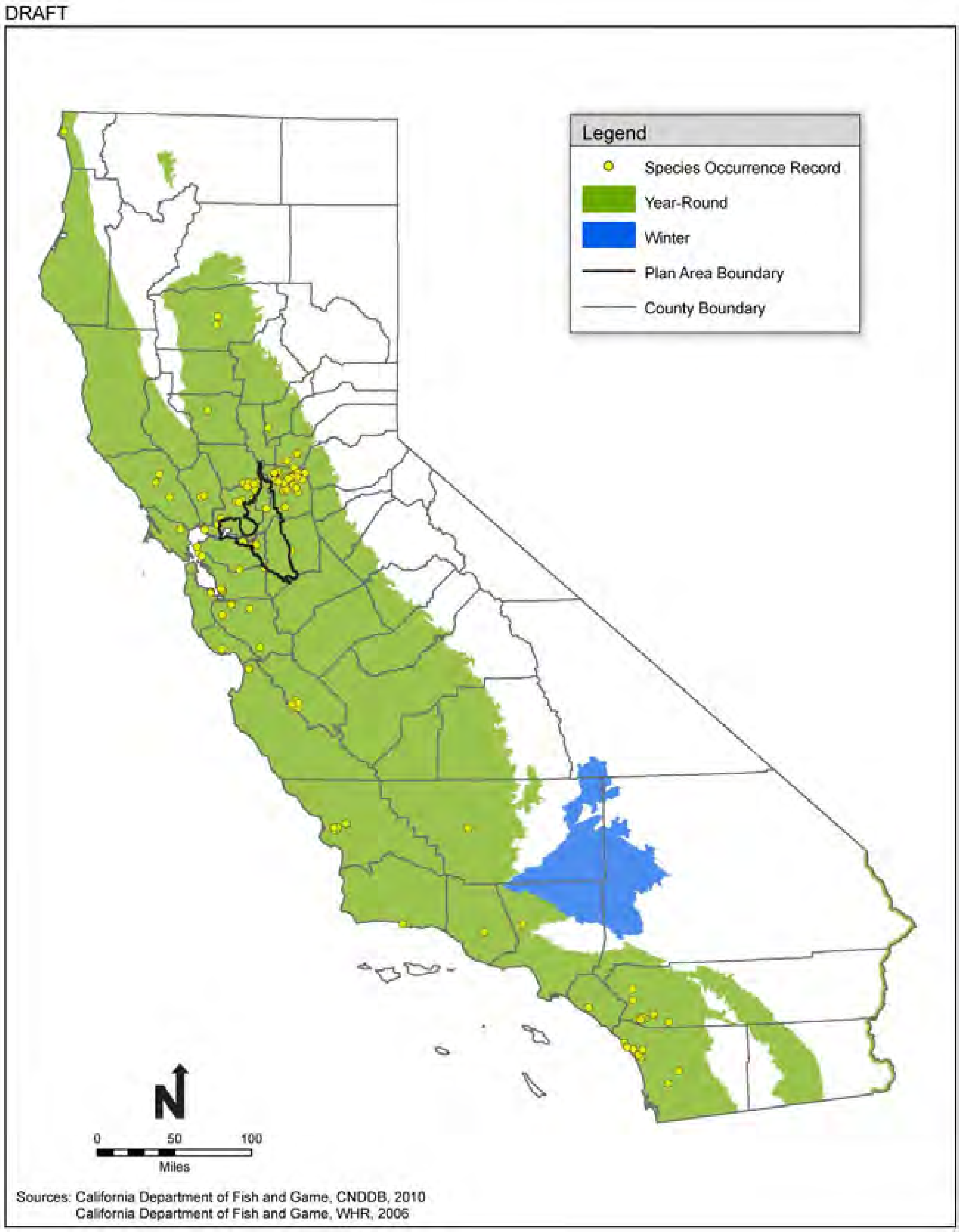

Figure A-29a. White-Tailed Kite Statewide Range and Recorded Occurrences

Although white-tailed kite is probably resident through most of its breeding range, dispersal occurs during the non-breeding season, leading to a winter range expansion that includes most of California (Small 1994, Dunk 1995).

A29.2.2 Distribution and Status in the Plan Area

White-tailed kite is distributed throughout the Plan Area during the breeding and wintering seasons (Figure A-29b), although relatively few nesting locations have been documented. The species is underrepresented in the California Natural Diversity Database (CNDDB), which reports only five locations within the Plan Area (CNDDB 2009). Recent surveys in the Yolo and Sacramento County portions of the Plan Area have documented active nests sites in riparian habitats in the Yolo Bypass and along Steamboat and Georgiana sloughs, and the Sacramento River (Estep 2007, 2008). Additional incidental observations are regularly noted in Audubon field notes, environmental documents, and management plans in the Delta. The California Department of Fish and Game (DFG) also maintains nesting and winter roosting records of white-tailed kites from the Yolo Bypass Wildlife Area. Most nesting habitat for kites in the Plan Area consists of riparian woodlands and scrub along large and small drainages. Nesting distribution is limited by the dearth of suitable trees in much of the central Delta, and nesting density in that area is likely significantly lower than that found in the northern and southern portions of the Plan Area. However, overall the species is likely under-represented by reported occurrences throughout the Plan Area. Most of the Plan Area, including grassland, seasonal wetland, and agricultural cover types, is potential foraging habitat for kites. Thus, the species potentially occurs throughout the entire Plan Area during winter and in the vicinity of suitable nesting habitat during the breeding season.

A29.3 Habitat Requirements and Special Conditions

The white-tailed kite inhabits low elevation, open grasslands, savannah-like habitats, agricultural areas, wetlands, and oak woodlands (Dunk 1995). They nest in trees – usually with a dense canopy, but nest trees can vary from single, isolated trees to trees within large woodlands. Habitat elements that influence nest site selection and nesting distribution include habitat structure (usually a dense canopy) and prey abundance and availability (primarily the association with meadow vole), while the association with specific vegetation types (e.g., riparian, oak woodland, etc.) appears less important (Dunk 1995, Erichsen 1995).

Nesting. White-tailed kite nests have been documented in a variety of tree species, including valley oak (*Quercus lobata*), Fremont cottonwood (*Populus fremontii*), willow (*Salix* spp.), live oak (*Quercus wislizenii*), boxelder (*Acer negundo*), ornamental trees including olive and pine trees, and occasionally in tall shrubs (Dixon et al. 1957, Dunk 1995, Erichsen 1995, Estep 2007, 2008). As noted above, nest trees appear to be selected on the basis of structure and security, and thus typically have a dense canopy or are within a dense group of trees, such as riparian forest or oak woodland. Kites will occasionally use isolated trees, but this is relatively rare.

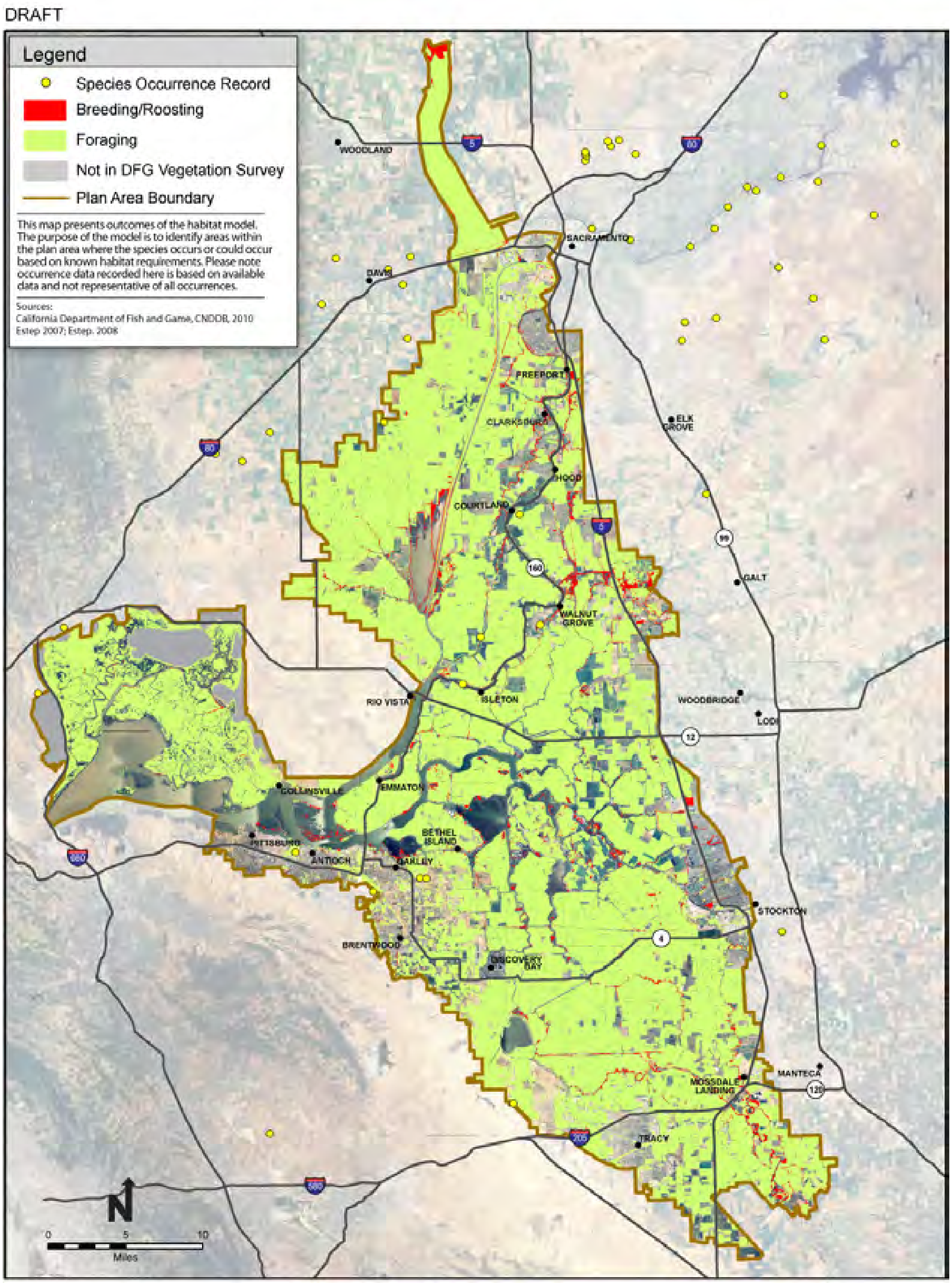

Figure A-29b. White-Tailed Kite Habitat Model and Recorded Occurrences

Most nests in the Sacramento Valley are found in oak/cottonwood riparian forests, valley oak woodlands, or other groups of trees and are usually associated with compatible agricultural foraging habitat, such as pasture and hay crops, compatible row and grain crops, or natural vegetation such as seasonal wetlands and annual grasslands (Erichsen 1995).

Kites often nest in close association with other nesting kites and with several other raptors – including Swainson's hawk (*Buteo swainsoni*), red-tailed hawk (*Buteo jamaicensis*), and red-shouldered hawk (*Buteo lineatus*) – particularly in riparian habitats of the Sacramento Valley (Erichsen 1995, Estep 2007, 2008).

Foraging. A variety of foraging habitat types are used, but those that support larger and more accessible prey populations are more suitable. The presence and abundance of white-tailed kites is strongly correlated with the presence of meadow voles (Stendell 1972). As a result, population cycles of meadow voles can also influence nesting and wintering abundance of white-tailed kites. For example, those portions of the Plan Area that are subject to seasonal flooding experience fluctuating prey numbers, which impacts the occurrence of white-tailed kites until prey populations recover. Cover types that appear to be preferred include alfalfa and other hay crops, irrigated pastures, and some cultivated habitats, particularly sugar beets and tomatoes, both of which can support relatively large populations of voles (Estep 1989) and which have been highly correlated with kite nest site densities (Erichsen et al. 1994). Kites also forage in dry pastures, annual grasslands, rice stubble fields, and occasionally in orchards (Erichsen 1995).

Winter foraging habitat is similar to breeding season foraging habitat – particularly the association with agricultural habitats and vole populations; however, there is less association with riparian forests and woodlands.

Winter Roosts. White-tailed kites roost communally during the winter months, sometimes in great concentrations of hundreds of birds. This roosting behavior usually occurs in large trees, but sometimes occurs in other upland habitats. Significant winter communal roosts have been reported in the Yolo Bypass on the Yolo Bypass Wildlife Area (Feliz pers. comm.)

A29.4 LIFE HISTORY

Description. White-tailed kites are medium-sized hawks (total length 32-38 centimeters (cm) [12.6-15 inches]) with a long white tail and large, black shoulder patches, and red eyes. In adults, these features contrast with the gray back and white underparts. The sexes are similar in size, but females tend to have darker backs than males. Juveniles have yellow eyes, buff streaks on the breast and head, and gray and white-tipped feathers on the back. White-tailed kites are also readily recognized by their foraging behavior, frequently hovering (kiting) in the air while hunting for prey.

Seasonal Patterns. Although apparently a resident bird throughout most of its breeding range, dispersal occurs during the nonbreeding season resulting in some range expansion during the winter. Stendell (1972) believed it to be resident, becoming nomadic during periods of low prey abundance. While population changes and local and regional movements appear to be somewhat predictable based on vole and other rodent cycles, it remains unknown whether in northern California this constitutes a migration movement or nomadic response to changes in the prey populations (Dunk and Cooper 1994).

Reproduction. The breeding season, from pair-bonding to juvenile dependence, occurs from approximately January to October with peak activity occurring from May through August (Dunk 1995). Nests are constructed of loosely piled sticks and twigs that are lined with grass, straw, or rootlets. The nest is placed near the top of a dense oak, willow, or other tree; usually 6 to 20 meters (20-65 feet) above ground in trees that vary from 3 to 50 meters (10-164 feet) in height (Dixon et al. 1957). Females typically lay a clutch of 4 eggs, with a range of 3 to 6. The female incubates exclusively and performs most brooding while the male provisions the female and nestlings. Eggs are incubated for about 28 days. Young fledge in 35 – 40 days following hatching, with the peak fledging period occurring in June (Erichsen 1995).

Home Range/Territory Size. Territory size is variable and regulated primarily by prey abundance and vegetation structure (i.e., accessibility of prey); however, this species also responds to the abundance of interspecific and intraspecific competitors (Dunk 1995, Erichsen 1995). Reported average territory sizes include 1.6 – 21.5 hectares (3.95 – 53.13 acres) (Dunk and Cooper 1994), 19 - 52 hectares (46.95 – 128.49 acres) with a mean of 29 hectares (71.66 acres) (Waian 1973), and 17 - 120 hectares (42.01 – 296.53 acres) (Henry 1983). As with other raptors species, particularly those occurring in agricultural habitats, home ranges may overlap and foraging may be limited to a small portion of the total area possibly a result of competition or fluctuating prey accessibility due to changes in vegetation structure (Henry 1983). Communal roosts are used during the non-breeding season (Waian and Stendell 1970). Home ranges for non-breeders is more difficult to determine since communal roosts may be tens of kilometers away (Dunk 1995).

Foraging Behavior and Diet. White-tailed kites generally hunt from a central perch over areas as large as 3 square kilometers (sq km) (1.16 square miles [sq m]) (Warner and Rudd 1975), but foraging usually occurs within 0.8 km (0.5 m) from the nesting site during the breeding season (Hawbecker 1942). Kites are not particularly territorial. The nest site and immediately surrounding area are defended against crows and other raptors (Pickwell 1930, Dixon et al. 1957), and small defended wintering territories of about 0.10 sq km (0.04 sq m) have been documented (Bammann 1975).

The white-tailed kite preys mostly on voles, but also takes other small, diurnal mammals, and occasionally birds, insects, reptiles, and amphibians. Small mammal prey comprises 95 percent of the kite diet (Dunk 1995). It forages in undisturbed, open grasslands, meadows, farmlands and emergent wetlands, ungrazed grasslands, fence rows and irrigation ditches adjacent to grazed lands (Dunk 1995). It soars, glides, and hovers less than 30 meters (98 feet) above the ground in search of prey. It hunts almost exclusively by hovering from 5 to 25 meters (16-82 feet) in height, with hovering bouts lasting up to 60 seconds. During this time, kites scan the ground searching for prey and watching for potential competitors or predators. The hovering bout ends in a dive to the ground for prey; flight to another location; soaring or interacting with another bird; or flight to the perch (Warner and Rudd 1975).

A29.5 Threats and Stressors

Urbanization/Habitat Fragmentation. Urbanization, including residential and commercial development and infrastructure development (roads and oil, water, gas, and electrical conveyance facilities) is one of the principal causes of continuing habitat loss for white-tailed kite and is a continuing threat to remaining populations, particularly in rapidly urbanizing areas in the Sacramento Valley. Urbanization permanently removes habitat and results in permanent abandonment of nesting territories. Proximity to urban areas also influences kite occurrence. While there are examples of kites nesting and roosting in urban areas, in general, the species is intolerant of noise and human activities and will abandon nesting areas that are subject to increasing levels of human disturbances. Kites are also sensitive to habitat fragmentation. Low density urbanization or isolation of habitats – even if relatively large patches remain undisturbed – also leads to territory abandonment.

Agricultural Crop Conversion. As noted above, white-tailed kite populations are closely associated with rodent abundance and accessibility, which can be influenced by crop patterns. Kite populations have recovered to some extent in California due in part to the expansion of compatible agricultural types. The conversion to crop patterns that do not support sufficient rodent prey, or that restrict accessibility to prey, can result in the abandonment of traditionally active territories.

A29.6 Relevant Conservation Efforts

Few conservation efforts have been undertaken to conserve white-tailed kite populations. The lack of state or federal listing limits the extent of regulatory influence. There remain several significant data gaps regarding population status and trends, migration, dispersal from nesting sites, and other aspects of annual movements.

Protection typically occurs at the local project level pursuant to the California Environmental Quality Act (CEQA). While project level mitigation may address protection of active sites and avoidance of take of this fully protected species, they do not address conservation or protection at a regional level.

Regional conservation efforts have focused on the development and implementation of habitat conservation plans/natural community conservation plans. These regional conservation approaches can be an effective tool to manage and sustain white-tailed kite populations if they protect sufficient suitable and occupied habitat. Much of the Plan Area overlaps with or is near other conservation planning efforts that are either currently being implemented or are in development. These plans include the San Joaquin County Multi-species Habitat Conservation and Open Space Plan, the South Sacramento County Habitat Conservation Plan, the Yolo County Natural Heritage Program Plan, and the Butte Regional Conservation Plan. If effectively coordinated, these efforts can be a valuable tool in managing white-tailed kite populations in the region. However, to date there has been limited coordination between these otherwise complimentary conservation planning efforts with respect to managing covered species.

A29.7 Species Habitat Suitability Model

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, and cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf 2007. Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers, connectivity between habitat types, and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The white-tailed kite model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), USDA 2005 aerial photography, and DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable white-tailed kite habitat in the Plan Area according to the species' two primary life requisites, nesting habitat and foraging habitat. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Breeding/Roosting Habitat. Nesting habitat in the Delta includes the following types from the BDCP composite vegetation layer:

- Agricultural land
    - Eucalyptus.
- Valley/foothill riparian
    - White alder (*Alnus rhombifolia*);
    - *Alnus rhombifolia/Salix exigua;*
    - *Alnus rhombifolia/Cornus sericea;*
    - Oregon ash (*Fraxinus latifolia*);
    - Box elder (*Acer negundo*);
    - *Acer negundo-Salix gooddingii;*
    - Hinds walnut (*Juglans hindsii*);
    - Fremont cottonwood (*Populus fremontii*);
    - Black willow (*Salix gooddingii*);
    - *Salix gooddingii*/wetland herbs;

  - *Salix gooddingii-Populus fremontii (Quercus lobata-Salix exigua-Rubus discolor*);
  - *Salix goodingii – Quercus lobata*/wetland herbs;
  - *Salix gooddingii/Rubus discolor;*
  - Coast live oak (*Quercus agrifolia*);
  - Valley oak (*Quercus lobata*);
  - *Quercus lobata/Rosa californica;*
  - *Quercus lobata – Acer negundo;*
  - *Quercus lobata – Alnus rhombifolia;*
  - *Quercus lobata – Fraxinus latifolia;*
  - Arroyo Willow (*Salix lasiolepis*);
  - *Salix lasiolepis* – Mixed brambles;
  - *Salix lasiolepis – Cornus sericea*/*Scirpus*[1] spp. – complex unit;
  - Shining willow (*Salix lucida*);
  - *Salix Exigua – (Salix lasiolepis – Rubus discolor – Rosa californica*);
  - Black willow (*Salix gooddingii*)-Valley oak (*Quercus lobata*) restoration;
  - Valley oak (*Quercus lobata*) restoration; and
  - White alder (*Alnus rhombifolia*) Arroyo willow (*Salix lasiolepis*) restoration.

Nesting/roosting habitat in the Suisun Marsh and Yolo Basin includes the following types from the BDCP composite vegetation layer:

- Eucalyptus;
- *Eucalyptus globules;*
- *Fraxinus latifolia;*
- Fremont cottonwood-Valley oak-Willow riparian forest;
- Landscape trees;
- Mixed Fremont cottonwood – Willow;
- Mixed willow super alliance;
- Oaks;

[1] Currently known as *Schoenoplectus*.

- *Quercus agrifolia;*
- *Salix lasiolepis/Quercus agrifolia;*
- Valley oak alliance – Riparian; and
- Willow trees.

Breeding habitat for white-tailed kite includes all valley riparian types that support an overstory component. The model does not distinguish habitat quality according to overstory composition, tree density, structure, or patch size. Natural vegetation types designated as species habitat in this model correspond to the mapped vegetation associations in the BDCP composite vegetation data layer. Breeding habitats may also function as winter roosting sites.

Assumptions. White-tailed kites nest in a variety of woodland habitat types (Dunk 1995, Erichsen 1995). Primary nesting habitat on the valley floor includes all riparian forest and some willow scrub habitats regardless of width or density. On the valley floor, kites also nest in isolated trees along irrigation canals, wind breaks and other tree rows, roadside trees, and in trees around rural residences (Erichsen 1995). Because these habitats are often below the minimum mapping unit, kite breeding habitat may be underrepresented here. Kites also roost in these habitats during winter. Large kite roosts have been reported in the Yolo Bypass on DFG's Yolo Bypass Wildlife Area (Feliz pers. comm.).

Foraging Habitat. Foraging habitat in the Delta includes the following types from the BDCP composite vegetation layer:

- Grasslands
  - Ruderal herbaceous grasses and forbs;
  - California annual grasslands;
  - *Bromus diandrus-Bromus hordeaceus;*
  - Italian rye-grass (*Lolium multiflorum*);
  - *Lolium multiflorum-Convolvulus arvensis;*
  - Degraded vernal pool complex – California annual grasslands;
  - Degraded vernal pool complex – Ruderal herbaceous grasses and forbs; and
  - Degraded vernal pool complex – Italian rye-grass (*Lolium multiflorum*).
- Managed wetlands
  - Temporarily flooded grasslands;
  - Rabbitsfoot grass (*Polypogon monspeliensis*);
  - Poison hemlock (*Coniumm maculatum*);

   - Intermittently flooded perennial forbs;
   - Managed annual wetland vegetation (non-specific grasses and forbs);
   - Shallow-flooding with minimal vegetation;
   - Seasonally flooded undifferentiated annual grasses and forbs;
   - Managed alkali wetland (*Crypsis*); and
   - Intermittently or temporarily flooded undifferentiated annual grasses and forbs.
- Alkali seasonal wetland complex and other natural seasonal wetlands
   - *Distichlis spicata* – Annual grasses;
   - Saltgrass (*Distichlis spicata*);
   - Seasonally-flooded grasslands;
   - Vernal pools;
   - Degraded vernal pool complex-vernal pools;
   - *Juncus balticus* – Meadow vegetation;
   - Temporarily flooded perennial forbs;
   - Alkaline vegetation mapping unit;
   - *Allenrolfea occidentalis* mapping unit;
   - *Suaeda moquinii* mapping unit; and
   - Salt scalds and associated sparse vegetation.
- Vernal pool complex
   - *Allenrolfea occidentalis* mapping unit;
   - Annual grasses generic;
   - Annual grasses/weeds;
   - California annual grasslands;
   - *Distichlis spicata;*
   - *Distichlis*/annual grasses;
   - *Distichlis spicata* – Annual grasses;
   - *Distichlis/S. maritimus;*
   - *Distichlis* (generic);
   - Italian rye-grass (*Lolium multiflorum*);
   - Ruderal herbaceous grasses and forbs;

- Salt scalds and associated sparse vegetation;
- Seasonally-flooded grasslands;
- *Suaeda moquinii* mapping unit; and
- Vernal pools.

Foraging habitat in the Suisun Marsh and Yolo Basin includes the following types from the BDCP composite vegetation layer:

- *Agrosits avenacea;*
- Annual grasses generic;
- Annual grasses/weeds;
- *Atriplex lentiformis* (generic);
- *Atriplex triangularis;*
- *Atriplex/*annual grasses;
- *Atriplex/Distichlis;*
- *Atriplex/S. maritimus;*
- *Atriplex/Sesuvium;*
- *Baccharis/*annual grasses;
- *Brassica nigra* (generic);
- *Bromus* spp.*(Hordeum);*
- *Crypsis schoenoides;*
- *Crypsis* spp. – Wetland grasses – Wetland forbs;
- Cultivated annual graminoid;
- *Distichlis* (generic);
- *Distichlis spicata;*
- *Distichlis-Juncus-Triglochin-Glaux;*
- *Distichlis/*annual grasses;
- *Distchilis cotula;*
- *Distichlis/Juncus;*
- *Distichlis/Lotus;*
- *Distichlis/S. americanus;*
- *Distichlis/S. maritimus;*

- *Distichlis/Salicornia*[2]*;*
- *Agrostis avenacea;*
- Annual grasses generic;
- Annual grasses/weeds;
- *Atriplex lentiformis* (generic);
- *Atriplex triangularis;*
- *Atriplex triangularis* (generic);
- *Atriplex/*annual grasses;
- *Atriplex/Distichlis;*
- *Atriplex/S. maritimus;*
- *Atriplex/Sesuvium;*
- *Baccharis/*annual grasses;
- Fallow disced field;
- Field crops;
- Flooded managed wetland;
- *Frankenia/Agrostis;*
- *Frankenia/Distichlis;*
- *Hordeum/Lolium;*
- Intermittently flooded to saturated deciduous shrubland;
- *Juncus balticus;*
- *Juncus balticus/Conium;*
- *Juncus balticus/Lepidium;*
- *Juncus balticus/Potentilla;*
- *Lepidium* (generic);
- *Lepidium/Distichlis;*
- *Leymus* (generic);
- *Lolium* (generic*);*
- *Lolium/Lepidium;*

[2] Currently known as *Sarcocornia*.

- *Lolium/Rumex;*
- *Lotus corniculatus;*
- Medium upland herbs;
- Medium upland shrubs;
- Medium wetland graminoids;
- Medium wetland herbs;
- Flooded managed wetland;
- Pasture;
- Perennial grass;
- *Phalaris aquatica;*
- *Polygonum-xanthium-echinochloa;*
- *Polypogon monspeliensis* (generic);
- Rice;
- *Rumex* (generic);
- *Salicornia* (generic);
- *Salicornia virginica*[3]*;*
- *Salicornia/*annual grasses;
- *Salicornia/Atriplex;*
- *Salicornia/Cotula;*
- *Salicornia/Crypsis;*
- *Salicornia/Polygonum-Xanthium-Echinochloa;*
- *Salicornia/Sesuvium;*
- *Sesuvium verrucosum;*
- *Sesuvium/Distichlis;*
- *Sesuvium/Lolium;*
- Short upland graminoids;
- Short wetland graminoids;
- Short wetland herbs

[3] Currrently known as *Sarcocornia pacifica*.

- Tall wetland graminoids;
- Tall wetland herbs;
- Truck/nursery/berry crops;
- Upland annual grassland and forbs formation;
- Upland herbs; and
- Wetland herbs.

Agriculture. The following DWR 2007 Land Use survey types are included as suitable agricultural foraging habitats for white-tailed kite. These types represent the typical agricultural cover types in the Plan Area that are included in the DWR 2007 land use survey. Rotational crop types that are not common to the Plan Area are not included here. Pasture types are mostly perennial; alfalfa is semi-perennial (3 to 7 years); and all other types are annually or seasonally rotated irrigated crops, only some of which provide suitable foraging habitat for white-tailed kites.

- Grain and hay crops
  - Barley;
  - Wheat;
  - Oats; and
  - Miscellaneous and mixed grain and hay.
- Rice
- Field crops
  - Safflower;
  - Sugar beets;
  - Corn;
  - Grain sorghum;
  - Sudan;
  - Beans;
  - Miscellaneous field; and
  - Sunflowers.
- Pasture
  - Alfalfa and alfalfa mixtures;
  - Clover;
  - Mixed pasture;

  - Native pasture;
  - Induced high water table native pasture; and
  - Miscellaneous grasses.
- Truck, nursery and berry crops
  - Asparagus;
  - Beans;
  - Onions and garlic;
  - Tomatoes; and
  - Peppers.
- Idle
  - Land not cropped the current or previous crop season, but cropped within the past three years; and
  - New lands being prepped for crop production.

Assumptions. Foraging habitat types noted above are considered available year-round; however, flooded seasonal wetlands receive less use during periods of inundation. During the breeding season, kites generally restrict their foraging territories to an approximately 1 square mile area around the nest (Warner and Rudd 1975). During the non-breeding season, kites are not confined to the limits of breeding territories and can be found throughout the Plan Area. Breeding and wintering season foraging habitat was not differentiated in this model.

A variety of foraging habitat types are used, but those that support larger and more accessible prey populations, particularly meadow voles, are more suitable (Stendell 1972). Grassland and seasonal wetland cover types generally provide more stable food resources over the long term; however, irrigated croplands and pasturelands are also widely used. Agricultural cover types that appear to be preferred include alfalfa and other hay crops, irrigated pastures, and some cultivated habitats, particularly sugar beets and tomatoes, both of which can support relatively large populations of voles and which have been highly correlated with kite nest site densities (Erichsen et al. 1994). Kites also forage in pastures, rice stubble fields, and occasionally in orchards (Erichsen 1995).

Winter foraging habitat is similar to breeding season foraging habitat – particularly the association with agricultural habitats and vole populations; however, there is less association with riparian forests and woodlands.

Kites generally forage in agricultural fields based on prey abundance and accessibility, which is highly variable among the crop types listed above. Some crop types provide higher value during the growing season than others due primarily to vegetation structure. However, because the Grain and Hay, Field, and Truck, nursery and berry crop types listed above are seasonally rotated, the value of individual fields changes each year. Therefore, these crop types are not differentiated based on their seasonal value and are instead combined into a category of seasonally rotated croplands. As a result, this model overestimates the extent of available agricultural foraging habitat in any given year.

Habitat Units. As described, the white tailed kite is closely associated with agricultural lands in the Plan Area. Most of the Plan Area consists of agricultural land and most is considered to have some value as foraging habitat for white-tailed kites. However, the value of crop types differ widely due to their growth and structure, which influences accessibility by foraging kites, and in prey abundance, which influences the availability of prey to foraging kites. Because of the dynamic nature of the agricultural landscape and the variability of crop patterns and conditions seasonally and annually, only a portion of the agricultural landscape is suitable or available for foraging in any given season or year. To account for this variability and to more accurately represent the value of Plan Area-wide foraging habitat, acres of white-tailed kite foraging habitat can be converted to habitat units.

Sufficient information is available on the growth and structure of different agricultural crops (Estep 2009) and the prey abundance and white-tailed kite use of different crop types to generally categorize crops based on their value as foraging habitat. By placing different crop types and other foraging habitats that traditionally occur in the Plan Area into crop value classes and assigning relative values to those classes (e.g., 0.1, 0.25, 0.5, 0.75, and 1.0), the habitat acres can be converted to habitat units. Habitat units, rather than acres, can then be used to describe and calculate impacts to white-tailed kite foraging habitat using this index of habitat value. Table A-29a provides the rationale for assigning crop types and other agricultural land uses to habitat value categories. Figure A-29c displays the distribution of foraging habitat and the assigned habitat values within the Plan Area.

Table A-29a. White-tailed Kite Agricultural Foraging Habitat Value Classes

Foraging Habitat Value Class	*Assigned Agricultural Crops/ Habitats*	*Rationale for Assignment of Agricultural Crop Class*	*Information Sources*[1]
1.0-Very High	Alfalfa	Alfalfa has the highest value because it is semi-perennial (up to 5 years before rotation), which increases prey abundance; has a relatively low profile such that prey are accessible season-long; and has a management regime (mowing and irrigation) which further increases prey accessibility.	Erichsen 1995, J. Estep, pers. comm., T. Beedy, pers. comm., Estep 1989, Estep 2009, Swolgaard et al. 2008.
.75-High	Native Pasture, Undifferentiated Pasture, Mixed Pasture, Clover, Miscellaneous Grasses (grown for seed)	These pasture types provide a relatively consistent vegetation structure and rodent prey populations. There is less seasonal variability with respect to prey abundance and accessibility compared with grain and vegetable crops, but they lack the management practices that enhance prey accessibility found in alfalfa.	Erichsen 1995, J. Estep, pers. comm., T. Beedy, pers. comm., Estep 1989, Estep 2009, Swolgaard et al. 2008.

Foraging Habitat Value Class	*Assigned Agricultural Crops/ Habitats*	*Rationale for Assignment of Agricultural Crop Class*	*Information Sources*[1]
.5-Medium	Sugar Beets, Tomatoes, Grain and Hay	Certain row crops, such as beets and tomatoes also have relatively high value because they support large rodent prey populations, are accessible season-long because of their relatively low vegetation profile, and they are harvested prior to migration, when an abundance of prey becomes available. Most grain crops (primarily wheat in Yolo County) provide value during and following harvesting, when prey become accessible.	Erichsen 1995, J. Estep, pers. comm., T. Beedy, pers. comm., Estep 1989, Estep 2009, Swolgaard et al. 2008.
.25-Low	Rice stubble, orchards	Kites occasionally use rice fields following harvest and during idle periods and have occasionally been observed to use orchards for foraging.	Erichsen 1995
.10-Marginal	Broccoli, safflower,corn, grain sorghum, sunflower, Sudan, Dry Beans, Undifferentiated Field Crops, Asparagus, Green Beans, Cole Crops, Carrots, Melons/Squash/Cucumbers, Onions/Garlic, Peppers, Cabbage, Undifferentiated Truck and Berry Crops, Artichokes, Lettuce (all types), Spinach, Mixed Truck and Berry	The truck and berry/field crop agriculture types are suitable for a portion of the breeding season depending on their structure and planting/harvesting regime. But in general, they produce less prey abundance and less prey availability than the other agriculture types listed above.	J. Estep, pers. comm., T. Beedy, pers. comm., Estep 1989, Estep 2009, Swolgaard et al. 2008.

[1]Literature cited or other information sources:

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A29.8 RECOVERY GOALS

A U.S. Fish and Wildlife Service (USFWS) recovery plan has not been prepared for this species and no recovery goals have been established.

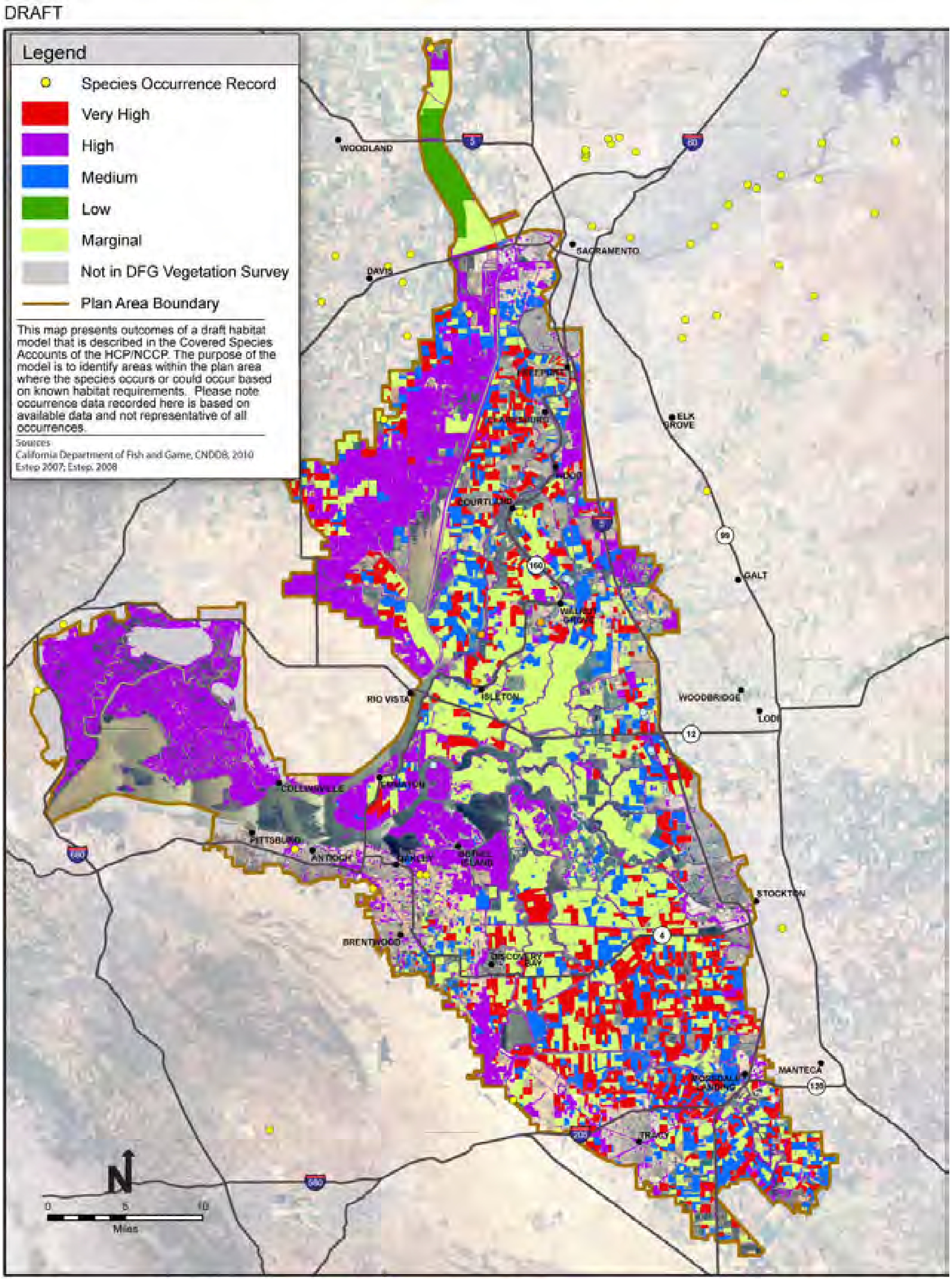

Figure A-29c. White-Tailed Kite Foraging Habitat Model and Associated Value Rankings

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APPENDIX A30. GIANT GARTER SNAKE (*THAMNOPHIS GIGAS*)

A30.1 LEGAL STATUS

The giant garter snake (*Thamnophis gigas*) is a state and federally threatened species. The State of California listed the giant garter snake as threatened on June 27, 1971 (DFG 2008). The U.S. Fish and Wildlife Service (USFWS) listed the species as federally threatened on October 20, 1993 (58 FR 54053). The Draft Recovery Plan for the Giant Garter Snake (*Thamnopsis gigas*) was completed in 1999 (USFWS 1999). Critical habitat has not been designated for this species.

A30.2 SPECIES DISTRIBUTION AND STATUS

A30.2.1 Range and Status

The giant garter snake is endemic to wetlands in the Sacramento and San Joaquin valleys and was historically distributed throughout the San Joaquin Valley (Hansen and Brode 1980). The current distribution extends from near Chico in Butte County south to the Mendota Wildlife Area in Fresno County (Figure A-30a). No occurrences of giant garter snakes are known from the northern portion of the San Joaquin Valley north to the eastern fringe of the Sacramento-San Joaquin River Delta, where the floodplain of the San Joaquin River is limited to a relatively narrow trough (Hansen and Brode 1980, 58 FR 54053). The resulting gap of approximately 100 kilometers (62.3 miles) separates the southern and northern populations, with no giant garter snakes known from the lowland regions of Stanislaus County (Hansen and Brode 1980, CNDDB 2009).

Occurrence records indicate that garter snakes are currently distributed in 13 unique population clusters coinciding with historical flood basins, marshes, wetlands, and tributary streams of the Central Valley (Hansen and Brode 1980, Brode and Hansen 1992, USFWS 1999). These populations are isolated, without protected dispersal corridors to other adjacent populations, and are threatened by land use practices and other human activities, including development of wetland and suitable agricultural habitats. The USFWS recognizes these 13 extant populations (58 FR 54053), including Butte Basin, Colusa Basin, Sutter Basin, American Basin, Yolo Basin-Willow Slough, Yolo Basin-Liberty Farms, Sacramento Basin, Badger Creek-Willow Creek, Coldani Marsh, East Stockton Diverting Canal and Duck Creek, North and South Grassland, Mendota, and Burrel-Lanare. These populations extend from Fresno north to Chico and encompass 11 counties: Butte, Colusa, Glenn, Fresno, Merced, Sacramento, San Joaquin, Solano, Stanislaus, Sutter, and Yolo.

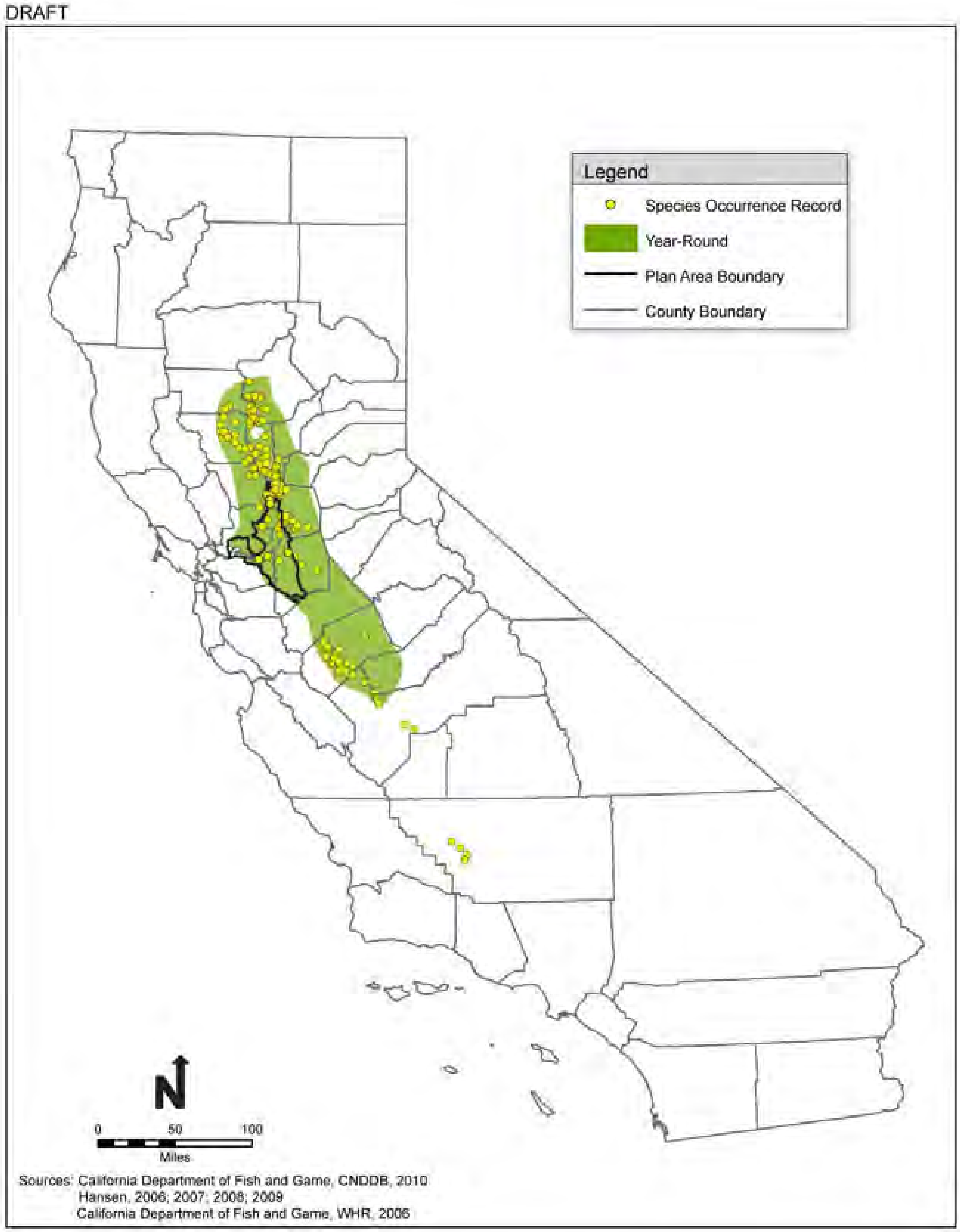

Figure A-30a. Giant Garter Snake Statewide Range and Recorded Occurrences

A30.3 DISTRIBUTION AND STATUS IN THE PLAN AREA

The Bay Delta Conservation Plan [BDCP] Plan Area is within the Mid-Valley Recovery Unit identified in the Draft Recovery Plan, and three of the thirteen giant garter snake populations identified by the USFWS occur within the Plan Area, including Yolo Basin – Willow Slough, Yolo Basin – Liberty Farms, and Coldani Marsh – White Slough populations (USFWS 1999).

Recent survey efforts suggest that extant giant garter snake populations continue to persist mainly in the periphery of the Plan Area in two locations north of the San Joaquin River, including the Yolo Bypass from the Yolo Basin Wildlife Area north to Willow Slough area and Coldani Marsh-White Slough area in the eastern Delta. The few isolated records occurring within most of the Sacramento-San Joaquin River Delta suggest the lack of other extant populations; and that while giant garter snakes may have occupied this region at one time, longstanding reclamation of wetlands for intense agricultural applications has eliminated most suitable habitat (Hansen 1986) and prohibited the reestablishment of viable giant garter snake breeding populations.

CNDDB (2009) reports 15 giant garter snake occurrences sparsely distributed north of State Route 4 (SR-4) in the central and northern Delta portions of the Plan Area (Figure A-30b). Four are west of the Sacramento Deep Water Ship Channel in the wetlands and pasturelands of the Yolo Basin; five are from the cultivated and remnant grassland areas east of the Sacramento River north of Walnut Grove; three are from the vicinity of White Slough south of SR-12 and west of Interstate 5 (I-5); and four are in the central Delta, including two reported from the vicinity of Sherman Island. With the exception of recent detections made from the Yolo Basin, most of these CNDDB records are from the mid-1980s (CNDDB 2009). There are no records from the area west of the Sacramento and Mokelumne Rivers and east of the Deep Water Ship Channel north of SR-12. There are only two records south of the San Joaquin River and none south of SR-4. Recent findings demonstrate that giant garter snake appears extant in portions of the Yolo Basin (Wylie et al. 2003, 2004, Wylie and Amarello 2006, Hansen 2007, E. Hansen pers. comm., CNDDB 2009), and at Coldani Marsh/White Slough (E. Hansen pers. comm.) (Figure A-30b).

Historically, giant garter snakes occurred in both the south and north Delta regions (Hansen and Brode 1980, Hansen 1988, CNDDB 2009). Individuals have been observed in the north Delta region east of the Sacramento River at North Stone Lake, Beach Lake, and near Locke (CNDDB 2009). The species also was recorded on Sherman Island near the Antioch Bridge north of the City of Oakley (Hansen personal observation). Other documented occurrences are distributed around the periphery of the north and east Delta. The extent to which these historically occupied areas represent viable breeding populations is unclear, given agricultural conversion of much of the Delta. Nonetheless, survey efforts since the mid-1980s suggest that much of the Delta is unoccupied or supports few giant garter snakes (see below).

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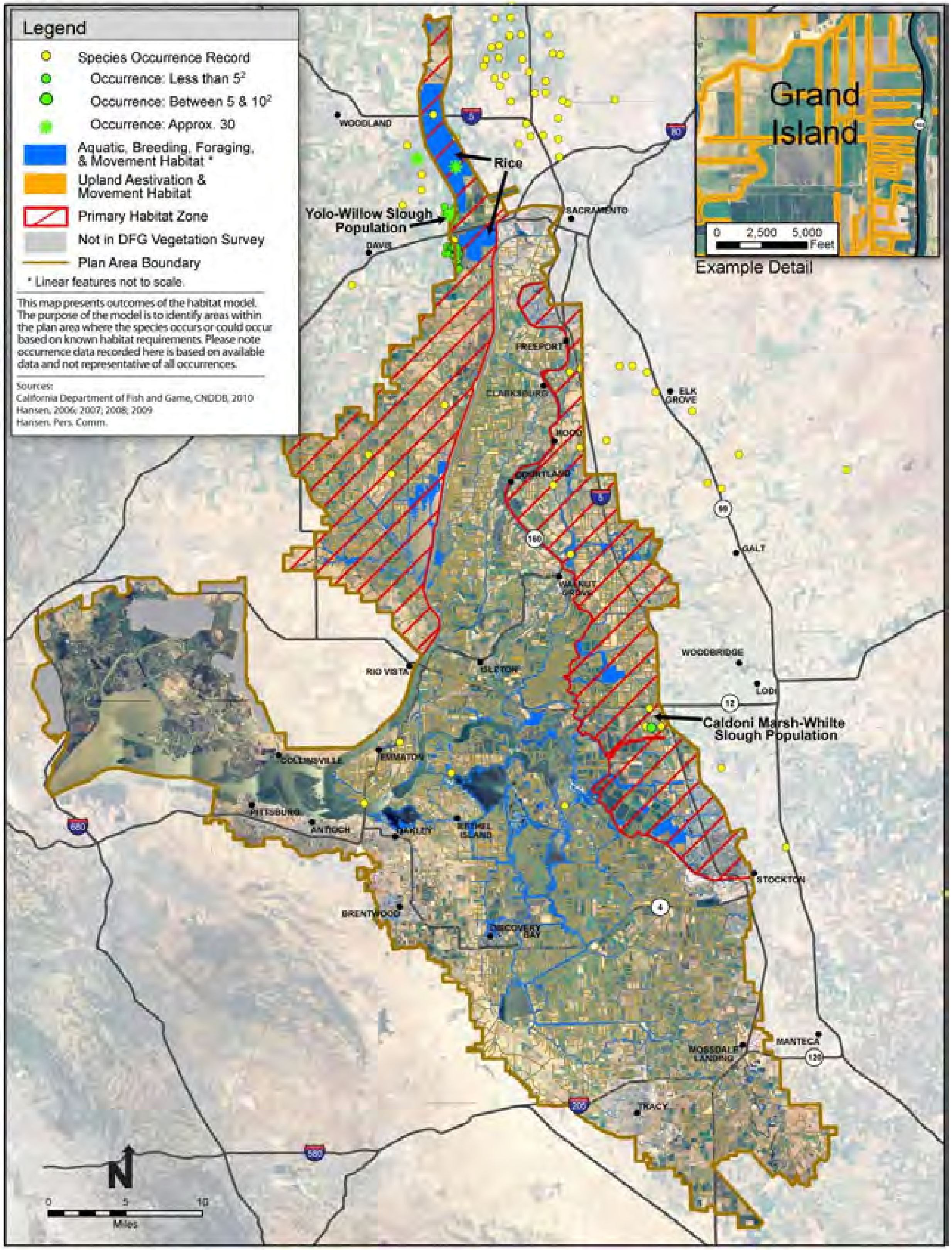

Figure A-30b. Giant Garter Snake Habitat Model and Recorded Occurrences

Still, Hansen (1988) reported that although the major permanent waterways of the Delta are apparently unsuitable for giant garter snake, small backwater sloughs and toe drains support suitable habitat for, and thus could potentially support, small numbers of giant garter snake.

The following describes the historical and current survey work and occurrence information within the Plan Area.

A30.3.1 South Delta

During 1987 and 1988, live trapping and visual surveys were conducted at various locations within the California Department of Water Resource's South Delta Water Management Project area including Trapper Slough, Salmon Slough, and along the irrigation canal at Highway 4 near the Clifton Court Forebay expansion area. No giant garter snakes were observed during either year, although virtually all islands and channels contained some suitable habitat (ECOS 1990).

In 1994, surveys were conducted to determine the status of giant garter snake within DWR's Interim South Delta Project (ISDP) area. The purpose of this study was to focus on particular areas of the ISDP containing the most suitable habitat and to conduct live-trapping as well as additional ground surveys. Ground surveys for giant garter snakes were undertaken during previous work in the south Delta region in 1987, 1988, and 1993. Although no giant garter snakes were observed during any of these surveys, suitable habitat for the snake was present in some of the more remote sloughs and waterways in the ISDP area (e.g., Tom Paine Slough, Salmon Slough, and Paradise Cut). Based on the presence of apparently suitable habitat, the potential for isolated populations of giant garter snake was not ruled out (Miriam Green Associates 1995).

There are only two isolated records of giant garter snake on the south side of the San Joaquin River in the northern aspect of the species' range. Although the historical and current distribution of giant garter snake in the Delta is poorly understood, the south bank of the San Joaquin River lies within the apparent gap between the northern and southern populations (CNDDB 2009). The isolated record on Sherman Island represents the northern population's known southern terminus. The nearest locality record to the south lies more than 50 air miles distant in Madera County; no giant garter snakes are documented in Stanislaus County between the documented extremes of the Sacramento Valley and San Joaquin Valley populations.

A30.3.2 North Delta

Surveys were also conducted to determine the status of giant garter snakes within DWR's Interim North Delta Program (INDP) area (Miriam Green Associates 1996). The species was observed at scattered locations within the INDP area during 1994 surveys, but were not encountered within the major waterways of the North Delta. The species was observed in marsh and canal habitats along the Upland Canal from the confluence of Sycamore Slough and the Upland Canal south to the vicinity of White Slough on the Terminous and Shin Kee tracts. Giant garter snakes also occur in the Upland Canal and the Coldani Marsh, north and east of Shin Kee Tract, respectively (Miriam Green Associates 1996).

A30.3.3 White Slough/Coldani Marsh and Eastern Delta Fringe

Between 1974 and 1978, 13 rectangular borrow pits were excavated from one to five miles west of I-5 to provide fill for freeway construction (DWR 1995). The pits are fed by groundwater and periodic runoff from precipitation, irrigation, and high canal flows, creating a series of ponds characterized by vegetated sloping or vertical banks and open water with adjacent uplands and high ground. White Slough Wildlife Area encompasses ponds 7-13 along a roughly 14-mile (22.5-kilometer) stretch between Thornton and Stockton.

The White Slough Wildlife Area supports one of 13 extant giant garter snake populations recognized by the USFWS (Coldani Marsh/White Slough population) (USFWS 1999). First identified on site in 1974 (CNDDB 2009), giant garter snakes were observed at the White Slough Wildlife Area by George Hansen from the time he began formally surveying for them in 1976 until the mid-1990's (Hansen and Brode 1980, Hansen 1988, 1996). Among two giant garter snake populations recognized in San Joaquin County, the White Slough population is perhaps the only locality still supporting a viable snake population.

Most giant garter snake observations at White Slough Wildlife Area are concentrated at Pond 9, but surveys conducted by George Hansen in 1994 yielded additional sightings at Pond 7, Pond 11, and a site between Ponds 6 and 7 (DWR 1995, CNDDB 2009). Although channels and drainages including Telephone Cut, Sycamore Slough, Hog Slough, and Beaver Slough were surveyed, observations were made only at the ponds (M. Green pers. comm.). Each of the ponds where snakes were observed are characterized by slow moving water with mud banks and bottoms, vegetation cover, and access to high ground (DWR 1995).

In 2009, under a grant provided by the Central Valley Project (CVP) Habitat Restoration Program, Eric Hansen began rigorous trap and visual encounter sampling at Ponds 7-13 of the White Slough Wildlife Area to determine the current status and distribution of giant garter snake. Though the project is not yet complete, giant garter snakes have only been confirmed within the emergent wetlands west of Pond 9 along the Upland Canal, east of Guard Road and south of Highway 12 (E. Hansen pers. comm.). Ten snakes have been captured to date (6 males and 4 females); all are sexually mature adults.

Surveys conducted within and in the vicinity of Lost Slough in 1996 and 2004 failed to detect giant garter snakes east of I-5 (Hansen 2004a, G. Wylie pers. comm.).

A30.3.4 Antioch/Oakley and West Delta

Recent, intensive trapping surveys conducted within Contra Costa County independently by Eric Hansen and by Swaim Biological, Inc. (SBI) have failed to detect giant garter snake. Likewise, SBI intensively trapped in regions northeast of Oakley in 2003 and 2005, including Marsh Creek, Big Break, and Contra Costa Canal, without success (Swaim 2004, Swaim 2005a-f, Swaim 2006). With few exceptions, these surveys spanned three to five months of the species' active period. SBI also rigorously investigated bullfrog stomach contents to see if undetected giant garter snakes had been consumed; none were detected. While all of these surveys produced captures of common snake species, giant garter snakes were not detected, and, in all cases, it was determined that self-sustaining populations were unlikely to occur. Each report cited marginal habitat quality as probable explanations for the species' absence. While the final disposition of SBI's results and recommendations are unknown, the Service concurred with Eric Hansen's findings that the species was unlikely to occur within the areas sampled.

A30.3.5 Central Delta

In support of DWR's Delta Wetlands Project, Eric Hansen intensively trapped for giant garter snakes on Webb Tract and on Bacon Island in 2003 and 2004 without success (Patterson and Hansen 2004, Patterson 2005). Ongoing 2009 surveys in the central Delta conducted by DWR have resulted in no giant garter snake occurrences (L. Patterson pers. comm.).

A30.3.6 Yolo County/Yolo Bypass

Giant garter snakes are documented in two distinct concentrations along the eastern edge of Yolo County (Hansen 2006, 2007, 2008, Wylie and Amarello 2006, CNDDB 2009). The first concentration lies north of the Yolo Basin in the northeastern portion of Yolo County, northwest of Knights Landing and in the southern end of the Colusa Basin near Sycamore Slough and the Colusa Basin Drainage Canal. Wylie and Amarello (2006) report a population density in the Colusa Basin Drainage Canal of 20±3 snakes per kilometer (0.6 mile) during 2006, falling within 2003 and 2004 confidence intervals; noting, however, that local distribution appears to have shifted away from areas formerly in rice production that have either been fallowed or converted to other crop types.

The second concentration lies in the east-central portion of Yolo County and corresponds with the USFWS' Yolo Basin – Willow Slough population (USFWS 1999). Recent records are from the Yolo Bypass east of Conaway Ranch near the Tule Canal; the Willow Slough/Willow Slough Bypass from Conaway Ranch south to the Yolo Wildlife Area; the Davis Wetlands complex south of Conaway Ranch between the Willow Slough Bypass and the Yolo Bypass; the Yolo Wildlife Area along the east edge of the Yolo Bypass west levee; and the adjacent ricelands west of the Yolo Wildlife Area (Hansen 2006, 2007, 2008) (Figure A-30b).

Surveys conducted in 2005, 2006, and 2007 resulted in captures of 34, 9, and 1 unique individual(s), respectively, in the Yolo Wildlife Area; 8, 18, and 8 unique individuals, respectively, in the adjacent ricelands; and 36 unique individuals (2007 only) in the Davis Wetlands complex (Hansen 2006, 2007, 2008). Hansen (2006, 2007, 2008) reports an even distribution within size classes, estimating local populations ranging from approximately 8 to 57 in the Yolo Bypass at the Yolo Wildlife Area; approximately 5 to 17 in the adjacent ricelands; and from approximately 26 to 67 within the Davis Wetlands Complex (Hansen 2006, 2007, 2008), which lies along the western Yolo Bypass levee north of I-80.

In 2009, Eric Hansen trapped in all portions of Conaway Ranch, north of I-80 in the Yolo Bypass, capturing 64 giant garter snakes in a period of roughly twelve weeks (E. Hansen pers. comm.). Of the 64 individuals, 29 were captured within ricelands in the interior of the Yolo Bypass and 35 were captured in the land side ricelands beyond the Yolo Bypass west levee.

USGS conducted surveys for giant garter snake in 2004 and 2005 in the southern portion of the Yolo Basin in the vicinity of Cache Slough between Liberty Island and Lower Ulatis Creek in Solano County (Wylie and Martin 2005). Surveys were conducted in areas that supported habitat similar to known occupied sites and in areas where several historical occurrences were apparently reported. No giant garter snakes were found during these surveys (Wylie and Martin 2005).

While suitable habitat continues to persist along natural streams and artificial channels throughout much of the Delta, historical and recent occurrence records based on substantial survey effort suggests two primary geographic areas that retain extant populations and probably a greater likelihood of potential occurrence and reestablishment of populations. These include the Yolo Bypass and vicinity west of the Deep Water Ship Channel and the eastern Delta fringe from approximately the Stone Lakes area south to Stockton and generally east of the Mokelumne River. These areas are referred to on Figure A-30b as the Primary Habitat Zone.

A30.4 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

The giant garter snake resides in marshes, ponds, sloughs, small lakes, low gradient streams, and other waterways, and in agricultural wetlands, including irrigation and drainage canals, rice fields, and the adjacent uplands (58 FR 54053). Habitat requirements include: (1) adequate water during the snake's active season (early-spring through mid-fall) to provide food and cover; (2) emergent, herbaceous wetland vegetation, such as cattails (*Typha* spp.) and bulrushes (*Schoenoplectus*[1]), accompanied by vegetated banks for escape cover and foraging habitat during the active season; (3) basking habitat of grassy banks and openings in waterside vegetation; and (4) higher elevation uplands for cover and refuge from flood waters during the snake's dormant season in the winter (Hansen and Brode 1980, Hansen 1998, USFWS 2006a). In some rice-growing areas, giant garter snakes have adapted well to vegetated, artificial waterways and associated rice fields (Hansen and Brode 1993). The giant garter snake resides in small mammal burrows and soil crevices located above prevailing flood elevations throughout its winter dormancy period (USFWS 2006a). Burrows are typically located in sunny exposures along south and west facing slopes.

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[1] Formerly known as *Scirpus*.

Due to lack of habitat and emergent vegetation cover, giant garter snakes generally are not present in larger rivers and wetlands with sand, gravel, or rock substrates. In addition, the major rivers have been highly channelized, removing oxbows and backwater areas that probably at one time provided suitable habitat. Riparian woodlands can provide suitable habitat, but it is not likely because most have excessive shade, lack of basking sites, and absence of prey populations. Giant garter snake is also usually absent from most permanent waters that support established populations of predatory game fishes and from sites that undergo routine dredging, mechanical or chemical weed control, or compaction of bank soils (Hansen and Brode 1980, Rossman and Stewart 1987, Brode 1988, USFWS 1999, 2006a).

Changing agricultural regimes, development, and other shifts in land use create an ever-changing mosaic of available habitat. Giant garter snakes move around in response to these changes in order to find suitable sources of food, cover, and prey. Connectivity between regions is therefore extremely important for providing access to available habitat and for genetic interchange. In an agricultural setting, giant garter snakes rely largely upon the interconnected network of canals and ditches that provide irrigation and drainage to provide this connectivity.

In the Central Valley, rice fields have become important habitat for giant garter snakes. Irrigation water typically enters the ricelands during April along canals and ditches. Giant garter snakes use these canals and their banks as permanent habitat for both spring and summer active behavior and winter hibernation. Where these canals are not regularly maintained, lush aquatic, emergent, and streamside vegetation develops prior to the spring emergence of giant garter snakes. This vegetation, in combination with cracks and holes in the soil, provides much needed shelter and cover during spring emergence and throughout the remainder of the summer active period.

Rice is planted during spring, after the winter fallow fields have been cultivated and flooded with several inches of standing water. In some cases, giant garter snakes move from the canals and ditches into these rice fields soon after the rice plants emerge above the water’s surface, and they continue to use the fields until the water is drained during late summer or fall (Hansen and Brode 1993). It appears that the majority of giant garter snakes move back into the canals and ditches as the rice fields are drained; although a few may overwinter in the fallow fields, where they hibernate within burrows in the small berms separating the rice checks (low dikes) (Hansen 1998).

While within the rice fields, the snakes forage in the shallow warm water for small fish and the tadpoles of bullfrogs and treefrogs. For shelter and basking sites, giant garter snakes utilize the rice plants, vegetated berms dividing the rice checks, and vegetated field margins. Gravid (pregnant) females may be observed within the rice fields during summer, and at least some giant garter snakes are born there (Hansen and Brode 1993, Hansen 1998).

Water is drained from the fields during late summer or fall by a network of drainage ditches. These ditches are sometimes routed alongside irrigation canals and are often separated from the irrigation canals by narrow vegetated berms that may provide additional shelter. Remnants of old sloughs also may remain within rice-growing regions, where they serve as drains or irrigation canals. Giant garter snakes may use vegetated portions along any of these waterways as permanent habitat. Studies indicate that despite the presence of ditches or drains, giant garter snakes will generally abandon aquatic habitat that is not accompanied by adjacent shallow-water wetlands (Wylie and Amarello 2006, Hansen 2007, Jones and Stokes 2008), underscoring the important role that this crop plays in this species' life history.

A30.5 LIFE HISTORY

Description. Giant garter snakes are one of the largest snakes in the genus *Thamnophis*. A sexually dimorphic species, females can reach sizes in excess of 5.3 feet and 1.87 pounds (lbs) (1.6 meters and 0.8 kilograms [kg]), while proportionally smaller males seldom exceed 0.55 lb (0.25 kg). Giant garter snakes possess a dark brown or olive background color separated by light-colored longitudinal stripes. For this species, coloration is geographically and individually variable. Snakes from the San Joaquin Valley region may exhibit a black-checkered pattern along the back and sides, and often lack a distinct dorsal stripe; while snakes from the Sacramento Valley region are typically darker, with a complete dorsal stripe that varies from bright yellow to orange or dull brown.

Activity. Spending cool winter months in dormancy or periods of reduced activity, giant garter snakes typically emerge from late March to early April and remain active through October; the timing of annual activity is subject to varying seasonal weather conditions. Daily activity consists of emerging from burrows after sunrise, basking to warm bodies to active temperatures, and foraging or courting for the remainder of the day (Hansen and Brode 1993). Activity generally peaks during spring emergence and courtship occurs from April into June, whereupon observations of giant garter snakes diminish significantly until a second peak is observed after females give birth during late July into August (Hansen and Brode 1993, Wylie et al. 1997, USFWS 1999, Hansen 2004b). Giant garter snakes then remain actively foraging and occasionally courting until the onset of cooler fall temperatures.

Giant garter snakes are strongly associated with aquatic habitats, typically overwintering in burrows and crevices near active season foraging habitat (Hansen 2004b). Individuals have been noted using burrows as far as 164 feet (50 meters) from marsh edges during the active season, and retreating as far as 820 feet (250 meters) from the edge of wetland habitats while overwintering, presumably to reach hibernacula above the annual high watermark (Hansen 1986, Wylie et al. 1997, USFWS 1999).

Reproduction. Upon emerging from overwintering sites, male giant garter snakes immediately disperse in search of mates and continue breeding from March into early May. Female giant garter snakes brood young internally, giving birth to live young from late July through early September (Hansen and Hansen 1990). Brood size ranges from 10 to 46 young, with a mean of

23.1 (n = 19) (Hansen and Hansen 1990). Young immediately disperse and seek shelter to absorb their yolk sacs, after which they molt and begin feeding on their own. Averaging 0.11 to 0.18 ounces (3 to 5 grams) with a snout-to-vent length of approximately 8.1 inches (20.6 centimeters [cm]), young giant garter snakes will double their size within their first year (Hansen and Hansen 1990, USFWS 1999). Sexual maturity probably averages 3 years in males and 5 years in females (USFWS 1999).

Home Range. Data based on radiotelemetry studies show that home range varies by location, with median home range estimates varying between 23 acres (range [10.3 to 203 acres], n = 8) (9 hectares, range = 4.2 to 82 hectares) in a semi-native perennial marsh system and 131 acres (range [3.2 to 2,792 acres], n = 29) (53 hectares, range = 1.3 to 1130 hectares) in a managed refuge (USFWS 1999).

Foraging Behavior and Diet. Giant garter snakes feed on small fishes, tadpoles, and small frogs (USFWS 1999), specializing in ambushing prey underwater (Brode 1988). Historically, giant garter snakes preyed on native species such as the thick-tailed chub (*Gila crassicauda*) and California red-legged frog (*Rana aurora draytonii*) (which have been extirpated from the giant garter snake's current range), as well as the pacific treefrog (*Pseudacris regilla*) and Sacramento blackfish (*Orthodox microlepidus*) (Cunningham 1959, Rossman et al. 1996, USFWS 1999). Giant garter snakes now utilize introduced species, such as small bullfrogs (*Rana catesbeiana*) and their larvae, carp (*Cyprinus carpio),* and mosquitofish (*Gambusia affinis*). While juveniles probably consume insects and other small invertebrates, giant garter snakes are not known to consume larger terrestrial prey such as small mammals or birds.

A30.6 Threats and Stressors

Habitat loss and fragmentation, flood control activities, changes in agricultural and land management practices, predation from introduced species, parasites, and water pollution are the main causes for the decline of this species.

Habitat Loss and Fragmentation. Continued loss of wetland or other suitable habitat resulting from agricultural and urban development constitutes the greatest threat to this species' survival. Conversion of Central Valley wetlands for agriculture and urban uses has resulted in the loss of as much as 95 percent of historical habitat for the giant garter snake (Wylie et al. 1997). In areas where the giant garter snake has adapted to agriculture, maintenance activities such as vegetation and rodent control, bankside grading or dredging, and discharge of contaminates, threaten their survival (Hansen and Brode 1980, Hansen and Brode 1993, USFWS 1999, Wylie et al. 2004). In developed areas, threats of vehicular mortality also are increased. Paved roads likely have a higher rate of mortalities than dirt or gravel roads due to increased traffic and traveling speeds, and as many as 31 giant garter snake traffic mortalities have been reported during a 4-year period in the Natomas Basin (Hansen and Brode 1993).

The loss of wetland habitat is compounded by elimination or compaction of adjacent upland and associated bankside vegetation cover, as well as water fouling; these conditions are often associated with cattle grazing (Thelander 1994). While irrigated pastures may provide the summer water that giant garter snakes require, high stocking rates may degrade habitat by removing protective plant cover and underground and aquatic retreats such as rodent and crayfish burrows (Hansen 1986, USFWS 1999). Studies of wandering garter snakes (*Thamnophis elegans vagrans*) in northern California have shown population numbers to be much higher in areas where grazing was excluded (Szaro et al. 1985). Radiotelemetry studies in perennial wetlands where grazing was differentially excluded show that giant garter snakes avoid areas where grazing is frequent (Hansen 2002). However, cattle grazing may provide an important function in controlling invasive vegetation that can compromise the overall value of wetland habitat (Hansen 2002).

Predation. Giant garter snakes are also threatened by the introduction of exotic species. Examinations of gut contents confirm that introduced bullfrogs (*Rana catesbeiana*) prey on juvenile giant garter snakes throughout their range (Treanor 1983, Dickert 2003, Wylie et al. 2003). While the extent of this predation and its effect on population recruitment is poorly understood, estimates based on preliminary data from a study conducted at Colusa National Wildlife Refuge suggests that 22 percent of neonate (newborn) giant garter snakes succumb to bullfrog predation (Wylie et al. 2003). Other studies of bullfrog predation on snakes have documented bullfrogs ingesting other species of garter snakes up to 31.5 inches (80 cm) long, resulting in a depletion of this age-class within the population (Bury and Wheelan 1984).

Large vertebrates, including raccoons (*Procyon lotor*), striped skunks (*Mephitis mephitis*), red foxes (*Vulpes vulpes*), gray foxes (*Urocyon cinereoargentius*), river otters (*Lutra canadensis*), opossums (*Didelphis virginiana*), northern harriers (*Circus cyaneus*), hawks (*Buteo* spp.), herons (*Ardea herodius, Nycticorax nyctycorax*), egrets (*Ardea alba*, *Egretta thula*), and American bitterns (*Botaurus lentiginosus*) also prey on giant garter snakes (USFWS 1999). In areas near urban development, giant garter snakes may also fall prey to domestic or feral house cats. In permanent waterways, introduced predatory game fishes, such as bass (*Micropterus* spp.), sunfish (*Lepomis* spp.), and channel catfish (*Ictalurus* spp.), prey on giant garter snakes and compete with them for smaller prey (58 FR 54053, Hansen 1998).

Water Pollution. Selenium contamination and impaired water quality have been identified as a threat to giant garter snakes, particularly in the southern portion of their range (USFWS 1999). While little data are available regarding the effects of specific contaminants, the bioaccumulative properties of selenium in the food web has been well documented in the Kesterson National Wildlife Refuge area (Ohlendorf et al. 1988, Saiki and May 1988, Saiki et al. 1991, USFWS 1999).

A30.7 RELEVANT CONSERVATION EFFORTS

Conservation efforts for the giant garter snake have included restoration efforts on wildlife refuges and through mitigation banking. With the continued loss of habitat within the range of the species, the snake has become increasingly dependent on ten refuges and wildlife management areas in the Central Valley (Czech 2006).

Hundreds of acres in the California refuge system are known to be occupied by the snake, however thousands of acres of apparently suitable habitat in the refuge system are currently unoccupied (Czech 2006). This suggests that factors such as winter flooding and predation (especially by nonnative species such as bullfrogs) may be limiting in some areas. The giant garter snake prefers summer flooding and winter drying, and Central Valley refuges system properties are likely managed intensively for wintering waterfowl with a reversed water regime, resulting in habitat features that are problematic for giant garter snake conservation. These opposing requirements suggest that separate conservation areas for the snake are necessary. In 1995, the Colusa National Wildlife Refuge acquired 449 acres (182 ha) of fallow rice fields, and efforts to restore the ecological integrity of the land have proven beneficial to the snake (Czech 2006).

Some mitigation banks are also designed specifically for giant garter snake habitat preservation and restoration, including the 565-acre (229-hectare) Gilsizer Slough South Giant Garter Snake Conservation Bank in Sutter County, and the 424-acre (172-hectare) Sutter Basin Conservation Bank. Giant garter snake mitigation banks in the Plan Area include the 379-acre (153-hectare) Pope Ranch in Yolo County and the 129-acre (52-hectare) South Stone Lakes Giant Garter Snake Preserve in Sacramento County.

Other wetland conservation efforts, under appropriate management regimes, can also benefit giant garter snakes. Central Valley wetland conservation occurs through a combination of both public and privately managed refuges, mitigation banks, and duck clubs, creating a large network of wetland preserves throughout the historical range of the giant garter snake. A large percentage of these wetland conservation efforts, however, are geared toward waterfowl management, often placing greater emphasis on winter water rather than the summer water upon which giant garter snakes depend (USFWS 1999). With proper consideration given to design, location, and management, these efforts might also significantly benefit the giant garter snake and other wetland-dependent species (USFWS 1999).

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designates the giant garter snake as "Contribute to Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its control and within its scope that are necessary to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts. The ERP has funded several projects designed to supplement current knowledge of giant garter snake populations and habitat use. Two projects were recently funded that contain actions to benefit giant garter snake through ongoing monitoring of semi-permanent wetlands, rice-cover crop rotation fields, and waterways adjacent to agricultural lands. Another project will evaluate the effects of fallowing agricultural habitat on giant garter snake by monitoring habitat use under normal rice growing conditions and comparing results with analogous data from those same fields and adjacent irrigation ditches after fallowing. This project will also monitor habitat use on wetland restoration sites and assess population demographics and viability of the giant garter snake. Study areas for all three projects include Barker Slough and Hastings Cut in Yolo County, Gilsizer Slough in Sutter County, areas within Richvale Water District in Butte County, and various other rice fields and managed wetlands in Butte County. These coordinated ERP projects began work in 2007 and are in the initial stages of data collection. They are designed to provide information that will help guide future restoration and conservation activities as they pertain to managing rice farms and surrounding natural habitats for the giant garter snake. Continuing project activities include ongoing telemetry of radio-marked snakes to evaluate habitat use and behavior, and trapping of snakes to develop mark/recapture estimates. Results from these projects will support filling in some of the research data gaps for the giant garter snake including determination of optimal habitat, effects of cropping patterns and specific agricultural practices on movement patterns and viability, value of restored habitats, and species status and distribution. Additionally, results from these research projects will directly facilitate future revisions of the conservation measures within this strategy.

In addition, the ERP implementing agencies have facilitated the development and preparation of the draft Sacramento Valley Giant Garter Snake Conservation Strategy. Giant garter snake is also a covered species under the Natomas Basin Habitat Conservation Plan, the San Joaquin County Multi-Species Habitat Conservation and Open Space Plan, and the East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan; and it is proposed for coverage in the Solano County Multispecies Habitat Conservation Plan, the South Sacramento County Habitat Conservation Plan, the Yolo Natural Heritage Program Plan currently under development, and the Butte Regional Conservation Plan.

A30.8 Species Habitat Suitability Model

Model Approach. BDCP Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information systems (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, and cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf 2007. Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers, connectivity between habitat types, and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The giant garter snake model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), USDA 2005 aerial photography, DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3, major hydrology 1:24,000 (USBR 2003), and the USGS-National Hydrography Dataset, 1:24,000 (USGS 1999). Using these data sets, the model maps the distribution of suitable giant garter snake habitat in the Plan Area. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

A30.8.1 Aquatic Breeding, Foraging, and Movement Habitat

Breeding, foraging, and movement habitat for the giant garter snake includes the following land cover types throughout the Plan Area and Yolo Bypass north to Fremont Weir.

- All natural perennial streams and canals with the exception of Sacramento and San Joaquin rivers. The National Hydrography Dataset hydrology dataset was used to characterize smaller hydro features such as canals, ditches, and perennial streams. The United States Bureau of Reclamation (USBR) major hydrology dataset was used to characterize the shorelines of larger hydro features such as Liberty Island.
- The following types in the Delta from the BDCP composite vegetation layer:
    - Tidal freshwater emergent wetland
        - Mixed *Scirpus*[2] mapping unit;
        - Mixed *Scirpus*/floating aquatics complex;
        - Mixed *Scirpus*/submerged aquatics complex;
        - Hard-stem bulrush (*Scirpus acutus*);
        - *Scirpus acutus* pure;
        - *Scirpus acutus – Typha angustifolia;*
        - *Scirpus acutus – Typha latifolia;*
        - *Scirpus acutus – (Typha latifolia) – Phragmites australis;*
        - California bulrush (*Scirpus californicus*);
        - *Scirpus californicus – Eichhornia crassipes;*
        - *Scirpus californicus – Scirpus acutus;*
        - American bulrush (*Scirpus americanus*);
        - Narrow-leaf cattail (*Typha angustifolia*); and
        - *Typha angustifolia – Distichlis spicata.*
    - Nontidal freshwater perennial emergent
        - Broad-leaf cattail (*Typha latifolia*);
        - American bulrush (*Scirpus americanus*);
        - Hard-stem bulrush (*Scirpus acutus*);
        - Mixed *Scirpus*/floating aquatics (*Hydrocotyle – Eichhornia*) complex;

[2] Currently known as *Schoenoplectus*.

        - Mixed *Scirpus* mapping unit;
        - Narrow-leaf cattail (*Typha angustifolia*);
        - Perennial pepperweed (*Lepidium latifolium*);
        - *Scirpus acutus* – (*Typha latifolia*) – *Phragmites australis*;
        - *Scirpus acutus* – *Typha angustifolia*;
        - *Scirpus acutus* pure; and
        - *Scirpus acutus* – *Typha latifolia*.
- The following types in the Yolo Bypass from the BDCP composite vegetation layer:
    - Bulrush – cattail freshwater marsh NFD super alliance;
    - *Conium maculatum;*
    - *Cotula coronopifolia;*
    - *Crypsis schoenoides;*
    - *Crypsis* spp. – wetland grasses – wetland forbes NFD super alliance;
    - Ditch;
    - Flooded managed wetland;
    - Freshwater drainage;
    - Intermittently flooded to saturated deciduous shrubland;
    - *Juncus balticus;*
    - *Juncus balticus/Conium;*
    - *Juncus balticus/Lepidium;*
    - *Juncus balticus/Potentilla;*
    - *Lepidium* (generic);
    - Medium wetland graminoids;
    - Medium wetland herbs;
    - *Phragmites australis;*
    - *Phragmites/Scripus;*
    - *Phragmites/Xanthium;*
    - Rice;
    - *Scirpus (californicus or acutus*)-*Typha* spp.;
    - *Scirpus (californicus or acutus*)/rosa;
    - *Scirpus (californicus or acutus*)/wetland herb;
    - *Scirpus americanus* (generic);

  - *Scirpus americanus/Lepidium;*
  - *Scirpus americanus/Potentilla;*
  - *Scirpus californicus/S. acutus;*
  - *Scirpus maritimus;*
  - *Scirpus maritimus/Salicornia*[3]*;*
  - Short wetland graminoids;
  - Short wetland herbs;
  - Slough;
  - Tall wetland graminoids;
  - Tall wetland herbs;
  - *Typha angustifolia/Distichlis;*
  - *Typha angustifolia/S. americanus;*
  - *Typha* species (generic);
  - *Typha angustifolia;*
  - *Typha angustifolia/Phragmites;*
  - *Typha angustifolia/Polygonum-Xanthium-Echino;* and
  - Wetland herbs.
- The following agricultural types from the DWR 2007 Land Use Survey:
  - Rice

Aquatic breeding, foraging, and movement habitat is also differentiated into two broad suitability categories, primary and secondary. This distinction is made on the basis of the known distribution of giant garter snakes from past and current survey results as described above. Primary habitat includes lands within the Yolo Bypass west of the Sacramento Deep Water Ship Channel north to Fremont Weir and south to its confluence with the Sacramento River; and lands in the east and northeast Delta (east of, but not including, the Sacramento River south of Stonecrest Avenue to its confluence with the Mokelumne River, east of the South Fork Mokelumne River south to White Slough, east of and including White Slough south to its confluence with the San Joaquin River, and east of the San Joaquin River to Rough and Ready Island) (Figure A-30b). These are areas that include known extant populations and suitable habitat that is similar and contiguous with known population centers based on historical and recent surveys. Secondary habitat includes all lands not within the primary habitat zone. This includes the central Delta, south Delta, and the portion of the north Delta that lies between the

[3] Currently known as *Sarcocornia*.

Deep Water Ship Channel and the Sacramento River. These are areas that appear to be unoccupied or that do not include viable extant breeding populations based on historical and recent survey efforts, but do include areas that generally meet habitat suitability requirements for giant garter snake.

A30.8.2 Upland Aestivation and Movement Habitat

Upland aestivation and movement habitat for giant garter snakes includes the following land cover types immediately adjacent to and within 200 feet (61 meters) of the aquatic habitat types listed above:

- The following types in the Delta from the BDCP composite vegetation layer:
  - Agricultural land – all types
  - Grassland – all types
  - Alkali seasonal wetlands, vernal pool complex, and other natural seasonal wetlands
    - Seasonally flooded grasslands;
    - Temporarily-flooded perennial forbs;
    - *Distichlis spicata* – annual grasses;
    - vernal pools; and
    - Degraded vernal pool complex-vernal pools.
  - Managed wetlands
    - Rabbitsfoot grass (*Polypogon monspeliensis*);
    - Poison hemlock (*Conium maculatum*);
    - Intermittently flooded perennial forbs;
    - Managed annual wetland vegetation (non-specific grasses and forbs);
    - Seasonally-flooded undifferentiated annual grasses and forbs;
    - Managed alkali wetland (*Crypsis*);
    - Intermittently or temporarily flooded undifferentiated annual grasses and forbs;
    - *Scirpus* spp. in managed wetlands;
    - Smartweed – *Polygonum* spp. – mixed forbs;
    - *Polygonum amphibium;* and
    - *Perennial pepperweed (Lepidium latifolium).*
- The following types in the Yolo Bypass from the BDCP composite vegetation layer:

- o Annual grasses generic;
- o Annual grasses/weeds;
- o *Baccharis*/annual grasses;
- o *Bromus* spp./*Hordeum;*
- o Cultivated annual graminoid;
- o *Cynodon dactylon;*
- o *Distichlis*/annual grasses;
- o Fallow disced field;
- o Field crops;
- o *Hordeum/Lolium;*
- o *Lolium* (generic);
- o *Lolium/Rumex;*
- o *Lotus corniculatus;*
- o Medium upland herbs;
- o Pasture;
- o Perennial grass;
- o Short upland graminoids;
- o Truck/nursery/berry crops;
- o Upland annual grasslands and forbs formation; and
- o Upland herbs.

- The following types from the DWR 2007 Survey layer:
  - o All agricultural class types.

Assumptions. Giant garter snakes inhabit marshes, ponds, sloughs, small lakes, low gradient streams, and other waterways, and agricultural wetlands, including irrigation and drainage canals, rice fields, and the adjacent uplands (USFWS 2006b). In the Sacramento Valley, their habitat requirements include: (1) adequate water during the snake's active season (early-spring through mid-fall) to provide food and cover; (2) emergent herbaceous wetland vegetation for escape cover and foraging habitat during the active season; (3) basking habitat of grassy banks and openings in waterside vegetation; and (4) higher elevation uplands for cover and refuge from flood waters during the snake's dormant season in the winter (USFWS 2006b).

For purposes of this model, it is assumed that giant garter snakes could potentially use any watercourse (except the Sacramento and San Joaquin rivers), perennial marsh, or flooded rice field in the Plan Area and Yolo Basin that is consistently inundated during the snake's active season for purposes of breeding, foraging, or movement.

Due to lack of habitat and emergent vegetation cover, giant garter snakes generally are not present in larger rivers with sand, rock, and gravel substrates (e.g., the Sacramento and San Joaquin rivers). Riparian woodlands are unlikely to provide suitable habitat due to excessive shade, lack of basking sites, and absence of prey populations (USFWS 2006b). However, it is assumed that because of the relatively low overstory structure and intermittent occurrence, giant garter snakes could potentially occur along watercourses with *Salix*-dominated riparian or riparian scrub habitats; and that all watercourses with the exception of the Sacramento and San Joaquin rivers can be used as movement corridors.

Giant garter snakes use grassy stream banks and upland habitats adjacent to perennial watercourses or wetlands as aestivation and movement habitat. For purposes of this model and for consistency with USFWS guidance, upland aestivation habitats include all grasslands, seasonal wetlands, and all irrigated croplands within 200 feet (61 meters) of potentially occupied aquatic habitat. Note, however, that it is generally accepted that actively cultivated fields do not support suitable aestivation habitat due to regular ground disturbance. But because fields can be fallowed or converted to more suitable perennial cover types (e.g., alfalfa), and because it is not possible to predict the condition of fields in the future, all agricultural cover types are included as potentially occupied upland aestivation habitat. Thus, the model overestimates the extent of upland aestivation habitat.

In addition, periodic inundation such as that which occurs in the Yolo Bypass, influences use as aestivation habitat; and depending on the frequency of inundation, could act as a biological sink as snakes reestablish aestivation patterns during periods of non-inundation and then are displaced from or killed at aestivation sites during an inundation event. Because there is little research on this topic, the Yolo Bypass is included as potential aestivation habitat for giant garter snake; however, it is likely that either the bypass is not used for this purpose because of the periodic inundation or that it represents a site where snakes are periodically displaced during the inactive season.

Most historical and recent occurrences of the giant garter snake in the Plan Area have been reported from outside of the central Delta, including portions of the Yolo Basin and at Coldani Marsh – White Slough along the eastern edge of the Plan Area (CNDDB 2009, Hansen 2006, 2007, 2008, Wylie and Amarello 2006, E. Hansen pers. comm.). These areas are also consistent with the USFWS' description of extant populations within the Plan Area and Yolo Basin (USFWS 1999). Additional relatively recent occurrences extend north of White Slough to Stone Lakes, east of the Mokelumne and Sacramento rivers. Areas that are known to support extant populations, or where records suggest a greater likelihood of extant populations as described above, are included within the Primary Habitat Zone.

Scattered records within the central Delta suggest that giant garter snakes may have occupied this region at one time, but longstanding reclamation of wetlands for intense agricultural applications has eliminated most suitable habitat (Hansen 1986). Historical and recent surveys conducted within the Sacramento-San Joaquin Delta have failed to identify any extant population clusters in the region (Hansen 1986, Patterson 2003, 2005, Patterson and Hansen 2004), including 2009 surveys conducted by DWR. There is also some speculation that recent occurrences in the central Delta (e.g., Sherman Island) could be of snakes that occasionally move into the central Delta by 'washing-down' from known populations, such as Coldani Marsh, and that these occurrences do not represent local breeding populations (E. Hansen pers. comm.). There are also only two known isolated occurrences south of the San Joaquin River and none south of SR-4. This area is within the approximately 50 air-mile gap that separates the northern and southern populations (Hansen and Brode 1980, 58 FR 54053). Nonetheless, because suitable habitat has been documented and potential occupancy could not be entirely ruled out (ECOS 1990, Miriam Green Associates 1995), areas that support suitable habitat (as defined here) that are not included within the Primary Habitat Zone are considered potentially occupied by giant garter snake. The western end of Sherman Island represents the western extent of potentially occupied habitat, and consistent with the permitted East Contra Costa Habitat Conservation Plan/Natural Communities Conservation Plan, SR-160 approximately represents the westernmost extent south of the San Joaquin River near Antioch.

A30.9 Recovery Goals

The Draft Recovery Plan for the Giant Garter Snake was prepared in 1999 by the USFWS. The overall objective of this recovery plan is to delist the giant garter snake. The goals of the draft plan include: (1) stabilizing and protecting existing populations, and (2) conducting research necessary to further refine recovery criteria.

The plan lists the following conservation actions: (1) Protect existing populations and habitat, (2) Restore populations to former habitat, (3) Survey to determine species distributions, (4) Monitor populations, (5) Conduct necessary research, including studies on demographics, population genetics, and habitat use, and (6) Develop and implement incentive programs, and an outreach and education plan.

The recovery plan divided the Central Valley into four recovery units to aid in the recovery process. These units are (1) the Sacramento Valley Unit, extending from the vicinity of Red Bluff south to the confluence of the Sacramento and Feather rivers; (2) the Mid-Valley Unit, extending from the American and Yolo basins south to Duck Slough near the City of Stockton; (3) the San Joaquin Valley Unit, extending south of Duck Slough to the Kings River; and (4) the South Valley Unit, extending south of the Kings River to the Kern River Basin.

Populations within the Plan Area are included in the Mid-Valley Unit. Recovery criteria for this unit are as follows:

- Monitoring shows that in 17 out of 20 years, 90 percent of the subpopulations in the recovery unit (with the exception of the East Stockton – Diverting Canal and Duck Creek population) contain both adults and young.

- The six existing populations within the recovery unit are protected from threats that limit populations.
- Supporting habitat within the recovery unit is adaptively managed and monitored.
- Subpopulations are well-connected by corridors of suitable habitat.
- Repatriation has been successful at all suitable sites that had recently (within the last 10 years) extirpated populations.

In addition, the CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designates the giant garter snake as "Contribute to Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its control and within its scope that are necessary to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

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Glenn D. Wylie. Research Biologist. Dixon Field Station; U.S. Geological Survey Western Ecological Research Center, 6924 Tremont Road; Dixon, CA 95620

Miriam Green. Consulting Biologist. Miriam Green Consulting. Sacramento CA.

Laura Patterson. Wildlife Biologist. California Department of Water Resources, Sacramento. Comments on draft species account.

APPENDIX A31. WESTERN POND TURTLE (*ACTINEMYS MARMORATA*)

A31.1 LEGAL STATUS

The western pond turtle previously included two subspecies, the western pond turtle (*Actinemys marmorata mormorata*) and the southwestern pond turtle (*Actinemys marmorata pallida*). Both subspecies were petitioned for federal listing as endangered or threatened on January 29, 1992. In 1993, the United States Fish and Wildlife Service (USFWS) determined that there was insufficient information to propose listing of the species. Recent phylogenetic research combines the two subspecies into a single species (*A. marmorata*) (Bury and Germano 2008, Spinks and Shaffer 2005). The western pond turtle is a California Species of Special Concern.

A31.2 SPECIES DISTRIBUTION AND STATUS

A31.2.1 Range and Status

The western pond turtle occurs in the Pacific states of North America from Baja California Norte, north through Washington, and possibly into southernmost British Columbia, Canada (Bury and Germano 2008). Elevation range for the species extends from near sea level to 4,690 feet (1,430 meters) (Jennings and Hayes 1994).

Outside California, occurrences east of the Cascade-Sierra crest include the Truckee, Carson, and East Walker Rivers in Nevada; Drews Creek and Canyon Creek in Lake County, Oregon; and introduced occurrences along the Deschutes River at Bend in Deschutes County, Oregon (Jennings and Hayes 1994, Stebbins 2003).

In California, this species historically occurred in most Pacific slope drainages between the Oregon and Mexican borders and in only two drainages on the desert slope: the Mojave River (San Bernardino County) and Andreas Canyon (Riverside County) (Jennings and Hayes 1994). Occurrences east of the crest of the Sierra Nevada Mountain Range include Susanville in Lassen County (Stebbins 2003) (Figure A-31a).

From their phylogenetic analysis, Spinks and Shaffer (2005) divide the current range into four geographically coherent clades: a northern clade extending from Washington State to San Luis Obispo County; a San Joaquin Valley clade; a Santa Barbara clade in Santa Barbara and Ventura counties; and a southern clade south of the Tehachapi Mountains and west of the Transverse Range south to Baja California.

DRAFT

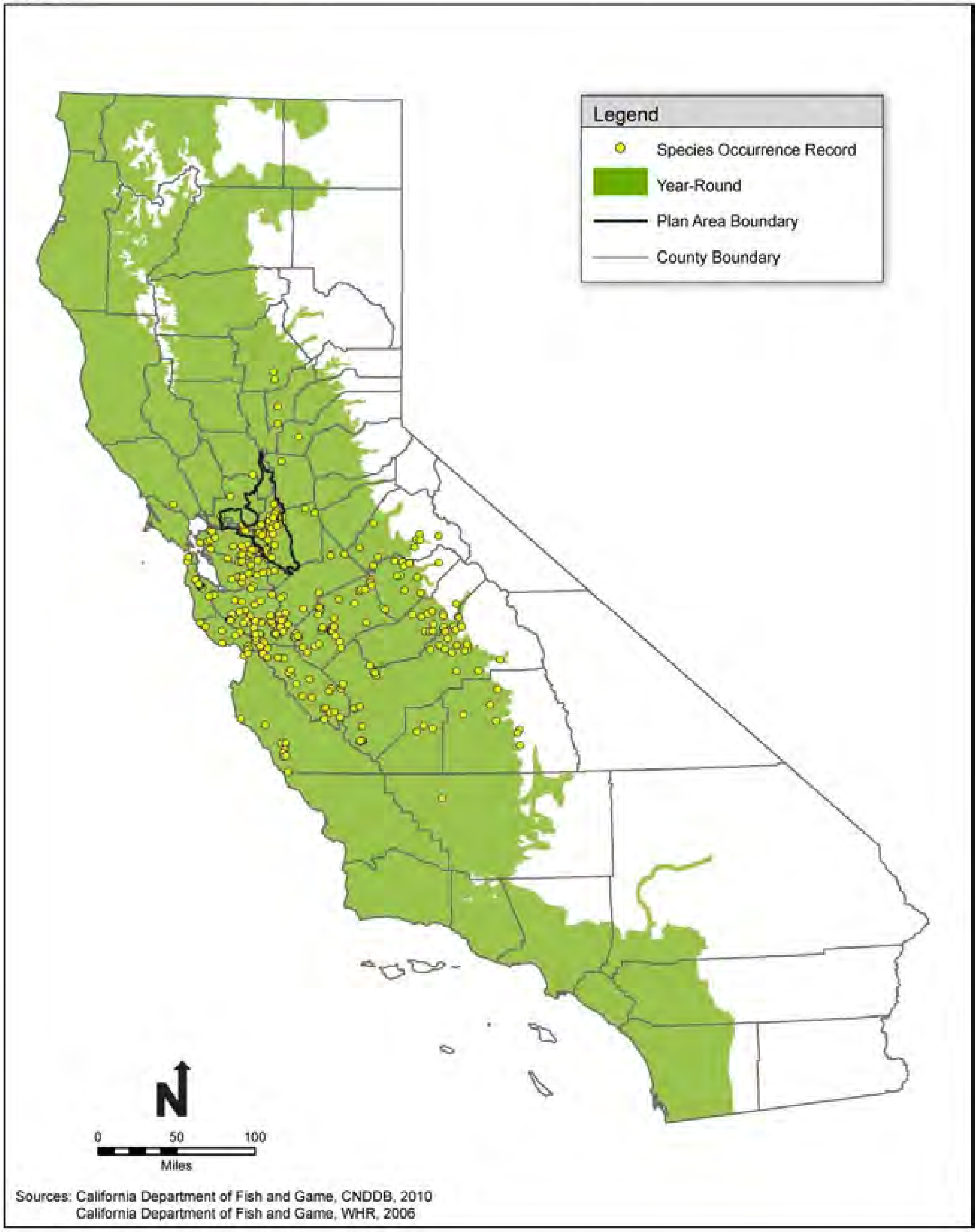

Figure A-31a. Western Pond Turtle Statewide Range and Recorded Occurrences

Population Trends. Most populations throughout the range have exhibited some declines. Bury and Germano (2008) report continued declines in the northern and southernmost portions of the range, but not in the core of the range from central California to southern Oregon. Hays et al. (1999) also report stable populations in southern Oregon while northern Oregon populations have suffered severe declines. Most populations in the state of Washington have been extirpated; however, there has been some progress through implementation of the Western Pond Turtle Recovery Plan (Hays et al. 1999).

In California, Jennings and Hayes (1994) consider the western pond turtle as endangered from the Mokelumne River south and threatened elsewhere within the state. Loss of habitat is the most significant factor in western pond turtle declines. Over 90 percent of the historical wetlands in California have been drained, filled, or diked to support agricultural and urban development (Frayer et al. 1989). In the Central Valley, pond turtles were exploited for food from the 1890s to the 1920s, which is believed to have played an important role in the declines in the San Francisco area and Central Valley populations (Storer 1930, Hays et al. 1999, Yolo Natural Heritage Program 2009). Nonetheless, despite significant population declines, populations in the Central Valley continue to persist in many areas and appear to have sufficient recruitment to maintain numbers (Germano and Bury 2001).

A31.2.2 Distribution and Status in the Plan Area

There are relatively few occurrence records from the Plan Area (Figure A-31b). The California Natural Diversity Database (CNDDB) reports several occurrences spread throughout the Plan Area in Sacramento, San Joaquin, and Contra Costa counties (CNDDB 2009); however, it is likely that this species is underreported and underrepresented in CNDDB. Jennings and Hayes' (1994) distribution map also shows three extant occurrences from the Sacramento River Basin along the southeastern boundary of Yolo County. Western pond turtles are common in the Suisun Marsh, which may be a key area for the species in the Bay-Delta system (Feliz pers. comm.). The species has potential to occur along most of the slower-moving sloughs and other natural watercourses and in artificial channels and other water bodies in the Plan Area where essential habitat elements (streamside cover, logs and other debris for basking, and adjacent upland habitats) are present.

Systematic boat surveys of sensitive species habitat have been conducted by the California Department of Water Resources (DWR) and the California Department of Fish and Game (DFG) staff throughout Suisun Marsh since 1991. These surveys have focused on the detection of sensitive plant and bird species. The presence or absence of western pond turtles has been incidental to these specialized surveys, but observations of pond turtles have been recorded (DWR 1994). Western pond turtles are present throughout Suisun Marsh. Pond turtles bask along the channel banks of tidal sloughs adjacent to emergent tidal marshes. Pond turtles bask on the banks with sunlight exposure at low tide.

DRAFT

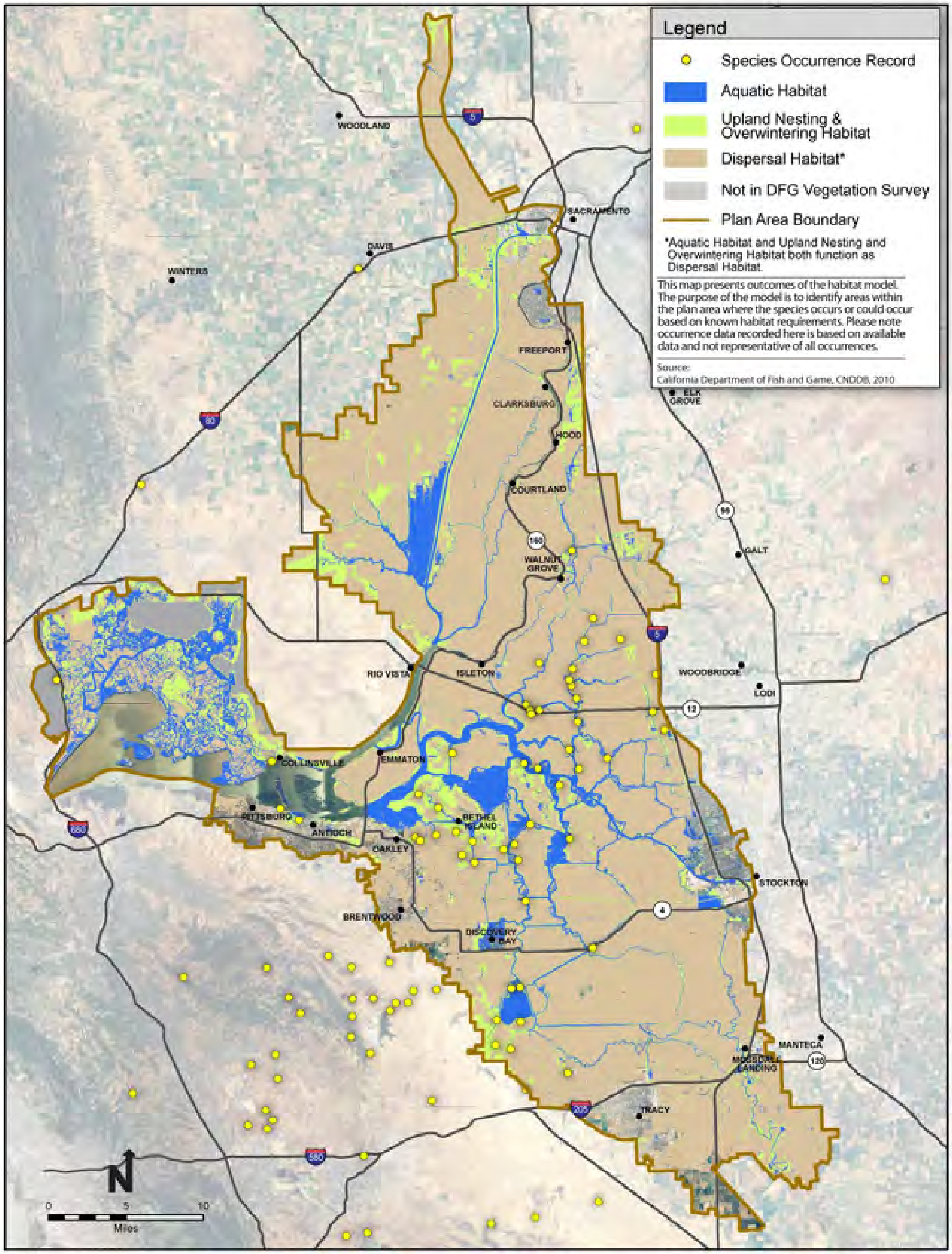

Figure A-31b. Western Pond Turtle Habitat Model and Recorded Occurrences

They have been observed basking on mud banks adjacent to the emergent wetlands of eastern Hill Slough, Nurse Slough, Cutoff Slough, First Mallard Branch, Second Mallard Branch, Boynton Slough, Peytonia Slough, Frank Horan Slough, and Cordelia Slough. Systematic surveys for pond turtles have not been conducted in diked, managed marshes. However, pond turtles have been observed from public roadways along internal water distribution systems which are cut off from natural tidal hydrology. The turtles have been observed along Roaring River, Grizzly Ditch, and Steve's Ditch of Grizzly Island. They have also been observed along Joice Island ponds, distribution ditches, and the Volanti Slough reservoir. It is assumed that western pond turtles are present at other pond and ditch systems within Suisun Marsh.

A31.3 Habitat Requirements and Special Conditions

The western pond turtle, although primarily found in natural aquatic habitats, also inhabits impoundments, irrigation ditches, and other artificial and natural water bodies (Ernst et al. 1994). The species is usually found in stagnant or slow-moving freshwater habitats, but brackish habitats are also utilized (Ernst et al. 1994). This species is uncommon in high gradient streams, most likely due to low water temperatures, high current velocity, and low food resources, which may limit their local distribution (Jennings and Hayes 1994).

The aquatic habitat may be comprised of either mud or rocky substrates and usually contains some vegetation (Ernst et al. 1994). Habitat quality often seems to be positively correlated with the number of available basking sites (Jennings and Hayes 1994). Turtles seem to avoid areas lacking in significant refugia (Holland 1994). Basking sites may be rocks, logs, vegetation, terrestrial islands within the aquatic habitat, and human-made debris (Holland 1994). Hatchlings forage in shallow water areas with dense submergent or short emergent vegetation, where small aquatic organisms are likely to be in abundance. Western pond turtles also inhabit the irrigation within agricultural areas, including ditches servicing rice agriculture (E. Hansen pers. comm.). While rice fields probably confer little advantage for adult western pond turtles, mature rice probably provides valuable cover and foraging habitat for hatchlings.

Upland habitats are also important to western pond turtles for nesting, overwintering, and overland dispersal (Holland 1994). Nesting sites may be as far as 400 meters (1,312 feet) or more from the aquatic habitat, although usually the distance is much less and generally around 100 meters (328 feet) (Jennings and Hayes 1994, Slavens 1995). Nesting sites typically have a southern or western aspect, with slopes of 0-46 percent and compact, dry soils (Holland 1994, Bury et al. 2001). When turtles choose to overwinter in upland habitats, individuals typically leave the aquatic habitat in late fall, moving as much as 500 meters (1,640 feet) from the aquatic habitat (Holland 1994). Turtles typically burrow into duff (leaf litter) and/or soil, where they remain during the winter months (Holland 1994). For reasons not entirely clear, western pond turtles may move into upland habitats for variable intervals at other times of the year, during which times they may be found burrowed into duff or under shrubs (Rathbun et al. 1993, Yolo Natural Heritage Program 2009).

A31.4 LIFE HISTORY

Description. The western pond turtle (Holman and Fritz 2001, Obst 2003, McCord and Joseph Ouni 2006) is a medium-sized aquatic turtle. Previously assigned to the genus *Clemmys,* Feldman and Parham (2002) has also proposed taxonomic realignments that would place *A. marmorata* within the genus *Emys*; current literature may refer to this taxon under either generic name. The carapace (upper portion of shell) color ranges from brown to black (Holland 1994). The carapace may be unmarked or covered with small, fine dark spots or lines (Holland 1994, Stebbins 2003). Adult size ranges from 8.9-21.6 centimeters (cm) (3.5-8.5 inches) straight-line carapace length (Stebbins 2003) and as large as 24.1 cm (9.5 inches) (Lubcke and Wilson 2007). The plastron (lower portion of shell) contains six pairs of yellowish shields, usually with dark blotches (Stebbins 2003). The head usually contains spots or a network of black coloring (Stebbins 2003). Adult females have a more domed, taller carapace, as compared to males, which have a more flattened, lower profile carapace (Holland 1994). Males also have larger, thicker tails than females (Holland 1994). Juveniles have a uniformly brown or olive carapace, with yellow markings along the edge of the marginals (the ring of shields encircling the carapace) and a tail nearly as long as the carapace (Stebbins 2003, Yolo Natural Heritage Program 2009).

Reproduction. Field observations have reported copulation in May, June, and late August (Holland 1988). Oviposition (egg-laying) may occur as early as late April in central California (Rathbun et al. 1993) to late July, with most occurring in June and July (Holland 1994). Western pond turtles may also double-clutch, potentially resulting in an extended breeding season (Scott et al. 2008). A gravid (pregnant) female approaches the nesting site, empties the contents of her bladder onto the soil, excavates a 90- to 125-millimeter (3.5- to 4.9-inch) deep nest chamber, and deposits 1 to 13 hard-shelled eggs (Holland 1994, Jennings and Hayes 1994). Incubation time ranges from 80 to more than 100 days in California (Holland 1994). In northern California, hatchling western pond turtles (which are about the size of a quarter) overwinter inside the nest chamber and emerge the following spring (Holland 1994). The terrestrial movements of post-emergent hatchlings are poorly understood (Holland 1994), although it is known that at least some move quickly to aquatic habitats (Yolo Natural Heritage Program 2009).

Basking. Western pond turtles spend considerable time basking in order to thermoregulate, preferring body temperatures between 24 and 32° C (75 and 90° F). Turtles seem to avoid body temperatures above 34° C (93° F) and usually cease basking at body temperatures well below their critical thermal maximum of 40° C (104° F). Individuals often bask above the water level on emergent logs, rocks, rocks, vegetation, or other objects. Turtles may sometimes bask at the surface, however, and sometimes within vegetation—where water temperatures may be 10 to 15° C (18 to 27° F) warmer than the water immediately below (Holland 1994). This type of basking may be utilized when air temperatures become too high for aerial basking. Western pond turtles also spend considerable time foraging, which occurs during the day or night (Holland 1994). Intraspecific (within-species) aggressive interactions, in the form of open-mouth gestures and shoving or bumping to secure positions on basking sites, are also common among western pond turtles (Holland 1994, Yolo Natural Heritage Program 2009).

Movements and Home Ranges. Adults sometimes engage in extended overland movements, which may be in response to drought or normal movements to aquatic habitats within a home range (Holland 1994). In one study, a turtle was observed making an overland movement of 5 kilometers (km) (3.1 miles), although in all other cases, overland movements were less than 3 km (1.9 miles) (Holland 1994). Such overland movements may be responses to an environmental stress such as drought or may be part of an individual's normal movements within a home range, which may consist of a series of ponds (Holland 1994). In lotic (stream) habitats, individuals move along the watercourse from pool to pool. During the course of one summer, Bury (1972) found average male, female, and juvenile linear movements were 354, 169, and 142 meters (1,161, 554, and 466 feet), respectively. In that study, adult males had the largest home ranges (0.98 hectares [2.42 acres]), followed by juveniles (0.36 hectares [0.89 acres]) and adult females (0.25 hectares [0.62 acres]) (Yolo Natural Heritage Program 2009).

Foraging Behavior and Diet. Western pond turtles are generalist feeders, with most food being obtained by opportunistic foraging or scavenging (Ernst et al. 1994). Known food items include algae, various plants, crustaceans, various types of insects, spiders, fish, frogs, tadpoles, and birds (Pope 1939 in Ernst et al. 1994, Evenden 1948 in Ernst et al. 1994, Carr 1952, Holland 1985, Bury 1986). Scavenging carrion of various vertebrate species may be a locally and/or seasonally important part of the diet (Holland 1994). Neustophagia, (a form of filter feeding) may be utilized to obtain abundant small invertebrate prey such as *Daphnia* (Ernst et al. 1994, Holland 1994, Yolo Natural Heritage Program 2009).

A31.5 THREATS AND STRESSORS

Habitat Loss and Fragmentation. Habitat loss and fragmentation produce small populations that are increasingly isolated and limited in space. This reduces movement of individuals and genetic exchange between populations. Small, isolated populations are highly susceptible to extinction caused by catastrophic or stochastic events. Isolation limits the ability of the population to recolonize areas with suitable habitat where western pond turtles may have been present in the past.

Agricultural practices such as disking and intensive livestock grazing and trampling have degraded many remaining vernal pools and wetland habitats, as have off-road vehicle use and contaminated runoff.

Roads can create a barrier to dispersal movements of western pond turtle and can isolate populations. Contaminants from road materials, leaks, and spills could further degrade aquatic habitats used by this species.

Corridors from aquatic habitat to historical and long-term nesting sites can be blocked by roads and development. Movement of adult females to and from the nesting locations and the movement of hatchlings from the nest to the aquatic site can be impeded and impacted (Jennings and Hayes 1994, Yolo Natural Heritage Program 2009).

Exotic Species. Nonnative invasive species are a threat to western pond turtles. Bullfrogs and exotic large predatory fish (e.g., largemouth bass) compete for invertebrate prey with western pond turtles and are known to eat hatchlings and small juveniles. Carp alter or eliminate emergent vegetation required as microhabitat by hatchlings (Holland 1994). Exotic turtles, including painted turtles, snapping turtles, and sliders, may compete with pond turtles for food and basking sites. These exotic turtles also may harbor and transmit diseases, such as upper respiratory diseases, to pond turtles (Holland 1994). Cattle trample and eat aquatic vegetation that serves as habitat for hatchlings and may crush nests. Domestic dogs sometimes kill or injure turtles (Yolo Natural Heritage Program 2009).

Flooding and Irrigation. Turtle nests may be inundated during floods and during irrigation of agricultural fields. The egg shells absorb water and can crack or explode from internal pressure (Feldman 1982). Therefore, nest success and recruitment may be reduced in flood-prone or active agricultural areas.

Predation. Predation is a major mortality factor for western pond turtles. Hatchlings and turtle eggs are particularly vulnerable (Holland 1994). Raccoons (*Procyon lotor*), bullfrogs (*Rana catesbeiana*), largemouth bass (*Micropterus salmoides*), gray fox (*Urocyon cineroargenteus*), coyote (*Canis latrans*), and feral and domestic dogs (*Canis familiaris*) are known to be major predators of western pond turtles (Holland 1994). Holland (1994) indicates that other known predators include osprey (*Pandion haliaetus*), bald eagle (*Haliaetus leucocephalus*), river otter (*Lutra canadensis*) (Manning 1990 in Holland 1994), and mink (*Mustela vison*). Numerous other fish, amphibian, bird, and mammal species are suspected to prey on the species (Holland 1994). Raccoons, in particular, are known to depredate nests, sometimes destroying all nests in an entire communal nesting area (Yolo Natural Heritage Program 2009). In urban areas, litter and pet food can increase the presence of some predators, potentially leading to increased predation on turtles.

A31.6 RELEVANT CONSERVATION EFFORTS

Conservation efforts for the western pond turtle are largely limited to those proposed under habitat conservation planning efforts, including those that overlap with the Plan Area. These include preservation of occupied and potentially-occupied habitats, management of watercourses and water bodies to protect existing populations and encourage reestablishment of populations, and restoration or enhancement of channel, riparian, and adjacent upland habitats to benefit pond turtles. The western pond turtle is a covered species under several permitted plans including the Natomas Basin Habitat Conservation Plan, the East Contra Costa County Habitat Conservation

Plan/Natural Community Conservation Plan, and the San Joaquin County Multi-Species Habitat Conservation and Open Space Plan; and is proposed for coverage under the South Sacramento County Habitat Conservation Plan, Yolo County Natural Heritage Program Plan, Solano County Multispecies Habitat Conservation Plan, and Butte Regional Habitat Conservation Plan and Natural Community Conservation Plan.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designates the western pond turtle as "Maintain" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions to maintain the species by avoiding, minimizing, and compensating for any adverse effects to the species created by ERP restoration actions. To the extent practicable, the ERP will improve species habitat conditions.

DFG recently commissioned the U.S. Forest Service's Redwood Sciences Lab to prepare a conservation strategy for the western pond turtle in California.

A31.7 Species Habitat Suitability Model

Model Approach. Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, and cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf 2007. Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers, connectivity between habitat types, and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The western pond turtle model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), USDA 2005 aerial photography, DWR Central Valley Levees 2001, and DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable western pond turtle habitat in the Plan Area according to three life requisite parameters: aquatic habitat, upland nesting and overwintering habitat, and dispersal habitat. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Aquatic Habitat. Aquatic habitat for the western pond turtle includes the following land cover types and conditions:

- Perennial streams, excluding the Sacramento River
- Large water delivery and irrigation channels
- Aquatic habitat in the Delta includes the following types from the BDCP composite vegetation layer:
    - Tidal freshwater emergent wetland – all types;
    - Tidal perennial aquatic types – all types;
    - Nontidal perennial aquatic types – all types;
    - Nontidal freshwater perennial emergent wetland;
        - American bulrush (*Scirpus americanus*);
        - Common reed (*Phragmites australis*);

        - Flooded managed wetland;
        - Hard-stem bulrush (*Scirpus acutus*);
        - Mixed *Scirpus*/floating aquatics (*Hydrocotyle – Eichhornia*) complex;
        - Mixed *Scirpus*/submerged aquatics (*Egeria-Cabomba-Myriophyllum* spp.) complex;
        - Mixed *Scirpus* mapping unit;
        - Narrow-leaf cattail (*Typha angustifolia*);
        - Perennial pepperweed (*Lepidium latifolium*);
        - *Scirpus acutus* (*Typha latifolia*) – *Phragmites australis*;
        - *Scirpus acutus – Typha angustifolia*;
        - *Scirpus acutus* pure; and
        - *Scirpus acutus – Typha latifolia*.
- Aquatic habitat in the Yolo Basin and Suisun Marsh from the BDCP composite vegetation layer (includes vegetation types from portions of tidal brackish emergent wetland, managed wetlands, alkali seasonal wetlands, vernal pool complex, tidal perennial aquatic, grassland and agricultural communities):
    - Freshwater drainage;
    - Slough;
    - Ditch;
    - *Scirpus*[1] *(californicus* or *acutus)/Rosa;*
    - *Scirpus (californicus* or *acutus*)/wetland herb;
    - *Scirpus (californicus* or *acutus)-Typha* spp.;
    - *Scirpus americanus* (generic);
    - *Scirpus americanus/Lepidium;*
    - *Scirpus americanus/Potentilla;*
    - *Scirpus californicus/S. acutus;*
    - *Scirpus maritimus;*
    - *Scirpus maritimus/Salicornia*[2]*;*
    - *Typha angustifolia/Distichlis;*

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[1] Currently known as *Schoenoplectus*.
[2] Currently known as *Sarcocornia*.

  - *Typha angustifolia/S. americanus;*
  - *Typha* species (generic);
  - Bulrush - cattail fresh water marsh NFD super alliance;
  - *Scirpus americanus/S. Californicus-S. acutus;*
  - *Scirpus maritimus/Sesuvium;*
  - *Typha angustifolia;*
  - *Typha angustifolia/Phragmites;*
  - *Typha angustifolia/Polygonum-Xanthium-Echino*; and
  - *Typha angustifolia/S. americanus.*

Assumptions. Western pond turtles reside in stagnant or slow-moving water in aquatic habitats (Ernst et al. 1994). The Sacramento River and the associated open water bays west of Sherman Island and west of the State Route (SR) 160 bridge along the San Joaquin River are excluded from the model because, with perhaps the exception of low velocity backwater areas, flow velocities are considered to be too high to provide habitat. Aquatic habitat on islands within the bay (e.g., Kimble Island, Brown Island, and Winters Island) are also excluded. Perennial stock ponds and other open water habitats also provide aquatic habitat when located near suitable upland areas. Western pond turtles are also associated with freshwater emergent and perennial aquatic types that are associated with open water habitats where they find cover and food resources. Juvenile western pond turtles may also find food and cover in seasonal wetlands and ricelands during periods of extended inundation (Hansen pers. comm.). However, for purposes of this model, these types are included as dispersal habitat.

While stock ponds and other small water impoundments may provide aquatic habitat for western pond turtle, these features could not be effectively mapped using the model data sources and are thus not included here. It is assumed that stock ponds and other small water impoundments occur within the grassland landscape identified below as potential upland nesting and overwintering habitat that provide additional potential breeding habitat for western pond turtle. It is also assumed that sufficient upland nesting and overwintering habitat has been identified based on proximity to mapped aquatic features to include all potential western pond turtle breeding habitat within the Plan Area.

Upland Nesting and Overwintering Habitat. Nesting and overwintering habitat in the Delta for the western pond turtle includes the following types from the BDCP composite vegetation layer within 500 meters (1,640 ft) of and contiguous with aquatic habitat:

- Grassland – all types (including levees)
- Valley/foothill riparian – all types
- Vernal pool complex

  - Annual grasses generic;
  - Annual grasses/weeds;
  - California annual grasslands;
  - Distichlis (generic);
  - *Distichlis spicata;*
  - *Distichlis spicata* – annual grasses;
  - Districhlis/annual grasses;
  - Distichlis/ *S. maritimus;*
  - Ruderal herbaceous grasses and forbs;
  - Italian rye-grass (*Lolium multiflorum*);
  - *Salicornia virginica*; and
  - *Salicornia*/annual grasses.

Nesting and overwintering habitat in the Yolo Basin and Suisun Marsh from the BDCP composite vegetation layer:

- Valley oak alliance – riparian;
- Fremont cottonwood-valley oak-willow (ash-sycamore) riparian forest NFD association;
- Valley oak alliance – riparian;
- *Salix laevigata/S. lasiolepis;*
- *Salix lasiolepis/Quercus agrifolia;*
- *Fraxinus latifolia;*
- Mixed willow super alliance;
- Annual grasses generic;
- Annual grasses/weeds;
- Perennial grass;
- Pasture;
- Upland annual grasslands and forbs formation;
- *Lolium* (generic);
- *Lolium/Rumex;*
- *Hordeum/Lolium;*
- Medium upland graminoids; and

- Short upland graminoids.

Assumptions. The western pond turtle is primarily aquatic and leaves the water only to reproduce, aestivate, and overwinter (Jennings and Hayes 1994). Females leave the aquatic habitat to find an upland location to nest. Proximity of nesting site to aquatic habitat is dependent on availability, and the nest site is generally within 200 meters (656 feet) from the aquatic habitat, but can be up to 400 meters (1,312 feet) away (Storer 1930, Jennings and Hayes 1994). Holland (1994) reported overwintering sites up to 500 meters (1,640 feet) from the aquatic habitat. Thus, a distance of 500 meters from and contiguous with aquatic habitat was selected to ensure that all likely habitats used for feeding, reproduction, and overwintering was encompassed in the model. Agricultural, urban, disturbed, orchard, and vineyard land cover types are not considered to support nesting or overwintering habitat because they are subject to regular disturbances that could destroy nests or overwintering sites.

Dispersal Habitat. Dispersal habitat includes all types listed under Aquatic Habitat and Upland Nesting and Overwintering Habitat within 3 km (1.86 miles) of aquatic habitat and the following:

Dispersal habitat within 3 km of and contiguous with aquatic habitat in the Delta from the BDCP composite vegetation layer includes:

- Agriculture – all types;
- Grassland – all types;
- Riparian – all types;
- Managed wetland – all types;
- Other natural seasonal wetland – all types;
- Vernal pool complex – all types and;
- Alkali seasonal wetland complex – all types.

Dispersal habitat within 3 km of and contiguous with aquatic habitat in the Yolo Basin and Suisun Marsh from the BDCP composite vegetation layer includes the following vegetation units:

- *Conium maculatum;*
- *Distichlis* (generic);
- *Distichlis spicata;*
- *Distichlis*/annual grasses;
- *Distichlis/Cotula;*

- *Distichlis/Juncus;*
- *Distichlis/Lotus;*
- *Distichlis/S. americanus;*
- *Distichlis/S. maritimus;*
- *Distichlis/Salicornia;*
- *Distichlis-Juncus-Triglochin-Glaux;*
- Flooded managed wetland;
- *Lepidium* (generic);
- *Lepidium/Distichlis;*
- Medium wetland graminoids;
- Medium wetland herbs;
- *Polygonum-Xanthium-Echinochloa;*
- *Polypogon monspeliensis* (generic);
- *Salix laevigata/S. lasiolepis;*
- Short wetland herbs;
- Tall wetland graminoids;
- *Juncus balticus;*
- *Juncus balticus/Conium;*
- *Juncus balticus/Lepidium;*
- *Juncus balticus/Potentilla;*
- Medium upland graminoids;
- Pasture;
- *Phragmites australis;*
- *Phragmites/Scirpus;*
- *Phragmites/Xanthium;*
- Rice;
- Short upland graminoids;
- Short wetland graminoids;
- Tall wetland herbs;
- Upland annual grasslands and forbs formation; and
- Wetland herbs.

Assumptions. Adults sometimes engage in extended overland movements, which may be in response to drought or normal movements to aquatic habitats within a home range (Holland 1994). In one study, a turtle was observed making an overland movement of 5 km (3.1 miles), although in all other cases, overland movements were less than 3 km (1.9 miles) (Holland 1994). Such overland movements may be responses to an environmental stress such as drought or may be part of an individual's normal movements within a home range, which may consist of a series of ponds (Holland 1994). Some of the seasonal wetland types and rice noted above may also be used as aquatic habitat during periods of inundation, particularly by juvenile pond turtles (Hansen pers. comm.). However, because of the shallow water depth and seasonal inundation, adults are more likely to use these habitats for dispersal purposes, and thus they are included here as dispersal habitat.

A31.8 Recovery Goals

A USFWS recovery plan has not been prepared for this species and no recovery goals have been established.

A31.9 References

A31.9.1 Literature Cited

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APPENDIX A32. CALIFORNIA RED-LEGGED FROG (*RANA DRAYTONII*)

A32.1 LEGAL STATUS

The California red-legged frog (*Rana draytonii*) was federally listed as threatened pursuant to the federal Endangered Species Act in 1996 (61 FR 25813); and is designated as a species of special concern in California (Jennings and Hayes 1994). A recovery plan was prepared for this species by the U.S. Fish and Wildlife Service (USFWS) in 2002 (USFWS 2002).

Critical habitat was initially designated for this species in 2001, which was subject to legal challenges and resulted in substantial modifications and a final ruling in 2006 (71 FR 19244). Further subsequent challenges resulted in additional modifications and a new proposed rule (73 FR 53492). Critical Habitat Units ALA-1A and CCS-1B border the western edge of the Plan Area.

A32.2 SPECIES DISTRIBUTION AND STATUS

A32.2.1 Range and Status

The historical range of the California red-legged frog is generally characterized as extending south along the coast from the vicinity of Point Reyes National Seashore, Marin County, California, and inland from the vicinity of Redding, Shasta County, California, southward along the interior Coast Ranges and Sierra Nevada foothills to northwestern Baja California, Mexico (USFWS 2007) (Figure A-32a). While there are a few historical records from several Central Valley locales (Jennings and Hayes 1994), Fellers (2005) considers persistent occupancy in the lowlands of the Central Valley unlikely due to extensive annual flooding.

The current range is generally characterized based on the current known distribution. The USFWS (2007) notes that while the California red-legged frog is still locally abundant within portions of the San Francisco Bay area and the central coast, only isolated populations have been documented elsewhere within the species' historical range, including the Sierra Nevada, northern Coast Ranges, and northern Transverse Ranges.

The USFWS (2002) estimates that the species has lost approximately 70 percent of its former range, with severe declines occurring primarily in the Central Valley and southern California (Jennings and Hayes 1994). Prior to recent discoveries at isolated locations in the Sierra Nevada (Placer, Nevada, Yuba, and El Dorado counties) and two populations in the southern Transverse and Peninsular Ranges, the subspecies was considered extirpated from the Sierra Nevada and southern Transverse and Peninsular Ranges.

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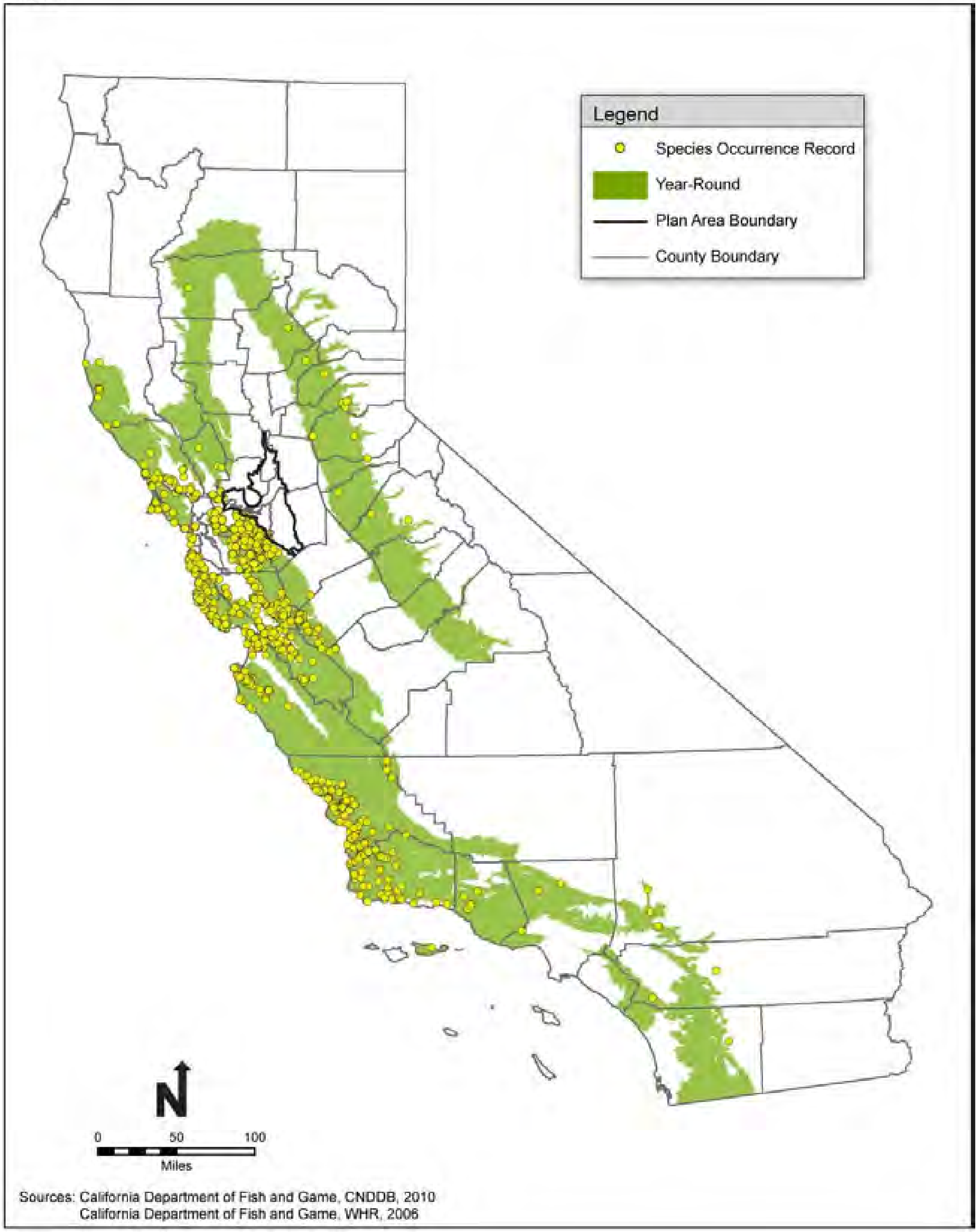

Figure A-32a. California Red-Legged Frog Statewide Range and Recorded Occurrences

Sizable populations continue to exist only in coastal drainages and associated pond habitats between Point Reyes and Santa Barbara (Jennings and Hayes 1994).

The principal factors contributing to the decline of the California red-legged frog are loss of habitat due to urban development, conversion of native habitats to agricultural lands, introduction of nonnative predators, and pesticide use (Fisher and Shaffer 1996, Hobbs and Mooney 1998, Davidson et al. 2002). Habitat loss and fragmentation result in small, isolated populations, which reduce individual movements and genetic exchange between populations.

A32.2.2 Distribution and Status in the Plan Area

Within the Plan Area, the California red-legged frog has been detected only in aquatic habitats within the grassland landscape west and southwest of Clifton Court Forebay and in the vicinity of Brentwood and Marsh Creek along the west-central edge of the Plan Area, and in some upland sites in the vicinity of Suisun Marsh (Figure A-32b). These areas represent the easternmost edge of the current range of California red-legged frog within the Coast Ranges. While there are several recent detections of the species in the Sierra Nevada foothills, California red-legged frog is not known to occur in the agricultural habitats of the Central Valley. The California Natural Diversity Database (CNDDB) reports several extant occurrences from approximately Marsh Creek and Clifton Court Forebay and the western edge of the Suisun Marsh (CNDDB 2009). Surveys conducted by the California Department of Water Resources (DWR) in 2009 confirmed occupancy at sites in the vicinity of Clifton Court Forebay. Occupied habitats are characterized by grassland foothills with stock ponds and slow-moving perennial drainages. The species is not known to occur, nor is it expected to occur, elsewhere in the Plan Area.

A32.3 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

Storer (1925) and Hayes and Jennings (1988) describe aquatic breeding habitat requirements for California red-legged frog as cold water pond habitats (including stream pools) with emergent and submergent vegetation, providing suitable cover for young and adults and ensuring successful reproduction. Optimal habitats are described as deep-water ponds or pools at least 2.3 feet (0.7 meters) deep along low gradient streams with dense stands of overhanging willows and a fringe of cattails between the willow roots and overhanging willow limbs. Note, however, that the lack of wetland or other shallow streamside vegetation does not necessarily preclude the presence of California red-legged frog. Hayes and Jennings (1988) also note that there may be a current preference for pools along intermittent streams rather than backwater pools along perennial streams possibly due to predator avoidance, particularly bullfrogs (*Rana catesbeiana*). The California red-legged frog uses a variety of aquatic habitats that meet these requirements, including permanent and ephemeral ponds, perennial and intermittent streams, seasonal wetlands, springs, seeps, marshes, dune ponds, lagoons, and human-made aquatic features (USFWS 2007).

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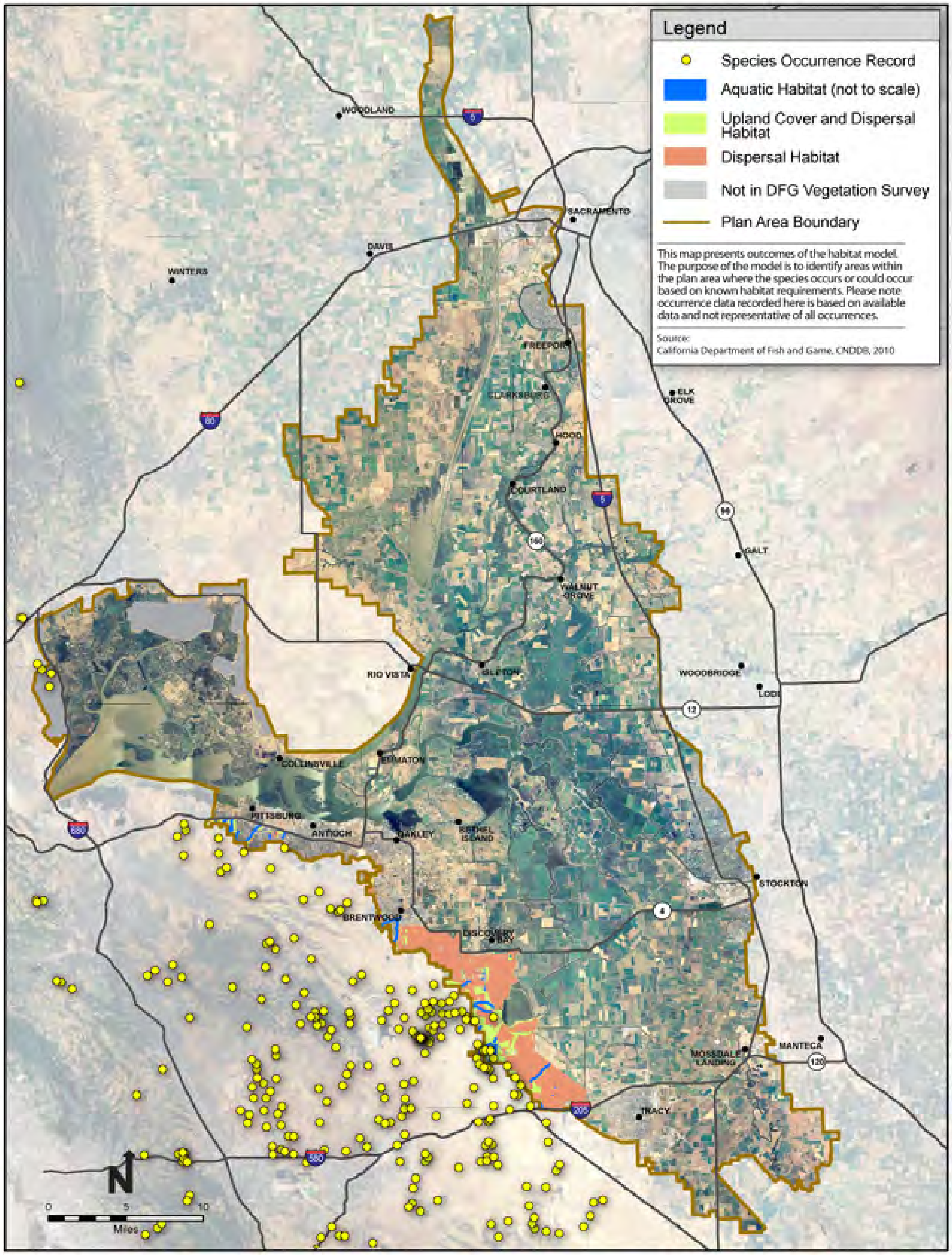

Figure A-32b. California Red-Legged Frog Habitat Model and Recorded Occurrences

In addition to aquatic breeding habitat, the California red-legged frog also requires upland non-breeding habitat used for cover, aestivation, and migration and other movements. Non-breeding cover habitat may include nearly any areas within 1-2 miles (1.6-3.2 kilometers [km]) of a breeding site that stays moist and cool through the summer, and can include vegetated areas with coyote bush (*Baccharis pilularis*), California blackberry thickets (*Rubus ursinus*), and root masses associated with willow (*Salix* spp.) and California bay trees (*Umbellularis californica*) (Fellers and Kleeman 2007). Potential cover habitat includes all aquatic, riparian, and upland areas that provide cover, such as animal burrows, boulders or rocks, organic debris such as downed trees or logs, and industrial debris; agricultural features such as drains, watering troughs, spring boxes, abandoned sheds, or hay stacks may also be used (61 FR 25813). Incised stream channels with portions narrower and depths greater than 18 inches (46 centimeters) also may provide important summer sheltering habitat (61 FR 25813). Accessibility to cover habitat is essential for the survival of red-legged frogs within a watershed and can be a factor limiting frog populations. Movement corridors may include annual grasslands, riparian corridors, woodlands, and sometimes active agricultural lands (Fellers and Kleeman 2007).

A32.4 LIFE HISTORY

Description. California red-legged frogs are brown to reddish brown with prominent dorsolateral folds (Jennings and Hayes 1994, Stebbins 2003). Adult size ranges from 85 to 138 millimeters (3.4-5.4 inches) in length from the snout to urostyle (frog homologue to pelvic bone) (Jennings and Hayes 1994). The dorsal surface is distributed with dark spots, occasionally with light centers (Storer 1925). The amount of red coloration present is variable; some individuals have no such coloration, and others may have red pigment distributed all over the dorsal and ventral surfaces of the body (Jennings and Hayes 1994). A dark mask bordered by a whitish jaw stripe is also usually present (Stebbins 2003).

Activity. Juvenile frogs are active diurnally and nocturnally, while adult frogs are primarily nocturnal (Hayes and Tenant 1985). Local climate influences the red-legged frog's seasonal activity period (Storer 1925). In coastal areas with mild climates, individuals are rarely inactive; however, at inland sites with colder winters individuals may become inactive for longer intervals (Yolo Natural Heritage Program 2009).

Seasonal Movements. California red-legged frogs are most likely to make overland movements through upland habitats at night during wet weather (USFWS 2002, Bulger et al. 2003, Fellers and Kleeman 2007). During the course of a wet season, movements up to 1.6 km (1 mile) are possible (USFWS 2002). During dry weather, the subspecies tends to remain very close to a water source and are typically within 60 meters (m) (~200 feet [ft]) of water (UFSWS 2002, Bulger et al. 2003, Fellers and Kleeman 2007). However, overland dispersal of the California red-legged frogs sometimes occurs in response to receding water during the dry season potentially necessitating greater dispersal distances (USFWS 2002). California red-legged frogs have been known to disperse distances up to 2.9 km (1.8 miles) from the breeding site to sites within the stream system (USFWS 2002, Fellers and Kleeman 2007). Note, however, that Jennings and Hayes (1994) suggest that, in general, adult California red-legged frogs do not appear to move large distances from their aquatic habitat. This is consistent with recent results from Tatarian (2008) who reported average terrestrial movement in Contra Costa County of 24.4 +/- 20.7 m (range: 1-71 m) (80 +/- 68 ft [range: 3.3 - 233 ft]) and average aquatic movement of 107.2 +/- 152.1 m (Range 11 – 661.4 m) (352 +/- 499 ft [range: 36 – 2,170 ft]).

Reproduction. Breeding occurs between late November and late April (Jennings and Hayes 1994) and most frogs lay their eggs in March (USFWS 2002). Males move to breeding sites 2 to 4 weeks before female arrival (Storer 1925). A pair moves into amplexus (breeding position), and the female moves the pair to the oviposition (egg-laying) site, where she deposits 2,000 to 6,000 eggs to an emergent vegetation brace (Storer 1925, Jennings and Hayes 1994). Hatching occurs in 20-22 days, depending on water temperature (USFWS 2002). Thereafter, tadpoles require 11 to 20 weeks to complete metamorphosis (Storer 1925).

Diet. Invertebrates comprise most prey taken by California red-legged frogs, although vertebrates such as pacific tree frogs (*Hyla regilla*) and California mice (*Peromyscus californicus*) comprise over half the prey consumed by larger frogs (USFWS 2002).

Predators. California red-legged frogs are subject to predation by a number of native and nonnative species. Some of the native predators include raccoon (*Procyon lotor*), garter snakes (*Thamnophis* spp.), great blue herons (*Ardea alba*), American bitterns (*Botaurus lentiginosus*), red-shouldered hawks (*Buteo lineatus*), and black-crowned night herons (*Nycticoras nycticoras*) (USFWS 2002, Fellers and Kleeman 2007). Nonnative predators include crayfish, bullfrogs (*Rana catesbeiana*) and various fish species (USFWS 2002).

A32.5 THREATS AND STRESSORS

Urbanization/Habitat Fragmentation. Habitat loss, degradation, and fragmentation are significant factors in declining populations of California red-legged frogs. Conversion of lands to agricultural and urban uses, overgrazing, mining, recreation, and timber harvesting have all contributed to habitat losses and disturbances. Urbanization often fragments habitat and creates barriers to dispersal (USFWS 2002). Road densities generally increase as a consequence of urbanization. Roads can create significant barriers to frog dispersal (Reh and Seitz 1990) and reduce population densities due to mortality caused by automobile strikes (Fahrig et al. 1995, Yolo Natural Heritage Program 2009).

Agricultural Crop Conversion. The conversion of natural lands to agricultural uses, such as stands of monotypic row crops, can alter habitats to the extent that they become uninhabitable for California red-legged frogs (USFWS 2002). Fisher and Shaffer (1996) suggest that intense farming within the San Joaquin Valley has resulted in drastic declines in California red-legged frog populations, resulting from little suitable habitat. Pesticides, herbicides, and other agrochemicals are known to be toxic to various life stages of ranid frogs (Hayes and Jennings

1986). Pesticide drift has also been suggested as a potential cause of declining populations of four species of ranids in California, including California red-legged frogs (Davidson et al. 2002, Yolo Natural Heritage Program 2009).

Exotic Species. Exotic predatory fish and bullfrogs also pose significant threats to California red-legged frogs. Hayes and Jennings (1986) noted that locations in which exotic fish were present contained few California red-legged frogs. Bullfrogs have been implicated in the decline of the subspecies in several studies (Fisher and Shaffer 1996, Kiesecker and Blaustein 1998, Lawler et al. 1999), and Moyle (1973) indicated that bullfrogs might have been the most important factor in the extirpation of California red-legged frogs from the Central Valley floor. Bullfrogs depredate and out-compete California red-legged frogs due to their larger size, more varied diet, and longer breeding season (Hayes and Jennings 1986, Yolo Natural Heritage Program 2009).

Water Diversions and Impoundments. Water diversions and impoundments have altered habitats and made them less suitable for many ranid species (Jennings 1996). The creation of reservoirs through dam construction in the Central Valley and southern California has directly eliminated, fragmented, or isolated populations of California red-legged frogs (USFWS 2002). Smaller impoundments and water diversions can also preclude or inhibit dispersal (USFWS 2002) and reduce high flows required to maintain deep holes in streams (Rathbun in litt. 1998 in USFWS 2002). The stock ponds and small reservoirs formed by smaller impoundments and water diversions often contain exotic fishes and bullfrogs that prey on red-legged frogs (G. Rathbun. and M. Jennings in litt. 1993 in USFWS 2002, Yolo Natural Heritage Program 2009).

Grazing. In some locales, California red-legged frogs appear to thrive in areas with managed grazing, and grazing may actually improve habitat conditions at sites where stock ponds have been constructed (USFWS 2002). However, unmanaged cattle trample and eat emergent riparian vegetation, resulting in severe habitat disturbances (Gunderson 1968 in USFWS 2002, Duff 1979 in USFWS 2002), causing increases in water temperatures (Van Velson 1979 in USFWS 2002). These effects diminish habitat quality for red-legged frogs and improve conditions for bullfrogs and exotic predatory fish (USFWS 2002). Grazing in riparian areas can result in the loss of willows, which are associated with the greatest densities of California red-legged frogs (Jennings 1988). High stocking rates can also result in increased erosion in the watershed (Lusby 1970 in USFWS 2002, Winegar 1977 in USFWS 2002) and sedimentation in the stream (Gunderson 1968 in USFWS 2002), which in turn can alter primary productivity and fill interstitial spaces of the streambed substrate with fine alluvium. This fill impedes water flow, reduces dissolved oxygen levels, and restricts waste removal (Chapman 1988 in USFWS 2002, Yolo Natural Heritage Program 2009).

A32.6 Relevant Conservation Efforts

Since the listing of the California red-legged frog, numerous conservation efforts have been undertaken by various federal, state, and local and private organizations to minimize impacts and establish preserves and protective policies to ensure the viability of this species (USFWS 2002). These include the establishment of federal guidelines to assess habitat and determine presence/absence of the species (USFWS 2005), the designation of critical habitat, and various protections of occupied habitat on public and private lands. The Recovery Plan (USFWS 2002) outlines a series of guidelines that recommend specific actions designed to protect California red-legged frogs and their habitat.

The California red-legged frog is a covered species in the East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan and the San Joaquin County Multi-Species Habitat Conservation and Open Space Plan; and it is proposed as a covered species in the Solano County Multispecies Habitat Conservation Plan, the Yolo County Natural Heritage Program Plan, and the Butte Regional Conservation Plan.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for the California red-legged frog is "Maintain" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions to maintain the species by avoiding, minimizing, and compensating for any adverse effects to the species created by ERP restoration actions. To the extent practicable, the ERP will improve species habitat conditions.

A32.7 Species Habitat Suitability Model

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, and cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf 2007. Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers, connectivity between habitat types, and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The California red-legged frog model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), U.S. Department of Agriculture (USDA) 2005 aerial photography, and DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable California red-legged frog habitat in the Plan Area according to the species' two primary life requisites, aquatic breeding habitat and upland cover and dispersal habitat. Vegetation types were assigned to a suitability category based on the species requirements as described above and the assumptions described below. The model also restricts the distribution of suitable habitat based on the known range of the species.

Aquatic Habitat. Aquatic habitat for the California red-legged frog includes the following land cover types and conditions within the area south and west of Highway 4 from Antioch (Bypass Road to Balfour Road to Brentwood Boulevard) to Old River; then south along Old River to

Clifton Court Forebay; along the west and south sides of Clifton Court Forebay to Old River; then south along the county line to Byron Highway; then west of Byron Highway to I-205, north of I-205 to I-580, and west of I-580. Aquatic habitat also includes the following land cover types along the western edge of the Suisun Marsh, west of I-680.

- Perennial and intermittent streams
- Aquatic habitat types from the BDCP composite vegetation layer including:
  - Managed wetland
    - *Scirpus*[1] spp. in managed wetlands; and
    - *Polygonum amphibium.*
  - Nontidal freshwater perennial emergent
    - Broad-leaf cattail (*Typha latifolia*);
    - American bulrush (*Scirpus americanus*);
    - Mixed *Scirpus* mapping unit;
    - *Scirpus acutus* pure; and
    - *Scirpus acutus* (*Typha latifolia*) – *Phragmites australis.*
  - Tidal freshwater emergent wetland
    - Mixed *Scirpus* mapping unit;
    - Mixed *Scirpus*/floating aquatics complex;
    - Mixed *Scirpus*/submerged aquatics complex;
    - Hard-stem bulrush (*Scirpus acutus*);
    - *Scirpus acutus* pure;
    - *Scirpus acutus – Typha angustifolia;*
    - *Scirpus acutus – Typha latifolia;*
    - *Scirpus acutus – (Typha latifolia) – Phragmites australis;*
    - California bulrush (*Scirpus californicus*);
    - *Scirpus californicus – Eichhornia crassipes;*
    - *Scirpus californicus – Scirpus acutus;*
    - American bulrush (*Scirpus americanus*);
    - Narrow-leaf cattail (*Typha angustifolia*); and
    - *Typha angustifolia – Distichlis spicata.*

[1] Currently known as *Schoenoplectus*.

- Perennial aquatic
  - Floating primrose (*Ludwigia poploides*);
  - *Ludwigia peploides;*
  - Generic floating aquatics;
  - Water hyacinth (*Eichhornia crassipes*);
  - Pondweed (*Potamogeton* spp.);
  - Milfoil – Waterweed (generic submerged aquatics) ;
  - Brazilian waterweed (*Egeria – Myriophyllum*) submerged;
  - *Hydrocotyle ranunculoides;*
  - Algae; and
  - Water.

Assumptions. Within the Plan Area, the California red-legged frog has been detected only in aquatic habitats within the grassland landscape west of Clifton Court Forebay, in the vicinity of Brentwood and Marsh Creek along the west-central edge of the Plan Area, and along the western edge of Suisun Marsh, west of I-680. Habitat occurring within the California Aqueduct and the Delta Mendota Canal were removed. These areas represent the easternmost edge of the current range of California red-legged frog within the Coast Ranges. The species is not known to occur, nor is it expected to occur, elsewhere in the Plan Area.

Storer (1925) and Hayes and Jennings (1988) describe aquatic breeding habitat requirements for California red-legged frog as cold water pond habitats (including stream pools and stock ponds) with emergent and submergent vegetation, providing suitable cover for young and adults and ensuring successful reproduction. Optimal habitats are described as deep-water ponds or pools along low gradient streams with dense stands of overhanging willows and a fringe of cattails between the willow roots and overhanging willow limbs. Hayes and Jennings (1988) also note that the lack of wetland or other shallow streamside vegetation does not necessarily preclude the presence of California red-legged frog and that there may be a current preference for pools along intermittent streams rather than backwater pools along perennial streams possibly due to predator avoidance. California red-legged frog uses a variety of aquatic habitats that meet these requirements, including permanent and ephemeral ponds including stock ponds, perennial and intermittent streams, seasonal wetlands, springs, seeps, marshes, dune ponds, lagoons, and human-made aquatic features (USFWS 2007).

While stock ponds and other small water impoundments provide important aquatic habitat for California red-legged frog, these features could not be effectively mapped using the model data sources and are thus not included here. It is assumed that stock ponds and other small water impoundments occur within the grassland landscape identified below as potential upland cover and dispersal habitat that provide additional potential breeding habitat for California red-legged frog. It is also assumed that sufficient upland and dispersal habitat has been identified based on proximity to mapped aquatic features to include all potential California red-legged frog breeding habitat within the Plan Area.

Upland Cover and Dispersal Habitat. Upland cover and dispersal habitat includes grassland and riparian habitats within the area described above and within 2 miles of aquatic habitat as described above.

Upland cover and dispersal habitat from the BDCP composite vegetation layer includes:

- Grassland – all types
- Valley/foothill riparian – all types
- Vernal pool complex
    - Annual grasses generic;
    - Annual grasses/weeds;
    - California annual grasslands;
    - *Distichlis* (generic);
    - *Distichlis spicata;*
    - *Distichlis spicata* – annual grasses;
    - *Districhlis*/annual grasses;
    - *Distichlis*/ *S. maritimus;*
    - Ruderal herbaceous grasses and forbs;
    - Italian rye-grass (*Lolium multiflorum*);
    - *Salicornia virginica*; and
    - *Salicornia*/annual grasses.

Dispersal Habitat. Upland dispersal habitat also includes agricultural lands within the area described above and within 2 miles (3.2 km) of the aquatic habitat as described above.

Upland Dispersal Habitat from the BDCP composite vegetation layer includes:

- Agricultural land – all types

Assumptions. The California red-legged frog also requires upland non-breeding habitat used for cover, aestivation, and migration and other movements. Non-breeding cover habitat may include nearly any areas within 1-2 miles (1.6-3.2 km) of a breeding site that stays moist and cool through the summer (Fellers and Kleeman 2007). Potential cover habitat includes all aquatic, riparian, and upland areas that provide cover, such as animal burrows, boulders or rocks, organic debris such as downed trees or logs, and industrial debris; agricultural features such as drains, watering troughs, spring boxes, abandoned sheds, or hay stacks may also be used (61 FR 25813). Movement corridors may include annual grasslands, riparian corridors, woodlands, and sometimes active agricultural lands (Fellers and Kleeman 2007).

A32.8 Recovery Goals

The Recovery Plan for the California red-legged frog (USFWS 2002) identifies five recovery criteria:

1. Protection of suitable habitat, in perpetuity, within each of the defined core areas. Protection of habitat would include impacts upstream that could make habitat unsuitable.
2. Documentation that existing populations are stable through a 15-year monitoring program. This program should include representative precipitation cycles.
3. Distribution of existing populations, allowing stable metapopulations despite fluctuations in local populations.
4. Reestablishment of frogs in at least one area of historical occurrence for each core area.
5. Additional habitat needed for connectivity of existing and reestablished populations, reestablishment, and dispersal has been determined and is protected and managed for red-legged frogs.

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APPENDIX A33. WESTERN SPADEFOOT TOAD (*SPEA HAMMONDII*)

A33.1 LEGAL STATUS

The western spadefoot toad (*Spea hammondii*) is designated as a state Species of Special Concern (Jennings and Hayes 1994). This species currently does not have any federal listing status. However, because it is associated with vernal pool habitats, it is addressed in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (USFWS 2005).

A33.2 SPECIES DISTRIBUTION AND STATUS

A33.2.1 Range and Status

In North America, the range of the western spadefoot toad includes portions of California, extending south to Mesa de San Carlos in Baja California Norte, Mexico (Stebbins 1985, Jennings and Hayes 1994, California Academy of Sciences 2008, Museum of Vertebrate Zoology 2008). In California, the current range of the western spadefoot toad includes portions of the Central Valley and bordering foothills, and the Coast Range south of Monterey Bay (Figure A-33a) (Stebbins 2003). The western spadefoot toad has been extirpated throughout most of the lowlands of southern California (Stebbins 1985) and from many historical locations within the Central Valley (Jennings and Hayes 1994, Fisher and Shaffer 1996). Fisher and Shaffer (1996) state that the western spadefoot toad populations have declined severely in the Sacramento Valley, and their density has been reduced in eastern San Joaquin Valley. The numbers in the Coast Range have declined more modestly than in the valleys. The population status and trends of the western spadefoot toad outside of California (i.e., Baja California Norte, Mexico) are not well known.

This species occurs mostly below 3,000 feet (914 meters) in elevation (Stebbins 1985). The average elevation of sites where the species still occurs is significantly higher than the average elevation for historical sites, further suggesting that declines have been more pronounced in lowlands (USFWS 2005).

The principal factors contributing to the decline of the western spadefoot are loss of habitat due to urban development, conversion of native habitats to agricultural lands, introduction of nonnative predators, and pesticide use (Fisher and Shaffer 1996, Hobbs and Mooney 1998, Davidson et al. 2002). Habitat loss and fragmentation result in small, isolated populations, which reduce individual movements and genetic exchange between populations.

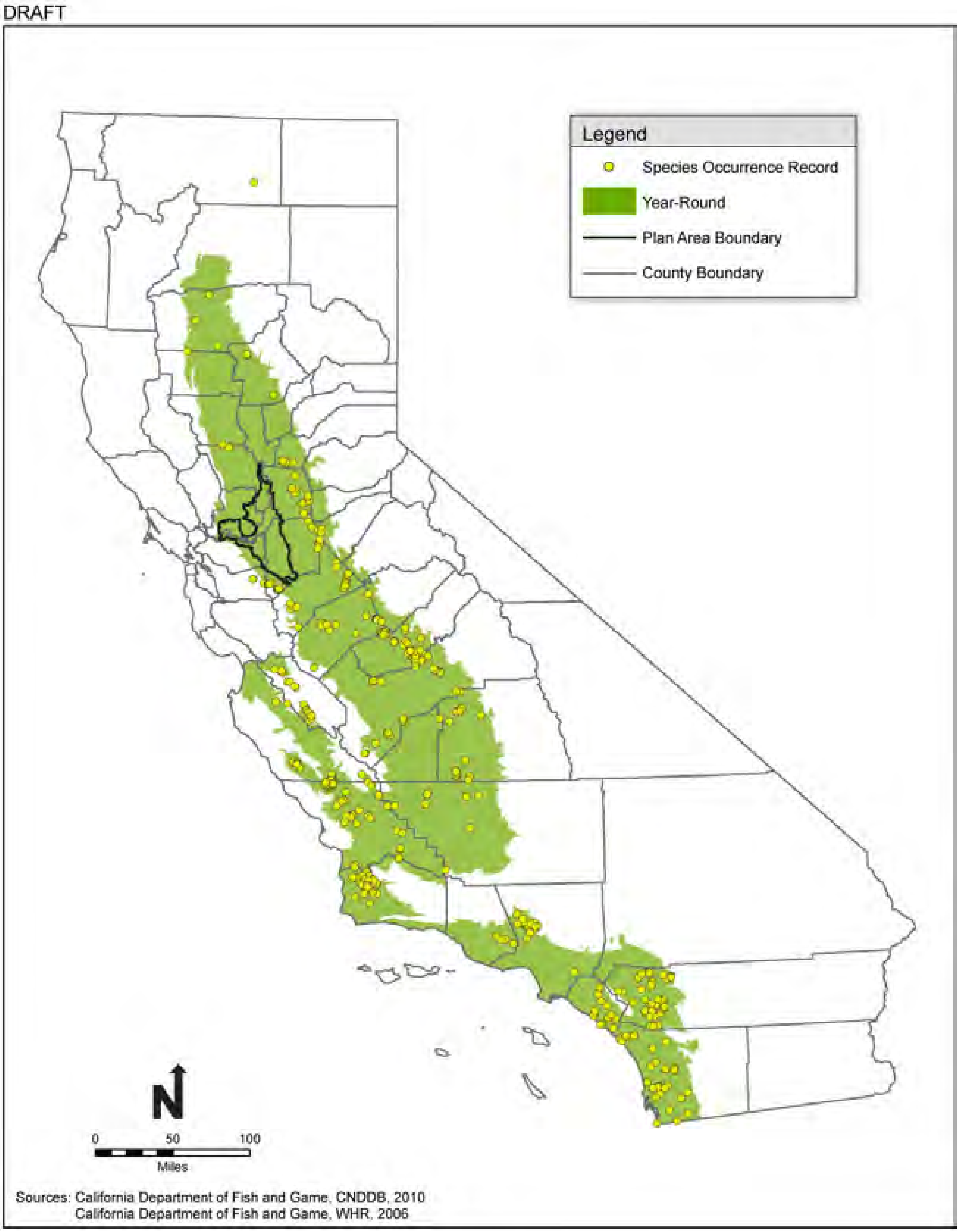

Figure A-33a. Western Spadefoot Toad Statewide Range and Recorded Occurrences

Reduction in gene flow may result in inbreeding depression and a subsequent reduction in population fitness. Furthermore, many remaining vernal pool and other wetland habitats are subject to continuing habitat degradation by disking, intensive livestock grazing, off-road vehicle use, and contaminant run-off (Fisher and Shaffer 1996, Hobbs and Mooney 1998, Davidson et al. 2002).

A33.2.2 Distribution and Status in the Plan Area

Although the expected range extends through the Plan Area (Figure A-33b), no records for western spadefoot toad occur (CNDDB 2009). Potentially suitable habitats occur in remaining uncultivated grasslands near Stone Lakes, east of Interstate 5 (I-5) in the vicinity of the Cosumnes River Preserve, along the southwestern edge of the Plan Area from approximately Brentwood to Tracy, in the southern Montezuma Hills near Collinsville, and in eastern Solano County including Jepson Prairie. While the species has not been documented, portions of the Yolo Basin, particularly the California Department of Fish and Game's (DFG) Yolo Bypass Wildlife Area Tule Ranch Unit may also support suitable habitat for western spadefoot toad.

A33.3 Habitat Requirements and Special Conditions

Western spadefoot toads typically inhabit lowland habitats such as washes, floodplains of rivers, alluvial fans, playas, and alkali flats (Stebbins 1985), extending into foothills and mountains to an elevation of 1,360 meters (4,462 feet) (Jennings and Hayes 1994). Western spadefoot toads select areas with sandy or gravelly soil with open vegetation and short grasses. Vegetation communities where this species may occur include valley and foothill grasslands, open chaparral, and pine-oak woodlands (USFWS 2005).

Western spadefoot toads require two distinct habitat components to complete their life cycle, and these habitats may need to be in close proximity (USFWS 2005). These components are presence of an aquatic habitat for breeding and a terrestrial habitat for feeding and aestivation. Western spadefoot toads are mostly terrestrial, using upland habitats to feed and burrow in for their long dry-season dormancy. Further research is needed to determine the distance this species may travel from aquatic habitats to upland habitats for dispersal and aestivation. Current research on amphibian conservation suggests that average terrestrial habitat use is within 368 meters (1,207 feet) of aquatic habitats (Semlitsch and Brodie 2003).

Western spadefoot toads lay their eggs in a variety of permanent and temporary wetlands including rivers, creeks, pools in intermittent streams, vernal pools, and temporary rain pools (CNDDB 2009) as well as stock ponds. This species reproduces in water when temperatures are between 48 °F and 86 °F, and water must be present for more than three weeks for metamorphosis to be completed (Jennings and Hayes 1994).

DRAFT

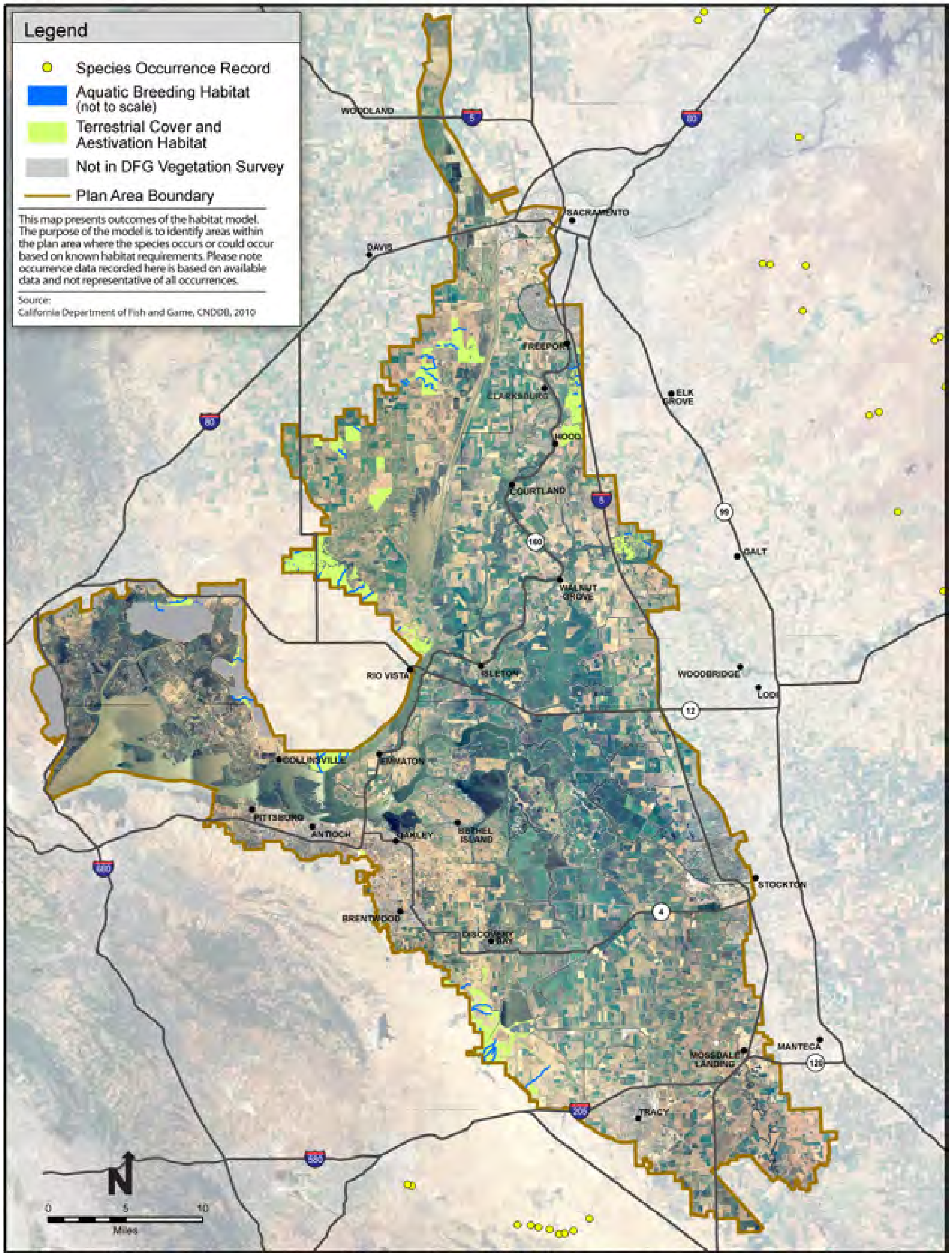

Figure A-33b. Western Spadefoot Toad Habitat Model and Recorded Occurrences

Optimal habitat in vernal pools and other temporary wetlands used for reproduction is free of native and nonnative predators, including fishes, bullfrogs, and crayfishes. Western spadefoot toads may be unable to recruit successfully in the presence of these predators (Jennings and Hayes 1994).

During dry periods, individuals typically excavate burrows into the ground at depths up to 3 feet, but they may also occupy burrows constructed by small mammals; whether these are used as short-term refugia during periods of surface activity is unknown (Jennings and Hayes 1994). Adult western spadefoot toads can consume roughly 11 percent of their body mass at a single feeding (Dimmitt and Ruibal 1980b), and can probably acquire the resources needed for aestivation in just a few weeks (Jennings and Hayes 1994). This aestivation period may continue for nine months at a time (Jennings and Hayes 1994). The skin of western spadefoots is very permeable, enabling them to absorb moisture from the surrounding soil. Spadefoots may also be able to retain urea, increasing their internal osmotic pressure, thereby preventing water loss and facilitating water absorption from soils with relatively high moisture tensions (Ruibal et al. 1969, Shoemaker et al. 1969).

Natural predators of larval and post-metamorphic western spadefoot toads include raccoons (*Procyon lotor*), garter snakes (*Thamnophis* spp.), great blue herons (*Ardea alba*), and California tiger salamanders (*Ambystoma californiense*) (Childs 1953). There are indications that the presence of introduced predators in breeding pools, such as mosquitofish (*Gambusia affinis*), crayfish (order Decapoda), and bullfrogs (*Rana catesbeiana*) may prevent recruitment (Jennings and Hayes 1994).

Although the degree to which predation affects the population dynamics of western spadefoot toads is poorly understood, their extended period of aestivation reduces exposure to predators. Spadefoot toads also produce toxic dermal secretions that deter predation (Duellman and Trueb 1986). Feaver (1971) noted that California tiger salamander larvae preyed on western spadefoot toad larvae whenever the two species co-occurred, and California tiger salamander larvae metamorphosed first. However, Anderson (1968) found that if larvae of the two species are the same size, predation may not occur.

A33.4 LIFE HISTORY

Description. The western spadefoot toad is a smooth-skinned, grayish-green toad with gold-colored eyes. The belly is white, and often the back will have orange or red spots. It is usually 1.5 to 2.5 inches long with a characteristic wedge-shaped spade on its rear feet.

Seasonal Patterns. Movement patterns and colonization abilities of the adult western spadefoot toad are not fully understood (Jennings and Hayes 1994). The western spadefoot toad is primarily a terrestrial amphibian and enters the water mainly for reproduction. They typically emerge at night during periods of warm rainfall to forage (Stebbins 1972). Emerging from burrows constructed in loose soil at least three feet deep (Stebbins 1972), they move toward breeding sites in late winter to spring, in response to favorable temperatures and rainfall (Morey and Guinn 1992). The breeding season is brief (Stebbins 2003), sometimes lasting no more than one to two weeks. Following breeding, individuals return to upland habitats, where they spend most of the year aestivating (in a dormant state) in burrows. The western spadefoot toad may breed in the same ponds as California tiger salamanders in areas where the two species are sympatric (CNDDB 2009).

Reproduction. Western spadefoot toads breed from January to May. Breeding aggregations can form with over 1,000 individuals, but the aggregations are usually much smaller. These groups are highly vocal, and breeding calls can be heard at great distances. These calls help individuals find each other to form breeding aggregations and suitable breeding sites (Stebbins 1985). Oviposition (egg-laying) will not occur until water temperatures reach the critical thermal minimum of 9 °C (48 °F), usually between late February and late May (Jennings and Hayes 1994). Females deposit their eggs in many small irregularly cylindrical clusters of 10 to 42 eggs with an average of 24 (Storer 1925) on stems or pieces of detritus in temporary rain pools, or sometimes in pools of ephemeral stream courses (Storer 1925, Stebbins 1985).

Depending on temperature and availability of food, eggs will hatch within 0.6 to 6 days after oviposition; and larvae can complete development in 3 to 11 weeks (Jennings and Hayes 1994). If the water temperature is too high, above 21 °C (70 °F), hatching success of the eggs may decrease by half possibly due to more favorable temperatures for destructive fungus (Storer 1925).

Metamorphosing larvae may leave the water before their tails fully disappear, and sometimes have tails longer than 0.4 inches (Storer 1925). Larvae benefit from longer periods of development with persisting water and adequate temperatures that allow juveniles to reach larger sizes with greater fat reserves at metamorphosis (Morey 1998). After the juveniles emerge from the water, they take refuge in the surrounding area and may remain nearby for several days before dispersing to adjacent upland habitat. These individuals will then construct subterranean burrows and remain dormant for the following eight to nine months during the warmer summer months to avoid desiccation. Individuals may require at least two years to reach sexual maturity (Jennings and Hayes 1994).

Diet. Adult western spadefoot toads feed on a variety of insects, worms, and other invertebrates, including grasshoppers, true bugs, moths, ground beetles, predaceous diving beetles, ladybird beetles, click beetles, flies, ants, and earthworms (Morey and Guinn 1992, USFWS 2005). Tadpoles forage on planktonic organisms, algae, small invertebrates (Bragg 1964), and dead aquatic larvae of amphibians, even their own species.

A33.5 Threats and Stressors

The main factors contributing to the decline of the western spadefoot toad population include loss of habitat from urban development and conversion of native habitats to agricultural lands, the increase of introduced nonnative predators, and stochastic events that particularly impact small, isolated populations (USFWS 2006).

Habitat Loss and Fragmentation. The loss of vernal pool or other seasonal pool habitats due to land conversion is likely the greatest threat to the western spadefoot toad. More than 80 percent of occupied habitat in southern California and more than 30 percent in northern California have been lost to development or other incompatible land uses (Jennings and Hayes 1994).

Habitat fragmentation resulting from urban development, agricultural conversion, and road construction also threatens western spadefoot toad populations. The relationship between habitat fragmentation and the metapopulation structure of the western spadefoot toad is not entirely understood (Jennings and Hayes 1994); however, ongoing land conversion is undoubtedly resulting in smaller, isolated populations. Habitat loss and fragmentation produces small populations that are increasingly isolated and limited in space. This reduces the movement of individuals and genetic exchange between populations. Small, isolated populations are highly susceptible to extinction caused by catastrophic or stochastic events. Isolation limits the ability of the population to recolonize areas with suitable habitat where western spadefoot toads may have been present in the past.

Agricultural practices such as disking and intensive livestock grazing and trampling have degraded many remaining vernal pools and wetland habitats, along with off-road vehicle use and contaminated runoff. Roads can create a barrier to dispersal movements of western spadefoot toads and isolate populations. Contaminants from road materials, leaks, and spills could further degrade aquatic habitats used by this species. Direct mortality of toads may occur when toads burrow in actively tilled fields, or are hit by vehicles when dispersing across roads.

Noise and Vibration. Low frequency noise and vibration in or near habitat for western spadefoot toads may be harmful, even fatal, to this species. Spadefoot toads are extremely sensitive to such stimuli, and it causes them to break dormancy and emerge from their burrows (Dimmitt and Ruibal 1980a). This could result in mortality or reduced productivity if it causes western spadefoot toads to emerge at inappropriate times (USFWS 2005).

Potential anthropogenic sources of such low-frequency noises and vibrations include seismic exploration for natural gas, land grading, or other motorized vehicles or machinery. Artificial irrigation can induce spadefoot toads to emerge and begin vocalizing in any month (Zeiner et al. 1988).

Nonnative Predators. Nonnative invasive species are also a threat to the western spadefoot toad. The predation of spadefoot toad eggs and larvae by mosquitofish introduced into vernal pools through mosquito abatement programs may threaten some populations (Jennings and Hayes 1994). Bullfrogs, which have been reported to emigrate to some western spadefoot toad breeding pools, may threaten those populations through predation of spadefoot toad eggs and larvae. Exotic predators such as mosquitofish may also compete with western spadefoot toad larvae for limited food resources.

A33.6 Relevant Conservation Efforts

Understanding the life history and important habitat requirements of the western spadefoot toad is essential for conservation of the species (Jennings and Hayes 1994). Jennings and Hayes (1994) state that the most significant data gap related to understanding western spadefoot toad populations is the relationship between habitat fragmentation and metapopulation structure. Movement patterns and colonization abilities of adult western spadefoot toads are also not fully understood. While habitat protection remains the primary strategy for conserving the western spadefoot toad, more research is required to better understand the species' habitat requirements with respect to patch sizes, movement corridors, and other elements of conservation design strategies.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designates the western spadefoot toad as "Maintain" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions to maintain the species by avoiding, minimizing, and compensating for any adverse effects to the species created by ERP restoration actions. To the extent practicable, the ERP will improve species habitat conditions.

Western spadefoot toad is a covered species under the approved San Joaquin County Multi-Species Habitat Conservation and Open Space Plan, and the Natomas Basin Habitat Conservation Plan. Western spadefoot toad is proposed for coverage under the South Sacramento County Habitat Conservation Plan, the Yolo County Natural Heritage Program Plan, and the Butte Regional Conservation Plan.

A33.7 Species Habitat Suitability Model

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information systems (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf 2007. Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers, connectivity between habitat types, and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The western spadefoot toad model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), USDA 2005 aerial photography, and DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable western spadefoot toad habitat in the Plan Area according to the species' two primary life requisites: aquatic breeding habitat and terrestrial feeding and aestivation habitat. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Terrestrial Cover and Aestivation Habitat. Terrestrial habitat is defined as all grassland types with a minimum patch size of 100 acres (40.5 hectares) located west of the Deep Water Ship

Channel; east of the Sacramento River between Freeport and Hood-Franklin Road; east of I-5 between Twin Cities Road and the Mokelumne River; and within the area south and west of Highway 4 from Antioch (Bypass Road to Balfour Road to Brentwood Boulevard) to Old River; then south along Old River to Clifton Court Forebay; along the west and south sides of Clifton Court Forebay to Old River; then south along the county line to Byron Highway; then west of Byron Highway to I-205, north of I-205 to I-580, and west of I-580. Grasslands associated with the Montezuma Hills and Potrero Hills were also included. Grassland strips solely occurring atop levees and not adjacent to grassland areas were excluded. Patches of grassland that were below the 100-acre minimum patch size but were contiguous with grasslands outside of the Plan Area boundary were included.

Terrestrial feeding and aestivation habitat includes the following grassland and alkali seasonal wetland complex types from the BDCP composite vegetation layer:

- Grassland
  - Ruderal herbaceous grasses and forbs;
  - California annual grasslands;
  - *Bromus diandrus-Bromus hordeaceus;*
  - Italian rye-grass (*Lolium multiflorum*);
  - *Lolium mulitflorum – Convolvulus arvensis;*
  - Degraded vernal pool complex – California annual grasslands;
  - Degraded vernal pool complex – ruderal herbaceous grasses and forbs;
  - Degraded vernal pool complex – Italian rye-grass (Lolium multiflorum);
  - Annual grasses generic;
  - Annual grasses/weeds;
  - *Bromus* spp./*Hordeum;*
  - *Hordeum/Lolium;*
  - *Lolium* (generic);
  - *Lotus corniculatus;*
  - Medium upland graminoids;
  - Medium upland herbs;
  - Perennial grass;
  - Short upland graminoids;
  - Upland annual grasslands and forbs formation; and

- Upland herbs.
- Alkali seasonal wetland complex
  - *Distichlis spicata* – annual grasses.

Assumptions. There are no reported occurrences of western spadefoot toad from the Plan Area. The nearest reported occurrences are in the foothill grasslands west of I-505 and south of I-205 southwest of the Plan Area.

Habitat for western spadefoot toad includes vernal pools and seasonal and perennial ponds, and seasonal streams within a grassland landscape (Jennings and Hayes 1994, USFWS 2005). Because the mapping of aquatic breeding habitats within the Plan Area is incomplete, this element cannot be effectively used to model the extent of suitable habitat for this species. Thus, grasslands are used to more generally describe the extent of suitable habitat.

Western spadefoot toad requires relatively large grassland landscapes and is unlikely to occur in fragmented or isolated patches of otherwise suitable habitat. A 100-acre minimum was selected to exclude very small and isolated patches. This generally corresponds to data from Semlitsch and Brodie (2003), who calculated a minimum patch size of 134 acres (54 hectares) to meet the ecological requirements of the species. Grasslands located along the narrow eastern edge of the Suisun Marsh that were contiguous with the larger grassland/agricultural landscape of the Montezuma Hills were reviewed and removed from the terrestrial cover and aestivation habitat component of the model because most appeared transitional to the tidal marsh wetlands that are not suitable for western spadefoot toad.

Cultivated habitats do not provide terrestrial habitat for western spadefoot toads because cultivation disrupts aestivation.

The model is further constrained geographically by eliminating grasslands that are not within seasonal pool or pond/grassland landscapes, such as the central Delta. While periodic flooding may preclude spadefoot toad from occurring in the Yolo Bypass, the vernal pool landscape on the DFG's Tule Ranch Unit and other similar areas on the DFG Yolo Bypass Wildlife Area could potentially support this species in some years. These areas are mapped as Alkali Seasonal Wetland Complex (*Distichlis spicata*-annual grasses); however, they have a substantial grassland component. The model overestimates suitable habitat by assuming there are sufficient aquatic breeding habitats within the grassland landscape as defined.

Aquatic Breeding Habitat. Aquatic habitats include a variety of permanent and temporary wetlands including pools in streams, ponds (including stock ponds), and vernal pools. Aquatic breeding habitat includes the following land cover types and conditions that are within the grassland landscape as defined above:

- Perennial and intermittent streams

- Aquatic breeding habitat includes the following other natural seasonal wetland types from the BDCP composite vegetation layer:
    - Vernal pools; and
    - Degraded vernal pool complex-vernal pools.
- Aquatic breeding habitat includes the following vernal pool complex types from the BDCP composite vegetation layer:
    - *Allenrolfea occidentalis* mapping unit;
    - Annual grasses generic;
    - Annual grasses/weeds;
    - California annual grasslands-herbaceous;
    - *Distichlis* (generic);
    - *Distichlis*/annual grasses;
    - *Distichlis*/*S. maritimus;*
    - *Distichlis spicata;*
    - *Distichlis spicata* – annual grasses;
    - Italian rye-grass (*Lolium multiflorum*);
    - Mix *Scirpus* mapping unit;
    - Ruderal herbaceous grasses and forbes;
    - *Salicornia virginica;*
    - *Salicornia*/annual grasses;
    - Salt scalds and associated sparse vegetation;
    - Saltgrass (*Distichlis spicata*);
    - Seasonally flooded grasslands;
    - *Suadeda moquinii* – (*Lasthenia californica*) mapping unit; and
    - Vernal pools.

Aquatic habitat types in the Suisun Marsh and Yolo Basin from the BDCP composite vegetation layer include:

- Freshwater drainage; and
- Slough.

Assumptions. Aquatic breeding habitats are mapped to the extent data are available, but not used as a model attribute. The data are insufficient to effectively model western spadefoot toad habitat on the basis of aquatic breeding habitat.

Proximity of aquatic breeding habitat and terrestrial habitat is an important element of spadefoot toad life history (current research suggests that average terrestrial habitat use is within 368 meters [1,207 feet] of aquatic habitat [Semlitsch and Brodie 2003]); however, due to the insufficient mapping of the vernal pools, stock ponds, and other small aquatic habitats in the Plan Area, this was not used as a factor in the model. Furthermore, the vernal pool complex natural community was used to represent aquatic breeding habitat, which is comprised of a combination of aquatic and upland habitat that is considered suitable for western spadefoot toad. Potential habitat included within the vernal complex natural community not having concave surfaces or land uses that are incompatible with the species' habitat requirements were removed from the aquatic breeding habitat component of the model.

A33.8 RECOVERY GOALS

While not federally listed, the western spadefoot toad was included in the "Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon" (USFWS 2005). The USFWS's stated goals for the western spadefoot toad and 12 other species of special concern covered under the Recovery Plan are to achieve and protect in perpetuity self-sustaining populations of each species and ensure the species' long-term conservation. The primary focus of the Recovery Plan is protection of vernal pool habitat—in the largest blocks possible—from loss, fragmentation, degradation, and incompatible uses (USFWS 2005). For the western spadefoot toad, the Recovery Plan calls for:

- Conducting research on juvenile and adult dispersal to and from breeding locations,
- Conducting research on the effects of habitat management practices on the western spadefoot toad and their habitat in order to determine the limiting factors with respect to determining minimum reserve sizes,
- Studying the impacts of low-frequency noises and vibrations, and
- Determining the influence of nonnative aquatic vertebrate predators (e.g., bullfrogs and mosquitofish) on population dynamics.

The overall goals of the Vernal Pool Recovery Plan, are to "achieve and protect in perpetuity self-sustaining populations throughout the full ecological, geographical, and genetic range of each listed species by ameliorating or eliminating the threats that caused the species to be listed" (USFWS 2005). Specifically for western spadefoot toad, the goal is to ensure long-term conservation. The Vernal Pool Recovery Plan concluded that:

"Based on calculations from upland habitat use data analyzed by Semlitsch and Brodie (2003), a minimum conservation area to preserve the ecological processes required for the conservation of amphibians may fall within a distance of approximately 368 meters (1,207 feet) from suitable breeding wetlands. Given a square preserve surrounding a single breeding pond, this estimate would suggest a minimum preserve size of approximately 54.2 hectares (134 acres). In any given western spadefoot toad metapopulation, we expect that some subpopulations will disappear, but the habitat they occupied will eventually be recolonized if it remains acceptable. To enable natural recolonization of unoccupied habitat, and to allow for gene flow that is vital for preventing inbreeding, opportunities for dispersal and interbreeding among subpopulations of the western spadefoot toad must be maintained. Where possible, habitat corridors between breeding sites should be protected and maintained."

A33.9 REFERENCES

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APPENDIX A34. CALIFORNIA TIGER SALAMANDER (*AMBYSTOMA CALIFORNIENSE*)

A34.1 LEGAL STATUS

The California tiger salamander (*Ambystoma californiense*) is federally listed range-wide as a threatened species (69 FR 47212) and in Sonoma and Santa Barbara counties as endangered (65 FR 57242, 68 FR 13498). The species is also designated as a species of special concern by the California Department of Fish and Game (DFG) (Jennings and Hayes 1994) and as of February 2009 is a candidate for state listing. DFG is currently conducting a status review.

On September 22, 2005, the United States Fish and Wildlife Service (USFWS) designated approximately 199,109 acres (80,576 hectares) of critical habitat for the Central California population. The critical habitat is located within 19 California counties (70 FR 49380). In a December 2005 Final Rule, the USFWS designated but excluded approximately 17,418 acres (7,049 hectares) of critical habitat for the Sonoma County population, stating that interim conservation strategies and measures being implemented by local governing agencies with land use authority over the area, along with economic exclusions authorized under section 4(b)(2) of the federal Endangered Species Act, would be greater than would be achieved through critical habitat (70 FR 74138). On May 6, 2009, the USFWS announced settlement of a lawsuit that challenged its 2005 final decision on proposed critical habitat for the Sonoma County population. In the settlement, the Service agreed to re-propose as critical habitat the same 74,223 acres (30,037 hectares) of the Santa Rosa Plain that it had originally proposed in August 2005 as critical habitat.

A34.2 SPECIES DISTRIBUTION AND STATUS

A34.2.1 Range and Status

The California tiger salamander is endemic to California (Barry and Shaffer 1994, Loredo et al. 1996). Historically, the species occurred throughout the grassland and woodland areas of the Sacramento and San Joaquin River valleys and surrounding foothills, and in the lower elevations of the central Coast Ranges (Barry and Shaffer 1994) (Figure A-34a). The species is found in a relatively xeric landscape where its range is limited by its aestivation and winter breeding habitat requirements, which is generally defined as open grassland landscapes with ephemeral pools and with burrowing squirrels and pocket gophers (Barry and Shaffer 1994).

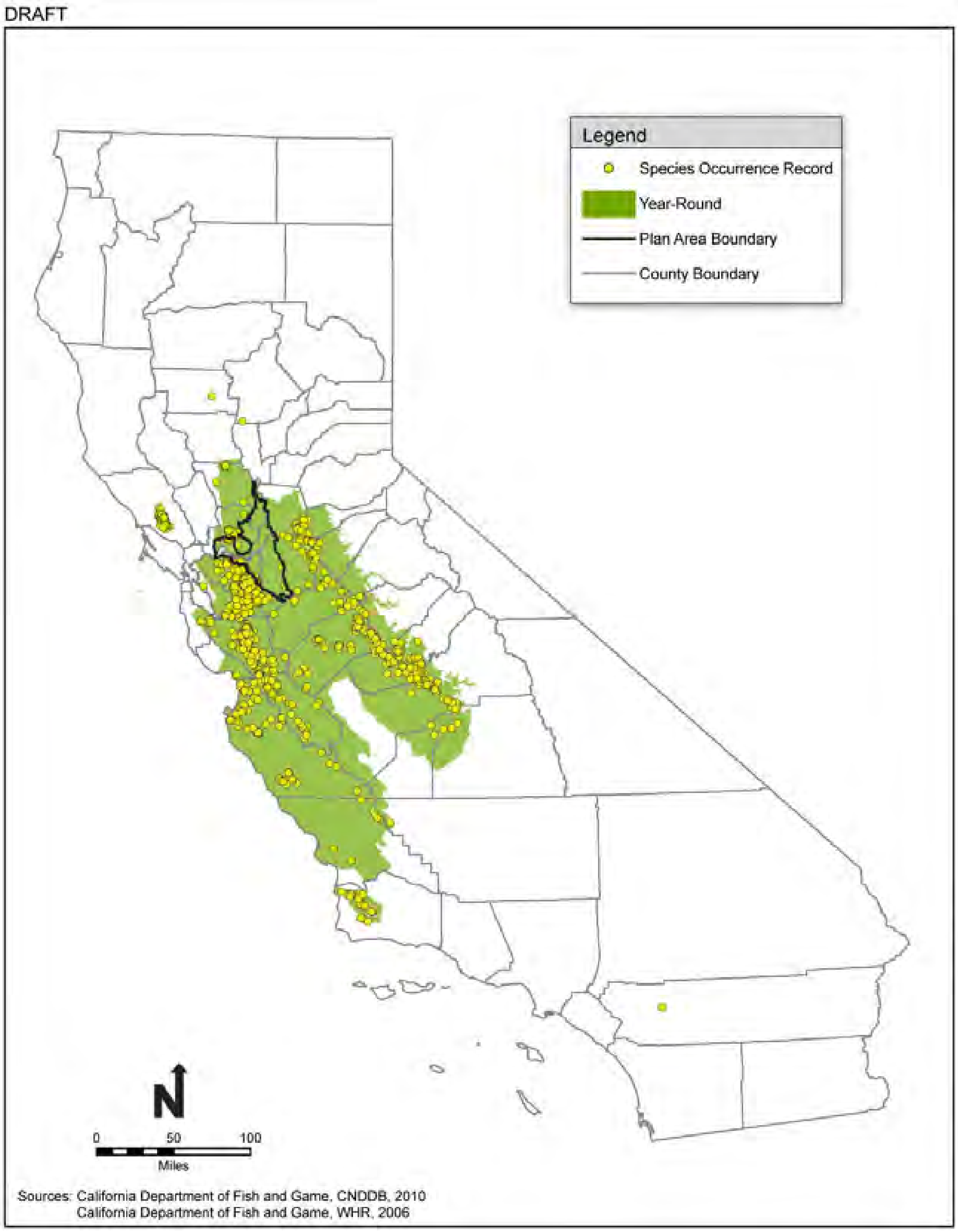

Figure A-34a. California Tiger Salamander Statewide Range and Recorded Occurrences

Within the coastal range, the species currently occurs from southern San Mateo County south to San Luis Obispo County, with isolated populations in Sonoma and northwestern Santa Barbara counties (CNDDB 2009). In the Central Valley and surrounding Sierra Nevada foothills, the species occurs from northern Yolo County southward to northwestern Kern County and northern Tulare and Kings counties (CNDDB 2009).

California tiger salamanders still occur throughout much of their historical range (Trenham et al. 2000) and can be common at localities where it still occurs. Total adult population size is unknown, but populations are thought to be declining due to habitat loss. An estimated 80 percent of the species' historical natural aquatic (i.e., vernal pool) habitat has been lost (Holland 1998) and the species has been eliminated from 55 to 58 percent of historical breeding sites (Barry and Shaffer 1994). Shaffer et al. (1993) also estimated that as much as 75 percent of the historical grassland habitat in the Central Valley used by California tiger salamander has been lost.

A34.2.2 Distribution and Status in the Plan Area

CNDDB (2009) reports several occurrences within the Plan Area immediately west of Clifton Court Forebay (Figure A-34b). There are numerous additional occurrences in vernal pool and pond habitats in the grassland foothills immediately west of the Plan Area between Corral Hollow and south of Antioch. Potential habitat exists in vernal pool habitats in Yolo and Solano counties west of Liberty Island and in the vicinity of Stone Lakes in Sacramento County.

A34.3 Habitat Requirements and Special Conditions

The California Tiger Salamander is found in annual grasslands and open woodland communities in lowland and foothill regions of central California where aquatic sites are available for breeding (USFWS 2003). The species is typically found at elevations below 460 meters (1,509 feet) (68 FR 13498), although the known elevational range extends up to 1,053 meters (3,455 feet) (Jennings and Hayes 1994). Ecological characteristics of this area include dry soils, needlegrass grasslands, valley oaks, coast live oaks and ephemerally flooded claypan vernal pools (USFWS 2003).

Vernal pools and other seasonal rain pools are the primary breeding habitat of California tiger salamanders (Barry and Shaffer 1994, 68 FR 13498). However, because the species requires at least 10 weeks of pool inundation in order to complete metamorphosis of larvae (Anderson 1968a, Feaver 1971), California tiger salamanders are usually only found in the largest vernal pools (Laabs et al. 2001). The species is also known to successfully reproduce in ponds, including artificial stock ponds (Barry and Shaffer 1994, 69 FR 47212). In the East Bay Regional Park District in Contra Costa and Alameda counties, California tiger salamanders breed almost exclusively in seasonal and perennial stock ponds (Bobzien and DiDonato 2007).

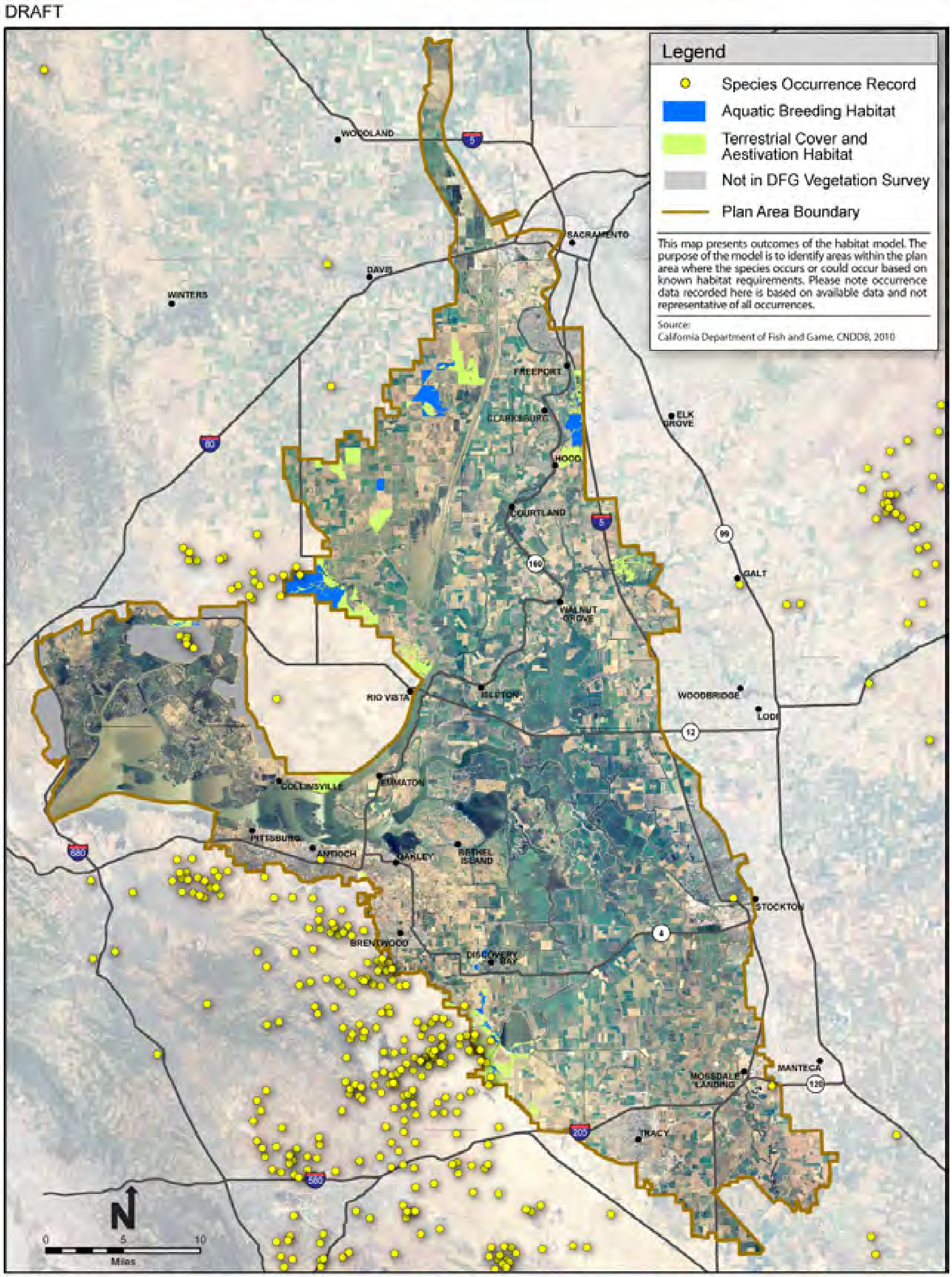

Figure A-34b. California Tiger Salamander Habitat Model and Recorded Occurrences

However, the presence of predatory fish and bullfrogs (*Rana catesbeiana*) can affect the suitability of perennial ponds (Holomuzki 1986, Fitzpatrick and Shaffer 2004). Barry and Shaffer (1994) note that stock ponds can be productive breeding sites as long as they are drained annually, which can prevent predatory species from establishing.

Adult California tiger salamanders are terrestrial and occur most of the year (six to nine months) in grassland and open woodland habitats where they find cover and aestivation sites in the underground burrows of small mammals, such as California ground squirrels (*Spermophilus beecheyi*) and Botta's pocket gopher (*Thomomys bottae*) (Storer 1925, Loredo and Van Vuren 1996, Petranka 1998, Trenham 1998a). Active rodent burrow systems are considered an important component of California tiger salamander upland habitat (Seymour and Westphal 1994, Loredo et al. 1996). Loredo et al. (1996) indicate that active ground-burrowing rodent populations are probably necessary to sustain California tiger salamander populations because inactive burrow systems begin to deteriorate and collapse over time. In a two-year radiotelemetry project in Monterey County (Hastings), Trenham (2001) found that salamanders preferentially used open grassland and isolated oaks; salamanders present in continuous woody vegetation were never more than 3 meters (10 feet) from open grassland, potentially because ground squirrels prefer to construct burrows in open habitats (Jameson and Peeters 1988 in Trenham 2001).

A34.4 LIFE HISTORY

Description. The California tiger salamander is large and thickset, with a wide, rounded snout (69 FR 47212). Average total length of males is 20.3 centimeters (cm) (8 inches) and average total length of females is 17.3 cm (6.8 inches) (69 FR 47212). Dorsal coloration consists of a black background on the back and sides, interspersed with white or pale yellow spots or bars (69 FR 47212). Ventral coloration ranges from almost uniform white or pale yellow to a variegated pattern of white, pale yellow, and black (Jennings and Hayes 1994). The salamander's small eyes have black irises and protrude from their heads (Jennings and Hayes 1994). During the breeding season, the cloacal region of males becomes enlarged (Petranka 1998) and is a useful means of distinguishing sexes. Males also have larger tails with more developed fins.

Activity Patterns. Adults emerge from upland sites on rainy nights during fall and winter rains to feed and migrate to breeding ponds (Stebbins 1989, 2003, Shaffer et al. 1993). Adults generally use the same traditional migratory routes between breeding pools and upland burrows each year (Loredo et al. 1996, Petranka 1998). Metamorphosed juveniles leave the breeding sites in late spring or early summer and migrate to small mammal burrows (Zeiner et al. 1988, Shaffer et al. 1993, Loredo et al. 1996). Like adults, juveniles may emerge from burrows to feed during nights of high relative humidity (Storer 1925, Shaffer et al. 1993) before settling in their selected upland sites for the summer months. California tiger salamanders are also active in and feed while in burrows (van Hattem 2004). While most California tiger salamanders rely on rodent burrows for shelter, some individuals may utilize soil crevices as temporary shelter during upland migrations (Loredo et al. 1996).

Reproduction. California tiger salamanders breed and lay eggs in vernal pools and ponds following relatively warm rains between November and February (Shaffer and Fisher 1991). Adults engage in mass migration (however, only a portion of the adult population emerges from underground burrows to breed in any give year) during a few rainy nights and leave the breeding ponds shortly after breeding. Males usually migrate to the breeding pond before females (Twitty 1941, Shaffer et al. 1993, Loredo and Van Vuren 1996, Trenham 1998b) and remain in the ponds for an average of 6 to 8 weeks, while females stay for approximately 1 to 2 weeks (69 FR 47212). Breeding activity occurs in pulses depending on rainfall patterns and wetland inundation. In drought years, insufficient water in the breeding pools may prevent breeding (Barry and Shaffer 1994). Late rains may also affect breeding opportunities and reproductive success (Trenham et al. 2000). Barry and Shaffer (1994) suggest that while local California tiger salamander populations may not breed during drought years when ephemeral pools do not fill, the longevity of adults is probably sufficient to ensure population persistence through all but the longest of droughts.

After mating, females lay eggs in the water and attach them singly or in small groups to underwater vegetation including twigs, grass stems, or other debris (Storer 1925, Twitty 1941, Jennings and Hayes 1994). Following breeding, adults leave the pool and return to the upland habitat, emerging at night to feed during the breeding season (Shaffer et al. 1993, Loredo et al. 1996, Trenham 1998a). Eggs hatch into aquatic larvae in two to four weeks (Petranka 1998). Larvae metamorphose during the summer and migrate from the ponds at night during dry weather. The larval stage usually lasts 3 to 6 months (Petranka 1998), but individuals may remain in their breeding sites over the summer if breeding pools remain inundated (Shaffer and Trenham 2005). The longer the inundation period, the larger the larvae and metamorphosed juveniles are able to grow, and the more likely they are to survive and reproduce (Semlitsch et al. 1988, Pechmann et al. 1989, Morey 1998, Trenham 1998b).

Movements and Spatial Considerations. The distance between occupied upland habitat and breeding sites depends on local topography and vegetation, and the distribution of California ground squirrel or other rodent burrows (Stebbins 1989). While juvenile California tiger salamanders have been observed to disperse up to 2.59 kilometers (km) (1.6 miles) from breeding pools to upland areas (Austin and Shaffer 1992) and adults have been observed up to 2 km (1.2 miles) from breeding ponds, most movements are closer to the breeding pond. Trenham et al. (2001) observed California tiger salamanders moving up to 670 meters (0.42 miles) between breeding ponds in Monterey County. Similarly, Shaffer and Trenham (2005) found that 95 percent of California tiger salamanders resided within 640 meters (0.4 miles) of their breeding pond at Jepson Prairie in Solano County.

Interconnectivity of breeding sites may be an important factor in long-term conservation of this species in order to sustain the species' metapopulation structure, where local extinction and recolonization by migrants of other subpopulations are probably common (69 FR 47212). Thus, providing movement corridors between potential breeding sites and avoiding isolation of these sites may be important to counterbalance the effects of normal ecological processes (e.g., drought) that may result in local extinctions by allowing for movements to new sites and facilitating recolonization (Semlitsch et al. 1996).

Diet. Adults probably feed mainly on a variety of invertebrates, including earthworms, snails, and insects, as well as fish and small mammals (Stebbins 1972, Lindquist and Bachmann 1980). Aquatic larvae feed on littoral, benthic, and planktonic arthropods (Anderson 1968b).

A34.5 Threats and Stressors

Urbanization/Habitat Fragmentation. Conversion of land to residential, commercial, and agricultural activities is considered the most significant threat to California tiger salamanders. These activities result in destruction and fragmentation of upland and/or aquatic breeding habitat, and killing of individual California tiger salamanders (Twitty 1941, Hansen and Tremper 1993, Shaffer et al. 1993, Jennings and Hayes 1994, Fisher and Shaffer 1996, Launer and Fee 1996, Loredo et al. 1996, Davidson et al. 2002).

Roads can fragment breeding and dispersal migratory routes in areas where they traverse occupied habitat. Features of road construction, such as solid road dividers, can further impede migration, as can other potential barriers such as berms, pipelines, and fences.

Nonnative Predators. Exotic species, such as bullfrog, mosquitofish (*Gambusia affinis*), sunfish species (e.g., largemouth bass [*Micropterus salmoides*] and bluegill [*Lepomis macrochirus*]), catfish (*Ictalurus* spp.), and fathead minnows (*Pimephales promelas*), that live in perennial ponds—such as stock ponds—are considered to have negatively affected California tiger salamander populations by preying on larval salamanders (Anderson 1968a, Morey and Guinn 1992, Graf and Allen-Diaz 1993, Shaffer et al. 1993, Seymour and Westphal 1994, Fisher and Shaffer 1996, Lawler et al. 1999, Laabs et al. 2001, Leyse 2005).

Fisher and Shaffer (1996) suggest that elevation may be a factor in local extirpations due to exotic predators. They suggest that introduced exotics are more common in low elevation aquatic habitats (below 200 meters [656 feet]) and that habitat modification and low levels of topographic relief may facilitate invasion by increasing opportunities for dispersal through interconnected watersheds or suitable terrestrial habitats, or through deposition by floodwaters (Fisher and Shaffer 1996).

Hybridization. Riley et al. (2003) examined hybridization between California tiger salamanders and an introduced congener, the tiger salamander (*Ambystoma tigrinum*). The tiger salamander had been deliberately introduced as fish bait in California and is thought to have contaminated the genome of California tiger salamanders through interbreeding (Riley et al. 2003). The sale and use of *A. trigrinum* as bait is now illegal in California. In the Salinas Valley, Riley et al. (2003) sampled salamanders from four artificial ponds and two natural vernal pools. Based on mitochondrial DNA and two nuclear loci, Riley et al. (2003) found that hybrids were present in all six ponds, and that these hybrids were viable and fertile. Hybridization with the barred tiger salamander (*Ambystoma tigrinum mavortium*) has been occurring since fishermen and bait shop owners began introducing the species 50-60 years ago, resulting in 15-30 generations of genetic mixing (Fitzpatrick and Shaffer 2004). Fitzpatrick and Shaffer (2004) report more nonnative alleles in large perennial ponds despite the proximity of ephemeral ponds, perhaps attributable to the presence of open water refugia providing an extended breeding season or facilitating a paedomorphic life history strategy in which adult nonnative salamanders retain larval characteristics. Fitzpatrick and Shaffer (2007) report evidence of hybrid vigor or increased fitness of hybrids based on early-larval survival (Yolo Natural Heritage Program 2009).

Pesticides. Pesticides, hydrocarbons, and other pollutants are all thought to negatively affect breeding habitat, while rodenticides and gases used in burrowing mammal control (e.g., chlorophacinone, diphacinone, strychnine, aluminum phosphide, carbon monoxide, and methyl bromide) are considered toxic to adult salamanders (Salmon and Schmidt 1984). California ground squirrel and pocket gopher control operations may have the indirect effect of reducing the availability of upland burrows for use by California tiger salamanders (Loredo-Prendeville et al. 1994).

A34.6 RELEVANT CONSERVATION EFFORTS

Critical habitat has been designated within 19 counties in central California (70 FR 49380). However, there are no critical habitat units within the Plan Area. A critical habitat unit initially planned for East Contra Costa County was rejected because the East Contra Costa County Habitat Conservation Plan/Natural Communities Conservation Plan (under which the California tiger salamander is a covered species) was permitted and operable and is expected to sufficiently address conservation of the species within that area. Occupied sites within the Plan Area are within the East Contra Costa County Habitat Conservation Plan/Natural Communities Conservation Plan Area.

A conservation strategy for the Santa Rosa Plains population of California tiger salamander and other sensitive species has been finalized (USFWS 2005); however, the local implementing agencies have to date been unsuccessful in adopting implementing ordinances or acquiring funding. The plan establishes conservation areas throughout the plan area and guidance regarding preserve acquisition and management, habitat enhancement, and mitigation.

Several other habitat conservation plans that address California tiger salamander are either in progress or are operational. Plans that overlap or are near the Plan Area and include the California tiger salamander as a covered species are the East Contra Costa County Habitat

Conservation Plan/Natural Community Conservation Plan, the San Joaquin County Multi-Species Habitat Conservation and Open Space Plan, the Natomas Basin Habitat Conservation Plan, the Yolo Natural Heritage Program Plan, the South Sacramento County Habitat Conservation Plan, the Solano County Multispecies Habitat Conservation Plan, and the Butte Regional Habitat Conservation Plan and Natural Community Conservation Plan. Each does or will include conservation measures to protect and restore populations and habitat for this species.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for the California tiger salamander is "Maintain" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions to maintain the species by avoiding, minimizing, and compensating for any adverse effects to the species created by ERP restoration actions. To the extent practicable, the ERP will improve species habitat conditions.

East Bay Regional Parks has established protections of California tiger salamander and California red-legged frogs on lands in the vicinity of the Los Vaqueros watershed, west of the Plan Area in Contra Costa and Alameda counties. Actions focus on protection of breeding sites, maintaining an intact landscape and protecting movement corridors, and managing grazing regimes.

In June 2009, East Bay Municipal Utility District and the USFWS finalized the largest environmental safe harbor agreement awarded to a single landowner. The 30-year agreement covers 28,000 acres of San Joaquin, Amador and Calaveras counties (USFWS 2009).

A34.7 Species Habitat Suitability Model

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, and cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf 2007. Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers, connectivity between habitat types, and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The California tiger salamander model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), USDA 2005 aerial photography, and DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable California tiger salamander habitat in the Plan Area according to the species' two primary life requisite parameters: aquatic breeding and terrestrial cover, and aestivation habitat. Vegetation types were assigned based on the species' requirements as described above and the assumptions described below.

Terrestrial Cover and Aestivation Habitat. Terrestrial habitat is defined as all grassland types with a minimum patch size of 100 acres (40.5 hectares) located west of the Yolo Basin but including the Tule Ranch Unit of DFG's Yolo Basin Wildlife Area; east of the Sacramento River between Freeport and Hood-Franklin Road; east of Interstate 5 (I-5) between Twin Cities Road and the Mokelumne River; and within the area south and west of Highway 4 from Antioch (Bypass Road to Balfour Road to Brentwood Boulevard) to Old River; then south along Old

River to Clifton Court Forebay; along the west and south sides of Clifton Court Forebay to Old River; then south along the county line to Byron Highway; then west of Byron Highway to I-205, north of I-205 to I-580, and west of I-580. Grasslands associated with the south Montezuma Hills and Petrero Hills were also included. Grassland strips solely occurring atop levees and not adjacent to grassland areas were excluded. Patches of grassland that were below the 100-acre minimum patch size but were contiguous with grasslands outside of the Plan Area boundary were included.

Terrestrial habitat includes the following types from the BDCP composite vegetation layer:

- Grassland
  - Ruderal herbaceous grasses and forbs;
  - California annual grasslands;
  - *Bromus diandrus-Bromus hordeaceus;*
  - Italian rye-grass (*Lolium multiflorum*);
  - *Lolium mulitflorum – Convolvulus arvensis;*
  - Degraded vernal pool complex – California annual grasslands;
  - Degraded vernal pool complex – ruderal herbaceous grasses and forbs;
  - Degraded vernal pool complex – Italian rye-grass (Lolium multiflorum);
  - Annual grasses generic;
  - Annual grasses/weeds;
  - *Bromus* spp./*Hordeum;*
  - *Hordeum/Lolium;*
  - *Lolium* (generic);
  - *Lotus corniculatus;*
  - Medium upland graminoids;
  - Medium upland herbs;
  - Perennial grass;
  - Short upland graminoids;
  - Upland annual grasslands and forbs formation; and
  - Upland herbs.
- Alkali seasonal wetland complex
  - *Distichlis spicata* – annual grasses.

Assumptions. Habitat for California tiger salamander includes vernal pools and seasonal and perennial ponds including artificial stock ponds within a grassland landscape (Barry and Shaffer 1994, 69 FR 47212, Bobzien and DiDonato 2007). Because the mapping of aquatic breeding habitats within the Plan Area is incomplete, this element cannot be effectively used to model the extent of suitable habitat for this species. Thus, grasslands are used to more generally describe the extent of suitable habitat. Minimum patch size is 100 acres, which corresponds with the minimum conservation patch size identified by Trenham (2009). Grasslands located along the narrow eastern edge of the Suisun Marsh that were contiguous with the larger grassland/agricultural landscape of the Montezuma Hills were reviewed and removed from the terrestrial cover and aestivation habitat component of the model because most appeared transitional to the tidal marsh wetlands that are not suitable for California tiger salamander. The model is further constrained geographically by eliminating grasslands that are not within seasonal pool or pond/grassland landscapes, such as the central Delta. While periodic flooding may preclude California tiger salamander from occurring in the Yolo Bypass, the vernal pool landscape on the DFG's Tule Ranch Unit and other similar areas on the DFG Yolo Bypass Wildlife Area could potentially support this species in some years. These areas are mapped as Alkali Seasonal Wetland Complex (*Distichlis spicata*-annual grasses); however, they have a substantial grassland component. The model overestimates suitable habitat by assuming there are sufficient aquatic breeding habitats within the grassland landscape as defined.

Aquatic Breeding Habitat. Aquatic breeding habitat for California tiger salamander includes vernal pools and seasonal and perennial ponds. Aquatic breeding habitat includes the following land cover types and conditions that are within the grassland landscape as defined above:

- Aquatic breeding habitat includes the following other natural seasonal wetland types from the BDCP composite vegetation layer:
    - Vernal pools;
    - Degraded vernal pool complex- vernal pools
- Vernal pool complex breeding habitat includes the following vernal pool complex types from the BDCP composite vegetation layer:
    - *Allenrolfea occidentalis* mapping unit;
    - Annual grasses generic;
    - Annual grasses/weeds;
    - California annual grasslands-herbaceous;
    - *Distichlis* (generic);
    - *Distichlis*/annual grasses;
    - *Distichlis*/*S. maritimus;*
    - *Distichlis spicata;*

- *Distichlis spicata* – annual grasses;
- Italian rye-grass (*Lolium multiflorum*);
- Mix *Scirpus* mapping unit;
- Ruderal herbaceous grasses and forbs;
- *Salicornia virginica;*
- *Salicornia*/annual grasses;
- Salt scalds and associated sparse vegetation;
- Saltgrass (*Distichlis spicata*);
- Seasonally flooded grasslands;
- *Suadeda moquinii* – (*Lasthenia californica*) mapping unit; and
- Vernal pools.

Assumptions. Aquatic breeding habitats are mapped to the extent data are available, but not used as a model attribute. The data for vernal pools and other seasonal wetlands and stock ponds are insufficient to effectively model California tiger salamander habitat on the basis of aquatic breeding habitat. Vernal pools and other seasonal rain pools are the primary breeding habitat of California tiger salamanders (Barry and Shaffer 1994, 68 FR 13498). While deeper and larger pools are more likely to be occupied (Anderson 1968a, Feaver 1971, Laabs et al. 2001), all vernal pools are considered here as potential habitat for this species. California tiger salamander is also known to successfully reproduce in ponds, including artificial stock ponds (Barry and Shaffer 1994, 69 FR 47212). Stock pond habitats are used almost exclusively at occupied sites on the western edge of the Plan Area and in the hills immediately west of the Plan Area (Bobzien and DiDonato 2007). Mapping of vernal pools and other isolated seasonal wetlands and stock ponds is incomplete. In lieu of this, the vernal pool complex natural community was used to represent aquatic breeding habitat, which is comprised of a combination of aquatic and upland habitat that is considered suitable for California tiger salamander. Potential habitat included within the vernal complex natural community not having concave surfaces or land uses that are incompatible with the species' habitat requirements were removed from the vernal pool complex breeding habitat component of the model. For example, polygons falling on lands that did not have characteristic vernal pool/swale signatures that would demonstrate seasonal inundation did not qualify for this habitat type. This element of the model overestimates the extent of potential breeding habitat.

A34.8 RECOVERY GOALS

A USFWS recovery plan has not yet been prepared for the California tiger salamander, although the USFWS (69 FR 47212) has stated its intention to do so. There are currently no recovery goals established for this species.

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APPENDIX A35. LANGE'S METALMARK BUTTERFLY (*APODEMIA MORMO LANGEI*)

A35.1 LEGAL STATUS

Lange's metalmark butterfly (*Apodemia mormo langei*) is listed as endangered under the Federal Endangered Species Act (June 1976) (41 FR 22041) but is not listed under the California Endangered Species Act. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G5T1/S1.1 which means that globally (G) the species is demonstrably secure to ineradicable due to being commonly found in the world, but the subspecies or variety (T) is has less than 6 viable element occurrences, less than 1,000 individuals, or less than 2,000 acres (809 hectares); and within the state (S) the threat level rank is "very threatened."

A35.2 SPECIES DISTRIBUTION AND STATUS

A35.2.1 Range and Status

The historical range of Lange's metalmark butterfly is uncertain as it has been collected from the Antioch Dune, near Brannan Island, and near the town of Oakley (Opler and Powell 1961, Arnold 1983, 2005). The collections from Brannan Island Oakley may have been vagrant individuals (hundreds of individuals per day) that had moved with the persistent upriver winds from the much larger populations that existed at the Antioch dune prior to the 1960s (Powell, pers. comm.). A reported genetic blending area along the inner southern Coast Range where there are colonies that are morphologically similar to Lange's metalmark butterfly (Opler and Powell 1961) has been recently shown to be genetically distinct (Powell, pers. comm.). Currently, Lange's metalmark is thought to be restricted to approximately 4 acres (1.6 hectares) of the 20-acre (8.1-hectare) remnant (plus an unknown amount of two Pacific Gas & Electric (PG&E) parcels that total 12 acres [4.9 hectares]) of a former 190-acre (77-hectare) dune near the city of Antioch, California (Arnold 1983, USFWS (1984, 2001, 2008, 2010) (Figure A-35a). It is one of 15 subspecies of *Apodemia mormo* in the state of California. There is a small red-orange central patch on the upper hind wing that separates this subspecies and the individuals of the genetic blending area mentioned above from the other subspecies (Opler and Powell 1961). Lange's metalmark is protected on the USFWS Antioch Dunes National Wildlife Refuge (NWR) and on the two small adjacent parcels owned by Pacific Gas & Electric which manages the property in cooperation with USFWS (USFWS 1984, 2001, 2008, 2010). Historical population estimates using peak count data have ranged up to approximately 2,300 individuals in 1999 but a steeply declining trend since 1999, with a peak flight count of only 45 individuals in 2006, triggered management actions including habitat restoration and a captive breeding and release program (Johnson et al. 2007, USFWS 2008, 2010).

Figure A-35a. Lange's Metalmark Butterfly Statewide Recorded Occurrences

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A35.2.2 Distribution and Status in the Plan Area

The recognized current distribution of Lange's metalmark is entirely within the Plan Area on the Antioch Dunes NWR and PG&E properties as described above (Figure A-35b). However, there apparently have been no recent searches for Lange's metalmark near Oakley or on Delta islands with deposits of Oakley sand soil (A. Shapiro in litt.) and colonies may have persisted in some of those areas if its host plant (discussed below) is present.

A35.3 HABITAT REQUIREMENTS AND SPECIAL CONSIDERATIONS

Lange's metalmark is entirely dependent on a particular white-flowered, sand-associated, ecotype of nakedstem buckwheat (*Eriogonum nudum* ssp. *auriculatum*) as its larval host plant and as its primary adult nectar plant. This particular ecotype has a later and longer blooming season than ecotypes growing on rocky areas nearby on Mt. Diablo. The dependence of Lange's metalmark on the plant extends to the leaf litter that accumulates near the base of large plants growing in large clumps (Arnold 1983). This ecotype of nakedstem buckwheat is currently only known from the former Antioch dune (Arnold 1983). For the buckwheat to function as habitat for Lange's metalmark it is critical that the individuals of nakedstem buckwheat be relatively large and robust, be more than three years old, be concentrated in fairly dense clumps, and that their leaf litter be undisturbed (Arnold 1983). The sandy soil of the former dune and the area near Oakley has been mapped as Oakley sand (Carpenter and Cosby 1939) and more recently as Delhi sand, 2 to 9 percent slopes (NRCS 2010). This soil is infertile with very uniform-textured fine sand and very little clay content. While the dune is localized immediately along the bank of the San Joaquin River, Oakley sand is also distributed from the dune to the southwest as a 5.5-mile (8.9-kilometer [km]) long by 2-mile (3.2-km) wide oblong patch (Carpenter and Cosby 1939).

Historically, based on early maps, charts, and a postcard dating from the early 1900s, the vegetation of the Antioch dune contained widely scattered large valley oaks, live oaks, various shrub species, and numerous herbaceous species (Howard and Arnold 1980, SFEI 2010). Very similar vegetation occurred 1.5 miles (2.4 km) southeast of the dune as a 3 mile (4.8 km) long by 1.5 mile (2.4 km) wide 3,000-acre (1214-acre) oblong patch on the Oakley sand soil southwest of Oakley (SFEI 2010). That area of chaparral/scrub, which was originally described as nearly impenetrable, was cleared for grain production in the 1800s, later planted as almond orchards and vineyards, and now is almost entirely developed (SFEI 2010). While there was one collection of Lange's metalmark from that area, there are no herbarium collections of the sand-associated ecotype of nakedstem buckwheat from that area.

Because of its relatively poor flight ability, Lange's metalmark appears to require perches in areas protected from the high velocity winds that are a common to the Antioch area. Most of the observed dispersal among the existing colonies, including one dispersal event of 2,025 feet (617 meters), was with the prevailing wind from east to west (Arnold 1983).

DRAFT

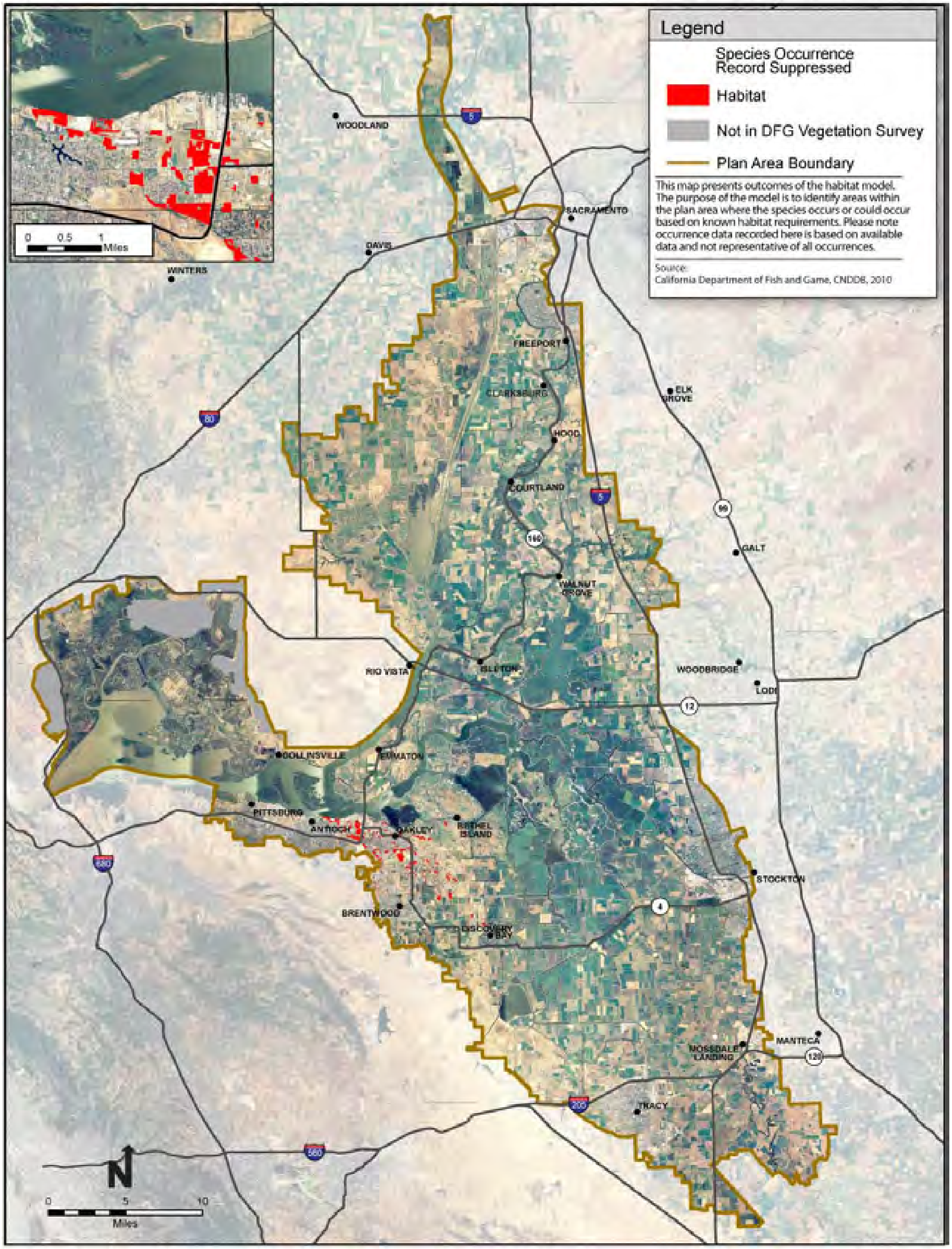

Figure A-35b. Lange's Metalmark Butterfly Habitat Model and Recorded Occurrences

These biological and environmental factors suggest that it may be a back-dune species that lived in the wind shadow of the south side of the 120-foot (37-meter) high dune, within the former dense patch of chaparral near Oakley, and possibly also in small patches of similar chaparral/soil combinations on Delta islands.

A35.4 Life History

Lange's metalmark is a fragile, brightly colored butterfly in the Riodinidae (metalmark) family. Adult wingspan varies from 1 to 1.5 inch (2.5 to 3.8 centimeter). Dorsal wing surfaces are largely black with white spots. Red-orange coloration extends through the inner forward half of the forewing, the hindwing bases, and a small central patch subtended by black. Below, the wings have a more muted pattern of gray, white, black, and orange. As described above, Lange's metalmark is a specialist on the sand ecotype of nakedstem buckwheat, which is its larval food plant, its primary nectar plant, and its primary perch site for males seeking females and for mating (Arnold 1983).

Adults, which live an average of about 13 days, begin to emerge in late July or early August. Continued emergence sustains the flight of adults, which continues for 30-40 days (Arnold 1983). The highest number of individuals in the flight generally occurs 10-15 days after emergence has begun and generally coincides with the peak blooming period of the sand ecotype of nakedstem buckwheat. Eggs are deposited throughout the flight in protected locations on senescing foliage in the lower portion of the buckwheat plant in clusters of about 2-4 eggs or less (Arnold 1983).

Larvae hatch from the eggs in late fall or early winter prior to leaf fall and enter diapause in the leaf litter at the base of the plants. Apparently, sufficient leaf litter for larval protection only accumulates under large plants growing in dense clusters (Arnold 1983). Termination of diapause occurs in late winter, when larvae begin feeding on basal foliage. Late instar[1] larvae climb the flowering stalks in June and July where they feed at night and retreat to the base of the plants for concealment during the day. Pupation occurs in the leaf litter around the base of the plants.

A35.5 Threats and Stressors

Invasive plants are one of the primary threats to Lange's metalmark because of their negative effects on its buckwheat host plant and also because they alter the microclimate around the base of host plants, which reduces the habitat quality for Lange's metalmark (Arnold 1983, USFWS 2008, 2010). The most common invasive nonnative grasses and forbs found at the Antioch Dunes NWR include ripgut brome (*Bromus diandrus*), winter vetch, (*Vicia villosa*) and star thistle (*Centaurea solstitialis*). Wildfires started by trespassers on the Antioch Dunes NWR

[1] Stage in the lifecycle of arthropods, between molts.

threaten the Lange's metalmark butterfly by reducing the plant size and density of its buckwheat host plant (Arnold 1983, USFWS 2008, 2010).

A35.6 Relevant Conservation Efforts

Because Lange's metalmark was declining significantly at Antioch Dunes NWR and appeared to be headed towards extinction, a captive breeding and release program was begun in 2006 (Johnson et al. 2007, USFWS 2008).

Neither the remnant dune environment nor the captive breeding program conditions replicate the conditions of its historical habitat. Instead, it will act as artificial selective agents likely to produce a new partially domesticated genotype that is distinct from Lange's metalmark as it existed prior to the destruction of the dune, development of the surrounding land, and recent recovery efforts. Genetic changes have occurred since the discovery of Lange's metalmark that include a decrease in the flight period by about 4 weeks, a 10-15 percent decrease in wing size, and decreased egg production (Arnold 1986).

The current management plan for the Antioch Dunes NWR provides for invasive nonnative plant species control efforts which are being implemented by hand pulling individual invasive plants through the efforts of volunteers, targeted herbicide application, the restoration of some dune-like topography, and planting of nursery-grown nakedstem buckwheat (USFWS 2001, 2008). Controlled burns have been discontinued as a management tool (L.Terrazas in litt.).

A35.7 Species Habitat Suitability Model

Model Approach. Bay Delta Conservation Plan (BDCP) species habitat suitability models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nevertheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lower probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf 2007. Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers, connectivity between habitat types, and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life history requirements. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The Lange's metalmark butterfly habitat suitability model is based on an iterative analysis of the following datasets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], USDA 2005 aerial photography, DWR 2007 LiDAR elevation data, and United States Department of Agriculture (USDA) Soils Survey (Carpenter and Cosby, 1939). Using these data sets, the model maps the distribution of suitable Lange's metalmark butterfly habitat in the Plan Area.

Habitat. The modeled habitat for Lange's metalmark consisted of areas of Oakley sand soils that appear to support shrubby vegetation when viewed with aerial imagery.

Vegetation Units. The following vegetation subunits were selected from the California Department of Fish and Game (DFG) vegetation units (Hickson and Keeler-Wolf 2007):

- *Lupinus albifrons* Antioch Dunes Association;
- *Lotus scoparius* Antioch Dunes Association;
- Sparsely or unvegetated areas;
- Abandoned orchards; and

- California annual grasslands herbaceous.

Soils Units. Using the USDA Soils Survey (Carpenter and Cosby 1939) the Oakley sand soil was considered suitable for this species when co-occurring with the identified vegetation units.

Elevation Constraints. The DWR 2007 LiDAR was used to identify areas located above the intertidal range. The upper limit of the intertidal marsh elevation range within the south-west delta has been estimated to be 6 feet (NAVD88) (Siegel 2007). Land areas having an elevation greater than 6 feet were determined to be suitable. Because the Oakley sand soil deposits in the Delta are older than the peat (Howard and Arnold 1980) they would have established on a solid substrate and would not have subsided due to anthropomorphic changes to the Delta. Therefore, they were intertidal historically and were not habitat.

A spatial intersection of the vegetation types, soils, and topography were used to identify potential suitable habitat. The potential habitat was then overlaid on Google Earth aerial imagery to assess physical characteristics and use conditions (Google 2009). Potentially suitable habitat located land uses that are incompatible with the species' habitat requirements, for example, potential habitat polygons falling on developed lands were removed from the model.

Assumptions. The habitat suitability model for Lange's metalmark assumes that habitat suitable for its host plant is also suitable for the butterfly. This assumption will overestimate the potential habitat for Lange's metalmark as it is not a strong flier and it would likely be blown off of small patches of habitat in the Delta due to strong and constant local wind conditions and the lack of substantial wind shadows.

A35.8 Recovery Goals

A USFWS revised Recovery Plan for Lange's metalmark was approved in 1984 but the recent 5-year species review (USFWS 2008) found that there are no recovery criteria listed in the Recovery Plan. Additionally, the CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for Lange's metalmark is "Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP has established a goal to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

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A35.9.2 Federal Record Notices Cited

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A35.9.3 Personal Communication

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APPENDIX A36. VALLEY ELDERBERRY LONGHORN BEETLE (*DESMOCERUS CALIFORNICUS DIMORPHUS*)

A36.1 LEGAL STATUS

The valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*) is listed as threatened under the federal Endangered Species Act (45 FR 52803). On October 2, 2006, the United States Fish and Wildlife Service (USFWS) announced a recommendation for this species to be removed from the endangered species list (USFWS 2006). Critical habitat was designated for this species in the initial listing of the species (45 FR 52803); however, neither of the two sites designated as critical habitat occur within the Plan Area. The valley elderberry longhorn beetle has no state regulatory status.

A36.2 SPECIES DISTRIBUTION AND STATUS

A36.2.1 Range and Status

Valley elderberry longhorn beetle is one of three species of *Desmocerus* in North America and one of two subspecies of *D. californicus*. The valley elderberry longhorn beetle subspecies is a narrowly defined, endemic taxon, limited to portions of the Central Valley below 900 meters (2,953 feet) in elevation (Figure A-36a) (USFWS 1999, 2006).

Historically, valley elderberry longhorn beetle presumably occurred throughout the Central Valley of California. Little is known about the historical abundance of valley elderberry longhorn beetle. The extensive destruction of its habitat, however, suggests that the beetle's range has been largely reduced and fragmented (USFWS 1984).

Studies to assess the distribution and extent of the valley subspecies began in the late 1970s (Eya 1976), and the USFWS proposed the species for listing in 1978. Since valley elderberry longhorn beetle was listed in 1980 (45 FR 52803), numerous distributional studies have been conducted (summarized in Talley et al. 2006).

Subsequent to various surveys throughout the Central Valley (Linsley and Chemsak 1972, Eya 1976, Jones & Stokes 1985, 1986, 1987a, 1987b, Barr 1991, Collinge et al. 2001), the USFWS (1999) prepared a map of the presumed range of valley elderberry longhorn beetle. This map encompasses the entire California Central Valley and the Sacramento River Delta below 900 meters (2,953 feet) elevation.

DRAFT

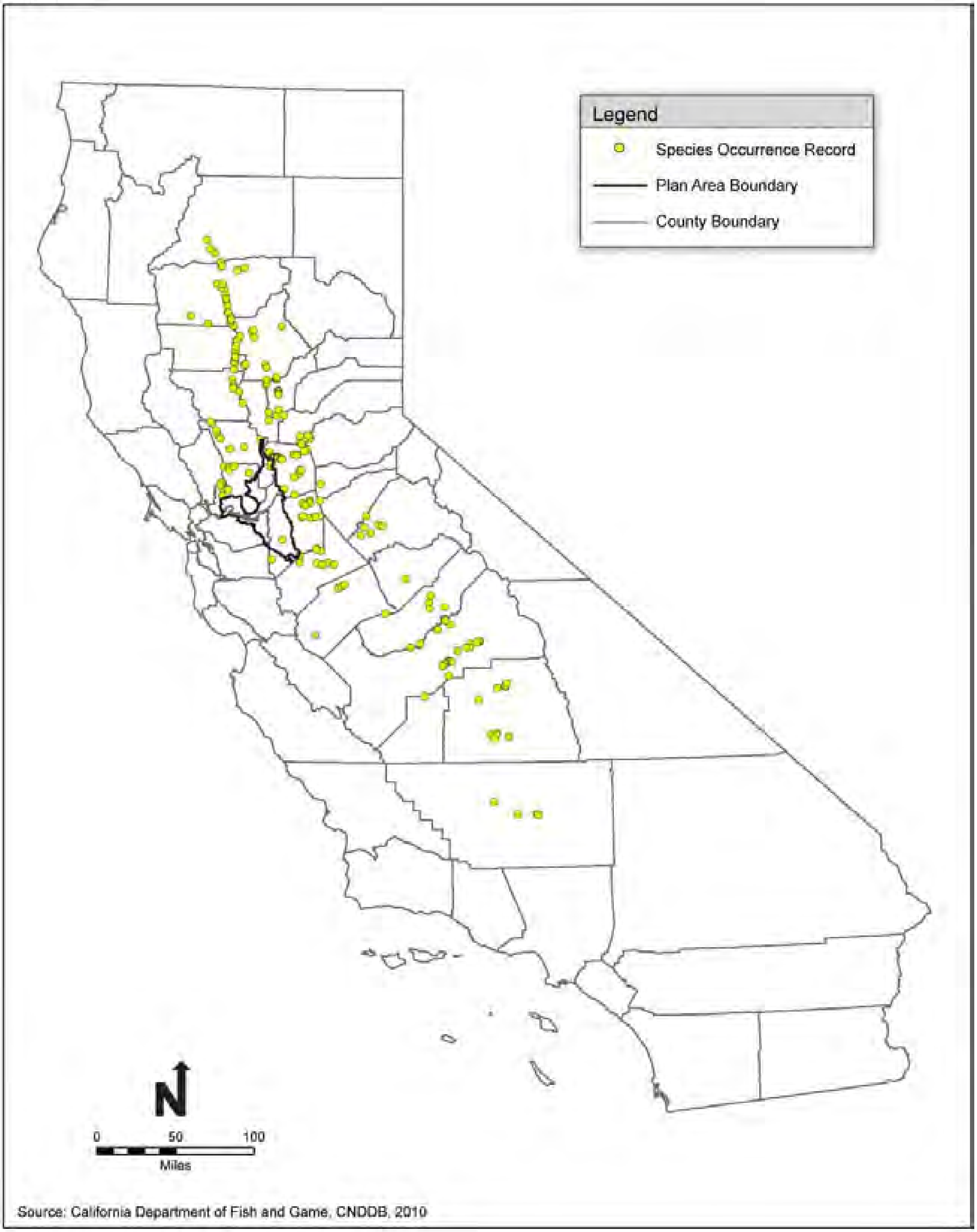

Figure A-36a. Valley Elderberry Longhorn Beetle Statewide Recorded Occurrences

Habitat occupied by valley elderberry longhorn beetle tends to form and exist in riparian corridors and on the level open ground of periodically flooded river and stream terraces and floodplains. This geomorphic setting historically has been desirable for agricultural, urban, or industrial development. As a result, much of this habitat type has been converted through dams and levees for use as developable land. Although it has been estimated that 90 percent of California riparian habitat has been lost over the last century and a half (Smith 1980, Barr 1991, Naiman et al. 1993, Naiman and Décamps 1997), these losses are difficult to accurately quantify in terms of direct valley elderberry longhorn beetle habitat losses (Talley et al. 2006). Therefore, an unknown amount of riparian forest and elderberry savannah habitat has been lost and an unknown number of valley elderberry longhorn beetle populations as well (Collinge et al. 2001). Due to current pressures from increasing human populations in California, more valley elderberry longhorn beetle habitat is being encroached upon and affected throughout the species' range (TAIC 2008).

A36.2.2 Distribution and Status in the Plan Area

There are only three reported occurrences of valley elderberry longhorn beetle from the Plan Area, including one along Old River north of Tracy and two recent occurrences along small drainages between the Sacramento River and the Sacramento Deep Water Ship Channel in the vicinity of West Sacramento (Figure A-36b) (CNDDB 2008). There are additional historical occurrences from along the Sacramento River corridor and Putah Creek in Yolo County (Eya 1976, Jones & Stokes 1985, 1986, 1987a, 1987b, USFWS 1984, Barr 1991, Collinge et al. 2001). Comprehensive surveys for the species or its host plant, elderberry, have not been conducted and thus the population size and location of the species within the Plan Area is unknown. Distribution is typically based on the occurrence of elderberry shrubs, which are known to occur along riparian corridors throughout the Plan Area, including the Sacramento River, Stanislaus River, San Joaquin River, and along smaller natural and channelized drainages, as well as in upland habitats. The valley elderberry longhorn beetle is considered to potentially occur in all mature elderberry shrubs in the Plan Area.

A36.3 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

Valley elderberry longhorn beetle is endemic to moist valley oak riparian corridors in the lower Sacramento and lower San Joaquin valleys (USFWS 1984). Valley elderberry longhorn beetle is closely associated with a few species of elderberry (*Sambucus* spp.). These plants are an obligate host plant for larvae and are necessary for the completion of the life cycle (Linsley and Chemsak 1972, 1997, Eng 1984, Barr 1991, Collinge et al. 2001). The two main species of elderberry utilized by this species are the blue elderberry (*S. mexicana*) and red elderberry (*S. racemosa*). This shrub is a component of riparian forests throughout the Central Valley. Although this shrub occasionally occurs outside riparian areas, shrubs supporting the greatest beetle densities are located in areas where the shrubs are abundant and interspersed among dense riparian forest.

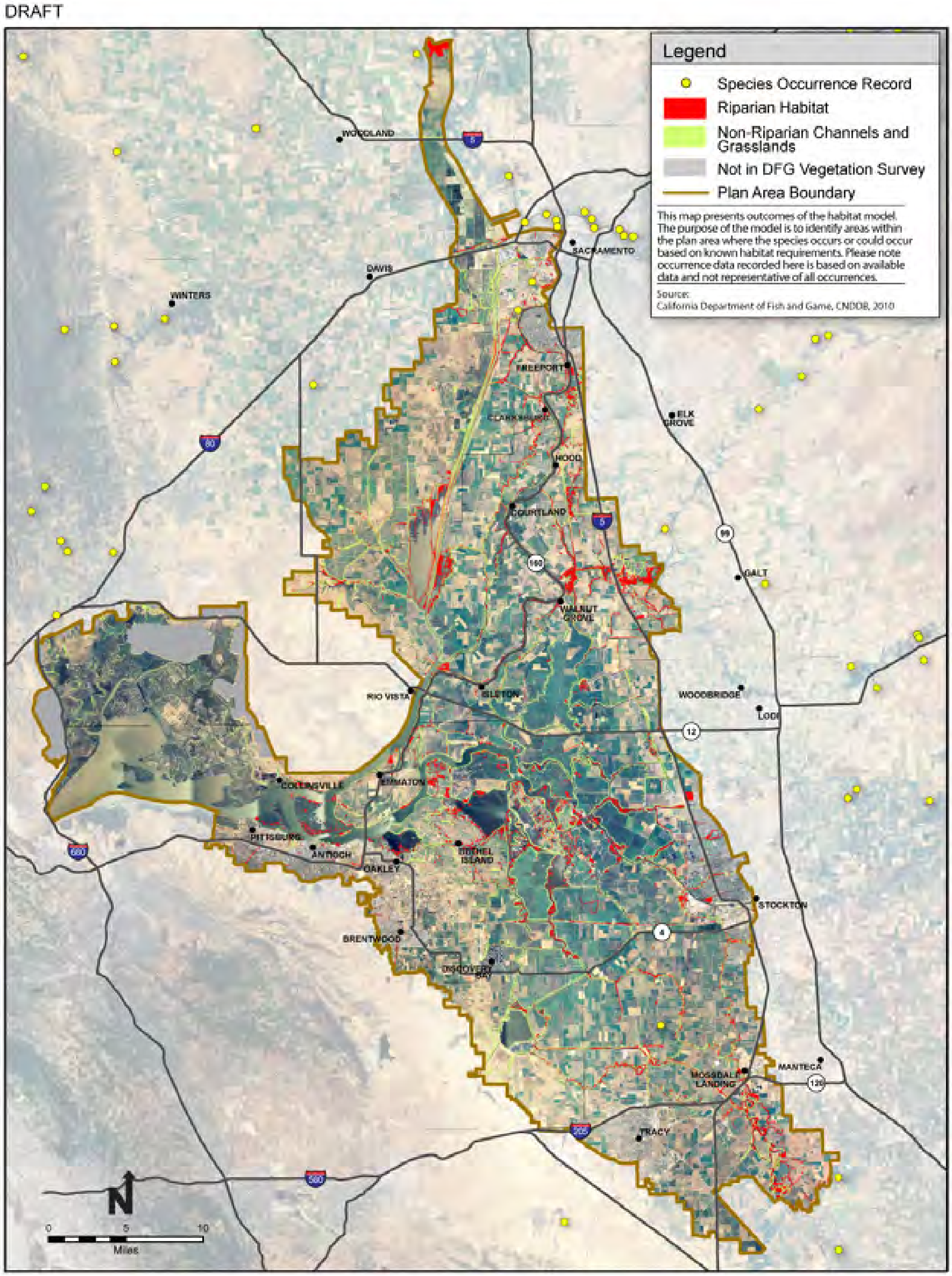

Figure A-36b. Valley Elderberry Longhorn Beetle Habitat Model and Recorded Occurrences

The existing remnants of riparian woodlands and forests within the distribution of valley elderberry longhorn beetle are a collection of various canopy layers and dominant species. Ideally, the riparian ecosystem consists of several canopy layers with dense understory. Fremont cottonwood (*Populus fremontii*), California walnut (*Juglans californica*), California sycamore (*Platanus racemosa*), willow (*Salix* spp.), and valley oak (*Quercus lobata*) commonly compose the upper canopy of the woodland (USFWS 1984). Common species contributing to the intermediate canopy include box elder (*Acer negundo* var. *californicum*), Oregon ash (*Fraxinus latifolia*), elderberries, and several willows. The understory can be widely diverse and may include wild grape (*Vitis californica*), California hibiscus (*Hibiscus californica*), and poison oak (*Toxicodendron diversilobum*), as well as many nonnative species (USFWS 1984, 1999, Barr 1991, Collinge et al. 2001). In some areas, the margins of riparian woodlands and forests are lined with elderberry savanna with *S. mexicana* as the dominant species (Holland 1986). Isolated elderberry shrubs separated from contiguous habitat by extensive development are not typically considered to provide viable habitat for the valley elderberry longhorn beetle (USFWS 1998, Collinge et al. 2001).

Elderberry savannah was a habitat type that was previously more extensive in the California Central Valley, but now is limited to the confluence area of the American River, which is outside the Plan Area (USFWS 1984, 1999, Jones & Stokes 1985, 1986, 1987a, 1987b, Barr 1991), and the valley elderberry longhorn beetle was probably a component of this habitat. Therefore, potential valley elderberry longhorn beetle habitat is defined as stands of elderberry shrubs that are adjacent to, or contiguous with, riparian forest, floodplains, or relict elderberry savannah (TAIC 2008).

A36.4 LIFE HISTORY

Description. The valley elderberry longhorn beetle is an atypical lepturine (the Lepturinae is a subfamily of the Cerambycidae, longhorn beetle family). Elderberry beetles are separated from all other lepturines by the form of the mandibles, which are broad and short, without internal pubescence (Linsley and Chemsak 1972). Originally described by Horn (1881), the valley elderberry longhorn beetle is black in color, with red to orange margins on the elytra (wing covers), which fades to yellow after death. The pronotum (plate behind the head) is smooth, with confluent punctuations. The elytra are densely punctate or rugose. Adult beetles range from 14 to 25 millimeters (mm) (0.5-1.0 inch) in length (Linsley and Chemsak 1972).

The valley elderberry longhorn beetle was described as a separate species by Fisher (1921) and was reduced to subspecific status by Doane et al. (1936). The majority of male valley elderberry longhorn beetles can be separated from other subspecies by the short, suberect, pale setae (bristle or hair-like structures) on the antennae (as opposed to dark setae) and the black markings on each forewing (Linsley and Chemsak 1972). The female valley elderberry longhorn beetle cannot be separated morphologically from other subspecies.

Life Cycle. Little research has been conducted on the life cycle of the valley elderberry longhorn beetle; therefore, current knowledge has been gathered from individual field observations and assumed similarities with closely related taxa. The following account of the life cycle chronicles the one reported in the USFWS Recovery Plan (USFWS 1984).

The beetle can be found from mid-March through early-June and is most active from late-April to mid-May. The adult beetles feed on the elderberry foliage and possibly its flowers. During this time of activity, the beetles mate, and the female lays between 8 and 20 eggs on the living elderberry plant host. The eggs are placed individually or in small clusters within crevices in the bark or junctions of the stem and trunk or leaf petiole and stem. The egg is attached to the shrub by a thin secretion, and the larva encloses within 30 to 40 days (Burke 1921). The eggs most likely hatch after a short time and the newly emerged larvae bore into the wood of the host plant (Linsley and Chemsak 1972, Barr 1991). Burke (1921) and Eya (1976) reported that the larvae take 2 years to mature; however, Halstead (1991) believes that 1 year is the norm. The larva typically bores into the central pith of stems and feeds there; however, on large trunks, the larvae feed on the wood (Burke 1921). The larvae create an elongated, longitudinal gallery through the heart of the stems, filling it with debris and shredded wood (Barr 1991). When the larva is ready to pupate, it chews a circular to slightly oval exit hole (7-10 mm in diameter [0.3-0.4 inch]) to the outside, which it plugs with frass (fecal material produced by insects). The exit holes are distinctive and typically are the only sign of the beetle's presence. Then the larva backs up into the gallery and constructs a pupal chamber out of shredded wood and frass (Barr 1991). Jones & Stokes (1985, 1986, 1987a, 1987b) and Halstead (1991) reported that 70 percent of exit holes are within 3.9 feet (1.2 meters) of the ground in stems greater than 13 mm (0.5 inch) in diameter; however, holes may be as high as 10 feet (3 meters) above the ground (Barr 1991). Pupae can be found between January and April, and the pupal stage lasts about one month (Burke 1921).

After pupation, the adult remains in the pupal cell for several weeks prior to emergence (Burke 1921). The adult eventually emerges from the pupal chamber, through the exit hole (Barr 1991). The adults readily fly from shrub to shrub. The valley elderberry longhorn beetle is most often seen on, in, or immediately under the host plant's flowers. However, copulation occurs on the lower parts of the stems (Barr 1991). The adults feed on the leaves (Linsley and Chemsak 1972, Barr 1991, Talley et al. 2006) and are active from March to early June.

A36.5 THREATS AND STRESSORS

The greatest historical threat to the valley elderberry longhorn beetle has been the elimination, loss, or modification of its habitat by urban, agricultural, or industrial development and other activities that reduce or eliminate its host plants (Talley et al. 2006). While mitigation and restoration actions do not come close to restoring the enormous amount of habitat lost in the more remote past they appear to be adequate for current levels of impact (Talley et al. 2006). However Talley et al. (2006) observed that the quality and persistence of mitigation and restoration efforts are uncertain and that there have been declines in the total number of valley elderberry longhorn beetle-occupied sites and in the number of riparian sites. Talley et al. (2006) also noted that the information included in reports is often unusable, making assessments of mitigation and restoration success difficult.

The greatest current threat to the valley elderberry longhorn beetle is from the invasive nonnative Argentine ant (*Linepithema humile*) and European earwig (*Forficula auricularia*) (Talley et al. 2006). The nonnative invasive Argentine ant has been observed attacking and killing valley elderberry longhorn beetle larvae. The ants enter the exit hole that the beetle makes prior to pupation and remove the larva (Huxel 2000, Huxel et al. 2003). Given that the invasion of riparian systems by Argentine ant in the Central Valley is continuing to spread, it is unclear how the invasion will impact the valley elderberry longhorn beetle, but it appears that the Argentine ant may have caused the disappearance of some populations (Talley et al. 2006). Field bait and trapping experiments have determined that the Argentine ant has been introduced widely through mitigation plantings and irrigation (Klasson et al. 2005). Irrigation plays a major role in the Argentine ant's rate and distance of dispersal in other ecosystems (Menke and Holway 2006). Those data also suggest that there may be a threshold of Argentine ant density above which valley elderberry longhorn beetle is extirpated from a site (Klasson et al. 2005). If confirmed, this would be a serious threat to the valley elderberry longhorn beetle's recovery because once the valley elderberry longhorn beetle is extirpated from a site recolonization is unlikely (Talley et al. 2006). The nonnative invasive European earwig is also considered to be a threat to the valley elderberry longhorn beetle through direct predation or by supporting higher populations of predators of insects (Talley et al. 2006), and earwig populations are also significantly larger in mitigation plantings and irrigated areas (Klasson et al. 2005).

Nonnative invasive plant species such as black locust (*Robinia pseudoacacia*), giant reed (*Arundo donax*), red sesbania (*Sesbania punicea*), Himalaya blackberry (*Rubus armeniacus*), tree of heaven (*Ailanthus altissima*), Spanish broom (*Spartium junceum*), Russian olive (*Eleagnus angustifolia*), edible fig (*Ficus carica*), and Chinese tallowtree (*Sapium sebiferum*), may have significant indirect impacts on the valley elderberry longhorn beetle by impacting elderberry shrub vigor and recruitment (Talley et al. 2006). It is also predicted that ripgut brome (*Bromus diandrus*), foxtail barley (*Hordeum murinum*), Italian ryegrass (*Lolium multiflorum*), and yellow starthistle (*Centaurea solstitialis*) may increase seedling mortality through competition for light and water or through increased fire return intervals (Talley et al. 2006).

Long-term data regarding site persistence, population size and dynamics, extirpation, and recolonization are also lacking as are estimates regarding the minimum self-sustaining population size, riparian forest corridor size, or habitat complex size for the valley elderberry longhorn beetle or other riparian forest organisms.

A36.6 Relevant Conservation Efforts

Conservation Guidelines for the Valley Elderberry Longhorn Beetle were established by the USFWS in 1999 (USFWS 1999). The guidelines were designed mainly to mitigate development-related impacts on valley elderberry longhorn beetle habitat. Using a formula based on stem sizes, habitat association, and presence of emergence holes, the guidelines require losses of elderberry shrubs that meet the minimum standard for potential occupancy to be mitigated through a program that: 1) identifies and secures suitable and approved mitigation land, and 2) includes transplanting of mature elderberry shrubs to the mitigation site, and replacement compensation using a standardized stem replacement formula. In response to the increasing need for valley elderberry longhorn beetle mitigation, numerous private valley elderberry longhorn beetle mitigation banks have become established throughout the Sacramento region. While the USFWS valley elderberry longhorn beetle mitigation compensates for the loss of elderberry shrubs (USFWS 1999), there is no evidence that it has been successful at either mitigating direct impacts on valley elderberry longhorn beetle or has successfully compensated for the loss of occupied valley elderberry longhorn beetle habitat.

Valley elderberry longhorn beetle conservation has also been addressed in several regional conservation plans. It is a covered species under the approved San Joaquin County Multi-Species Habitat Conservation and Open Space Plan and the Natomas Basin Habitat Conservation Plan. It is proposed for coverage under the South Sacramento Habitat Conservation Plan, the Solano County Multispecies Habitat Conservation Plan, the Yolo County Natural Heritage Program Plan, and the Butte Regional Conservation Plan.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for the valley elderberry longhorn beetle is "Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP has established a goal to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

A36.7 Species Habitat Suitability Model

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf 2007. Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers, connectivity between habitat types, and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The valley elderberry longhorn beetle model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin], USDA 2005 aerial photography, and DWR 2007 land use survey of the Delta and Suisun Marsh area-version 3. Using these data sets, the model maps the distribution of suitable valley elderberry longhorn habitat in the Plan Area. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Habitat. Habitat in the Delta includes the following types from the BDCP composite vegetation layer:

- Valley riparian – all types
- Grassland – all types within 200 feet of streams
- Vernal pool complex types within 200 feet of streams
    - Annual grasses generic;
    - Annual grasses/weeds;
    - California annual grasslands;
    - *Distichlis* (generic);
    - *Distichlis spicata;*
    - *Distichlis spicata* – annual grasses;
    - *Districhlis*/annual grasses;
    - *Distichlis/ s. maritimus*;
    - Ruderal herbaceous grasses and forbs;
    - Italian rye-grass (*Lolium multiflorum*);
    - *Salicornia virginica*; and
    - *Salicornia*/annual grasses.

Habitat in the Suisun Marsh and Yolo Basin includes the following riparian types from the BDCP composite vegetation layer:

- *Fraxinus latifolia;*
- Fremont cottonwood-valley oak – willow riparian forest;
- Mixed Fremont cottonwood – willow;
- Mixed willow super alliance;
- *Quercus agrifolia;*
- *Salix lasiolepis/Quercus agrifolia*; and
- Valley oak alliance – riparian.

Habitat in the Suisun Marsh and Yolo Basin also includes following grassland types within 200 feet of streams:

- Annual grasses generic;
- Annual grasses/weeds;
- *Bromus* spp./*Hordeum;*
- *Hordeum/Lolium;*

- *Lolium* (generic);
- *Lotus corniculatus;*
- Medium upland graminoids;
- Medium upland herbs;
- Perennial grass;
- Short upland graminoids;
- Upland annual grasslands and forbs formation; and
- Upland herbs.

Assumptions. The valley elderberry longhorn beetle is endemic to moist riparian corridors in the Sacramento and San Joaquin valleys (USFWS 1984). The species is completely dependent on its host plant, the elderberry (*Sambucus* spp.) (Collinge et al. 2001). This model identifies habitat for the valley elderberry longhorn beetle as locations where the elderberry shrub is expected to be found in the Plan Area. Elderberry is a common component of the remaining riparian forests and woodlands of the Central Valley (USFWS 1984). In these forests and woodlands, a variety of tree species compose the upper canopy, including Fremont cottonwood, valley oak, willow, walnut, alder, and Oregon ash. However, low abundances of valley elderberry longhorn beetle also occur in some non-riparian scrub and grassland habitats adjacent to waterways (Talley et al. 2007, Talley et al. 2006). Elderberry shrubs also occur in upland areas, mainly in grasslands adjacent to riparian forests and woodlands (Barr 1991). Therefore, this model designates additional habitat as grasslands within 200 feet of streams. Note, however, that elderberry shrubs are unevenly distributed along riparian corridors and adjacent upland habitats and in some areas may be lacking entirely. Thus, the model overestimates the extent of suitable habitat for valley elderberry longhorn beetle. Elderberry shrubs also occur incidentally along fence rows and in a variety of other disturbed conditions, particularly where birds may congregate and deposit seeds. This model does not include these incidental habitat areas, and thus in this respect may underestimate the distribution of potential habitat (i.e., elderberry shrubs) for the valley elderberry longhorn beetle in the Plan Area.

A36.8 RECOVERY GOALS

The USFWS Recovery Plan for valley elderberry longhorn beetle was established in 1984 (USFWS 1984). Due to limited knowledge of the species' requirements, recovery objectives were restricted to the following: 1) preserve and protect known habitat sites to provide adequate conditions for the beetle; 2) survey riparian vegetation along certain Central Valley rivers for remaining colonies and habitat; 3) determine ecological requirements and management needs; 4) preserve and protect newly discovered habitat to provide suitable conditions for the species; 5) reestablish the species at rehabilitated habitat sites within the presumed historical range; 6) increase public awareness of the species through education and information programs; and 7) enforce laws and regulations to protect the species.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for the valley elderberry longhorn beetle is "Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP has established a goal to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

A36.9 References

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APPENDIX A37. VERNAL POOL TADPOLE SHRIMP (*LEPIDURUS PACKARDI*)

A37.1 LEGAL STATUS

Vernal pool tadpole shrimp (*Lepidurus packardi*) was listed as endangered throughout its range under the federal Endangered Species Act on September 19, 1994 (59 FR 48136). In September, 2007, USFWS published a 5-year review recommending that the species remain listed as endangered. Revised critical habitat was designated on February 10, 2006 (71 FR 7118). This species is covered by the December 15, 2005, Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon. None of the critical habitat units are within the Plan Area; however, one unit (Unit 11 A-D) is just west of the Plan Area in Solano County. Vernal pool tadpole shrimp has no state regulatory status.

A37.2 SPECIES DISTRIBUTION AND STATUS

A37.2.1 Range and Status

Vernal pool tadpole shrimp is distributed across the Central Valley of California and in the San Francisco Bay area (Figure A-37a). Populations are found at 18 vernal pool complexes in the Sacramento Valley from east of Redding in Shasta County south through the Central Valley to the San Luis National Wildlife Refuge in Merced County. It also occurs in a single vernal pool complex located on the San Francisco Bay National Wildlife Refuge in the City of Fremont, Alameda County. The easternmost known location is around 3,500 feet (1,067 meters) in elevation in the central Sierra Nevada foothills (Merced County) and the westernmost known location is in the San Francisco Bay Area (Alameda County). The Bay Area location is the only known population of vernal pool tadpole shrimp outside of the Central Valley (USFWS 2005, 2007). The largest concentration of vernal pool tadpole shrimp occurrences is found in the Southeastern Sacramento Vernal Pool Region, where the species occurs on a number of public and private lands in Sacramento County (USFWS 2005, 2007).

A37.2.2 Distribution and Status in the Plan Area

Vernal pool tadpole shrimp has been reported from several locations within the Plan Area (Figure A-37b) (USFWS 2005, 2007, CNDDB 2010). In general, within the Plan Area, vernal pools that may support the species occur on alkaline soils from the DFG Tule Ranch Unit of the Yolo Bypass Wildlife Area southwest to the Montezuma Wetlands Mitigation Projects and from the Byron Airport to Discovery Bay. Other potential vernal pool habitat occurs along the eastern boundary of the Plan Area near Stone Lakes (Figure A-37b). Six additional occurrences were discovered in the Stone Lakes area during 2009 surveys conducted by the California Department of Water Resources (DWR). A comprehensive survey of vernal pools or habitat for vernal pool tadpole shrimp has not been conducted in the Plan Area.

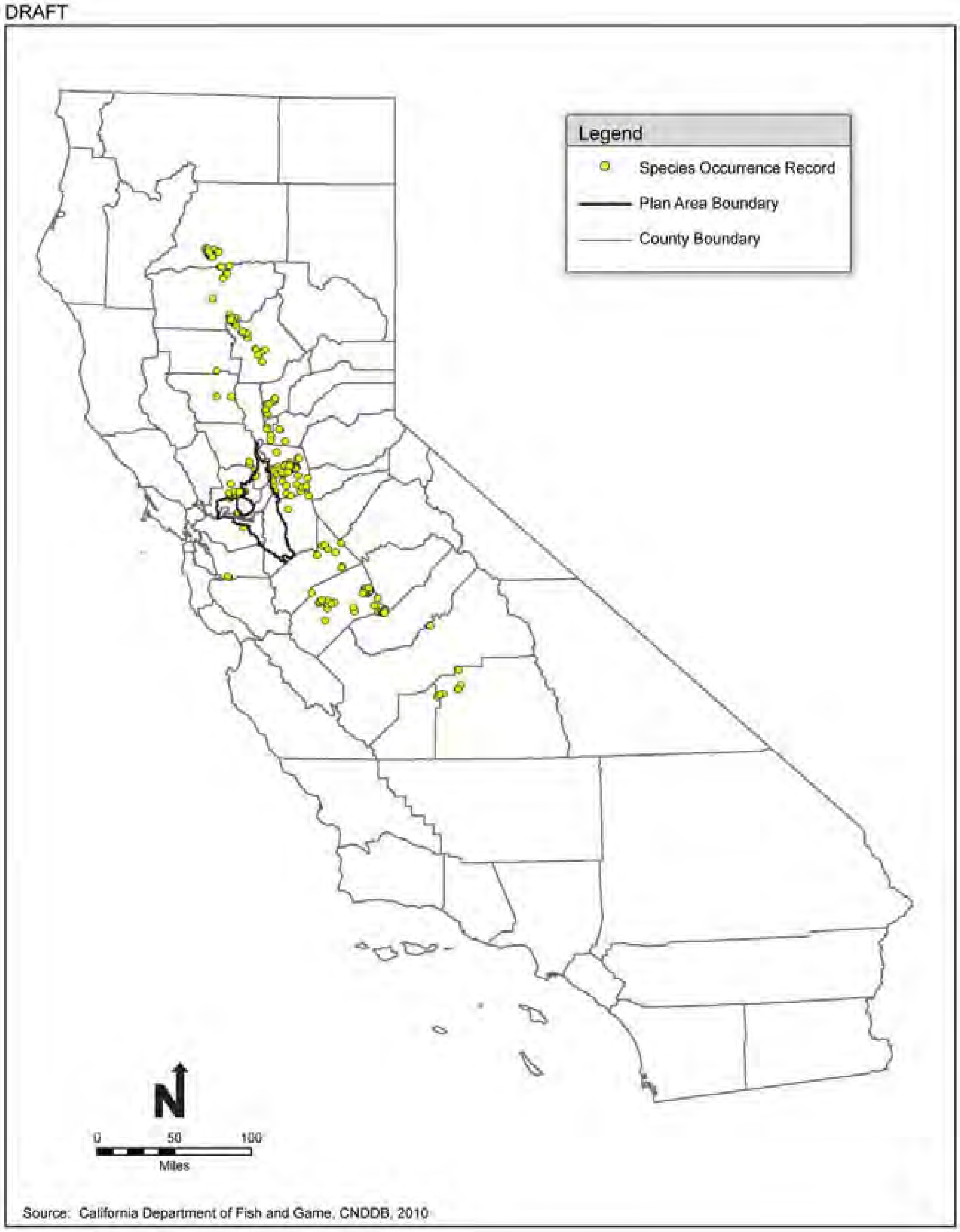

Figure A-37a. Vernal Pool Tadpole Shrimp Statewide Recorded Occurrences

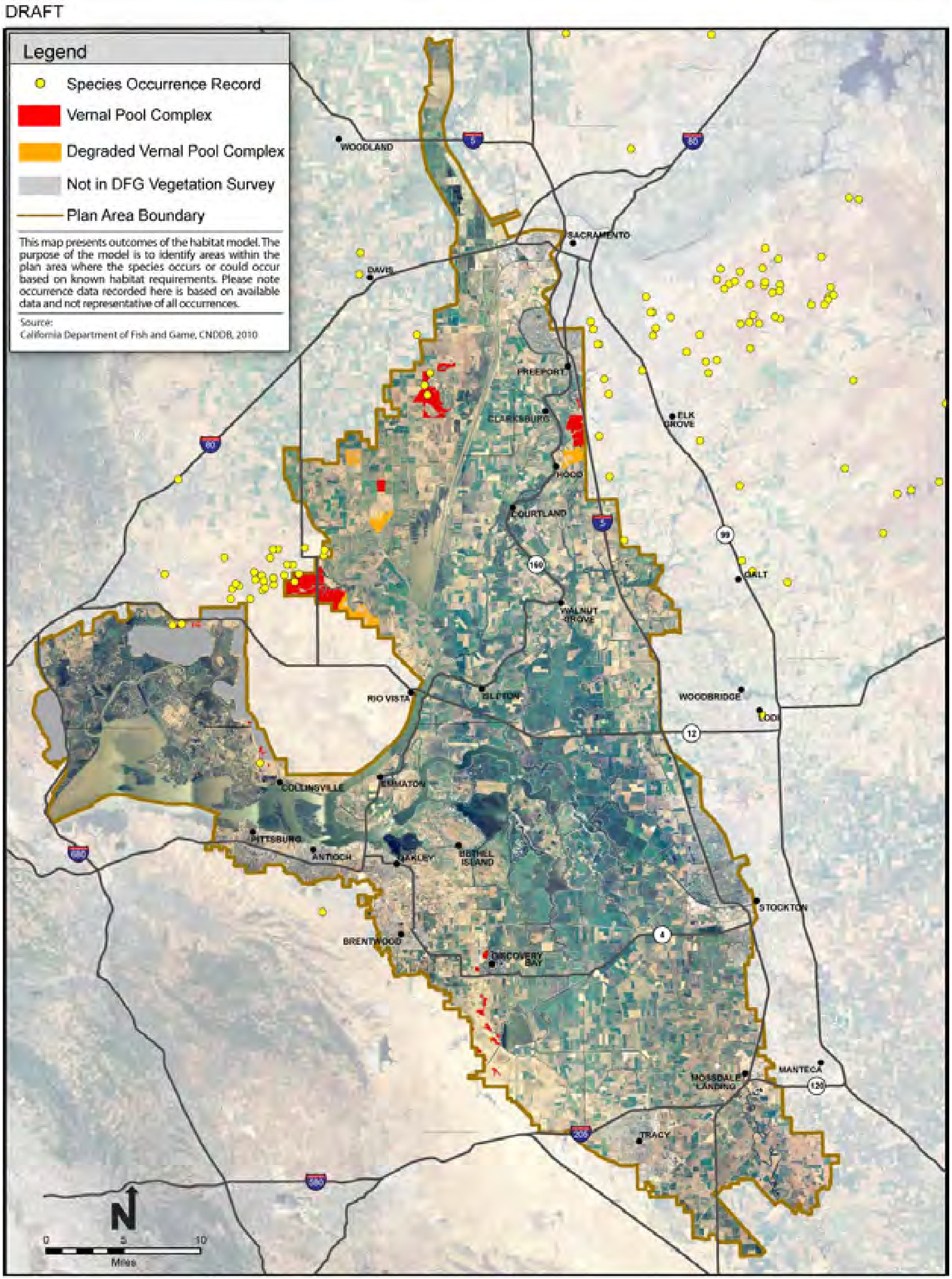

Figure A-37b. Vernal Pool Tadpole Shrimp Habitat Model and Recorded Occurrences

A37.3 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

This species is entirely dependent on the aquatic environment provided by the temporary waters of natural vernal pool and playa pool ecosystems as well as the artificial environments of ditches and tire ruts (King et al. 1996, Helm 1998, Eriksen and Belk 1999). The temporary waters in which vernal pool tadpole shrimp inhabits fill in the fall and winter during the beginning of the wet season and dry in late-spring at the beginning of the dry season and remain desiccated throughout the summer (Helm 1998, Eriksen and Belk 1999). The temporary waters fill directly from precipitation as well as from runoff from their watersheds (Williamson et al. 2005, Rains et al. 2006, 2008, O'Geen et al. 2008). The watershed extent that is necessary for maintaining the hydrological functions of the temporary waters depends on a number of complex factors including the hydrologic conductivity of the surface soil horizons, the continuity and extent of hard-pans and clay-pans underlying non-clay soils, the existence of a perched aquifer overlying the pans, slope, effects of vegetation on evapotranspiration rates, compaction of surface soils by grazing animals, and other factors (Marty 2004, Pyke and Marty 2005, Williamson et al. 2005, Rains et al. 2006, 2008, O'Geen et al. 2008).

The temporary waters that are habitat for vernal pool tadpole shrimp are extremely variable and range from clear sandstone pools with little alkalinity to turbid vernal pools on clay soils with moderate alkalinity (King et al. 1996, Eriksen and Belk 1999). Common wetland plant species that co-occur with vernal pool tadpole shrimp include toad rush (*Juncus bufonius*), coyote thistle (*Eryringium* spp.), downingia (*Downingia ornatissma* or *D. bicornuta*), goldfields (*Lasthenia* spp.), woolly marbles (*Psilocarphus* spp.), and hair grass (*Deschampsia* spp.) (King et al. 1996, Alexander and Schlising 1997, 1998, Helm 1998, Plattencamp 1998, Eriksen and Belk 1999, Alexander 2007).

Vernal pool tadpole shrimp commonly co-occur with the fairy shrimp (*Linderiella occidentalis*, *Branchinecta conservatio*, *B. lindahli*, *B. coloradensis*) and vernal pool fairy shrimp (*B. lynchi*). The midvalley shrimp (*B. mesovallensis*) and *B. longiantenna* both occur within the range of vernal pool tadpole shrimp but are typically found in different habitats (USFWS 2005, 2007).

A37.4 LIFE HISTORY

Description. Vernal pool tadpole shrimp is characterized by a smooth protective concave shell or carapace that protects its head and thorax. A pair of eyes is centered at the anterior end of its shell. Its segmented abdomen is visible (posterior), and the last segment produces a caudal lamina (tail plate), which is diagnostic for the genus, and a pair of whip-like appendages called cercopods. At full maturity, vernal pool tadpole shrimp has 30-35 pairs of appendages called phyllopods (leaf-feet) that propel it through the water and through which it exchanges oxygen (Rogers 2001). Vernal pool tadpole shrimp may vary in coloration, depending on habitat, although it is most commonly green. In highly turbid water, this species may be nearly translucent to buff-colored with brown mottles. In slightly turbid to clear water, vernal pool tadpole shrimp shows greater variety; coloration may be light green, dark green, dark green mottled with brown, chocolate brown, brown with green mottles, and black.

Reproduction and Growth. Vernal pool tadpole shrimp are adapted to the environmental conditions of their ephemeral habitats. One adaptation is the ability of vernal pool tadpole shrimp eggs, or cysts, to remain dormant in the soil when their vernal pool habitats are dry. The cysts survive the hot, dry summers and cold, wet winters that follow until the vernal pools and swales fill with rainwater and conditions are right for hatching. When the pools refill in the same or subsequent seasons some, but not all, of the eggs may hatch. The egg bank in the soil may comprise eggs from several years of breeding (USFWS 2005, 2007). Beyond inundation of the habitat, the specific cues for hatching are unknown, although temperature and conductivity (solute concentration) are believed to play a large role (Helm 1998, Eriksen and Belk 1999).

In a study using large plastic pools to simulate natural vernal pools, Helm found no difference in the time to reproduce among California linderiella, Conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, midvalley fairy shrimp, and vernal pool tadpole shrimp (46 days) (Helm 1998). However, that experiment supplemented by field data (Gallagher 1996, Alexander 2007) suggests that the average time to reproduce for California linderiella, Conservancy fairy shrimp, longhorn fairy shrimp, and vernal pool fairy shrimp is approximately 8 weeks, while that for midvalley fairy shrimp is approximately 2 weeks. No data were reported regarding pool fertility or the impacts of predation on the time to reproduce. These reproduction periods may be shortened or lengthened by warmer or colder water temperatures (Helm 1998).

Vernal pool tadpole shrimp have relatively high reproductive rates and may be hermaphroditic. Sex ratios can vary, perhaps in response to changes in water temperature (Ahl 1991). Genetic variation among vernal pool tadpole shrimp was studied in populations at 20 different sites in the Central Valley (King 1996). The results found that 96 percent of the genetic variation measured was due to differences between sites. This result corresponds with the findings of other researchers that vernal pool crustaceans have low rates of gene flow between separated sites. The low rate of exchange between vernal pool tadpole shrimp populations is probably a result of the spatial isolation of their habitats and their reliance on passive dispersal mechanisms. However, the studies also found that gene flow between pools within the same vernal pool complex is much higher. This indicates that vernal pool tadpole shrimp populations, like most vernal pool crustacean populations, are defined by vernal pool complexes and not by individual vernal pools (USFWS 2005).

Feeding. Vernal pool tadpole shrimp are omnivorous, with a strong preference for animal matter, and will capture and consume live invertebrates including fairy shrimp and other vernal pool tadpole shrimp, amphibian larvae, or carrion, and they also filter detritus for micrometazoa (USFWS 2005, 2007).

Predation and Dispersal. Planktonic Crustacea are important in the food web, as they represent a high-fat, high-protein resource for migratory waterfowl. Mallard (*Anas platyrhynchos*), green-winged teal (*A. crecca*), bufflehead (*Bucephala albeola*), greater yellowlegs (*Tringa melanoleuca*), and killdeer (*Charadrius vociferus*) all forage actively in Central Valley vernal pools on the invertebrate and amphibian fauna during the winter months (Silveira 1996, Bogiatto and Karnegis 2006).

Predator consumption of tadpole shrimp cysts aids in distributing populations of tadpole shrimp. Predators (e.g., birds and amphibians) expel viable cysts in their excrement, often at locations other than where they were consumed. If conditions are suitable, these transported cysts may hatch at the new location and potentially establish a new population. Cysts are also transported by wind and in mud carried on the feet of animals, including livestock that may wade through vernal pool tadpole shrimp habitat. This type of dispersal aids ephemeral pool crustaceans in exploiting a wide variety of ephemeral habitats (Erickson and Belk 1999).

A37.5 THREATS AND STRESSORS

Threats to vernal pool habitat and species in general, including vernal pool tadpole shrimp, were identified in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (USFWS 2005). In addition, the Recovery Plan identified several threats specific to vernal pool tadpole shrimp.

Habitat Loss and Fragmentation. Habitat loss and fragmentation were identified as the largest threats to the survival and recovery of vernal pool species. Habitat loss generally is a result of agricultural conversion from rangelands to intensive farming, urbanization, aggregate mining, infrastructure projects (such as roads and utility projects), and recreational activities (such as off-highway vehicles and hiking) (USFWS 2005, 2007). Habitat fragmentation occurs when vernal pool complexes are broken into smaller groups or individual vernal pools and become isolated from each other as a result of activities such as road development and other infrastructure projects (USFWS 2005, 2007).

Agricultural Conversion. Conversion of land use, such as from grasslands or pastures, to more intensive agricultural uses (e.g., croplands) or from one crop type to another, has contributed and continues to contribute to the decline of vernal pools in general (USFWS 2005, 2007).

Invasive Species. The invasions of vernal pools by waxy mannagrass (*Glyceria declinata*), an invasive aquatic grass (Gerlach et al. 2009), greatly increases the amount of decomposing biomass in vernal pools and may result in higher respiratory oxygen consumption relative to photosynthetic oxygen generation (Rogers 1998). Also, upland biomass of invasive species such as medusahead (*Taeniatherum caput-medusae*) can produce dense vegetation and thatch, shortening the ponding duration of some vernal pools (Marty 2004, Pyke and Marty 2005). Italian ryegrass (*Lolium multiflorum*) has rapidly become a dominant invasive species of the uppermost zone of vernal pools and appears to have undergone rapid adaptation to alkaline clay soils (Dawson et al. 2007).

Altered Hydrology. Human disturbances can alter the hydrology of temporary waters and result in a change in the timing, frequency, or duration of inundation in vernal pools, which can create conditions that render existing vernal pools unsuitable for vernal pool species (USFWS 2005, 2007).

A37.6 Relevant Conservation Efforts

Vernal pool tadpole shrimp is protected as a threatened species under the Endangered Species Act, and critical habitat has been designated as noted above. Critical habitat unit 11D includes the Potrero Hills and adjacent areas, some of which is within the Plan Area. In the Solano-Colusa Vernal Pool Region, vernal pool tadpole shrimp are protected at the Burke Ranch mitigation bank and on the Jepson Prairie Preserve which is owned by the Solano County Open Space and Farmland Conservancy (USFWS 2005, 2008).

Although conservation efforts have been undertaken for vernal pool ecosystems in general, very few actions have been taken specifically to benefit vernal pool tadpole shrimp. An example of one of these actions is a grazing program at the Stone Corral Ecological Reserve for the benefit of vernal pool crustaceans that is being monitored by California Department of Fish and Game staff (USFWS 2005).

Vernal pool tadpole shrimp is covered under the Natomas Basin Habitat Conservation Plan, the San Joaquin County Multi-species Habitat Conservation and Open Space Plan, and the East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan. In addition, the species is proposed for coverage in the Solano County Multispecies Habitat Conservation Plan, the South Sacramento County Habitat Conservation Plan, the Yolo Natural Heritage Program Plan currently under development, and the Butte Regional Habitat Conservation Plan and Natural Community Conservation Plan.

A37.7 Species Habitat Suitability Model

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing GIS data sources (described below and in Section 2.3.1, *Data Sources and Natural Community Classification*). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as vernal pools, individual trees, or small groups of trees. It is also possible, as with some vernal pool invertebrates that are restricted to seasonally ponded habitats, to underestimate potentially-occupied habitat due to the lack of information on small, degraded or artificially-created seasonal wetland habitats.

Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The vernal pool tadpole shrimp model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), DWR 2007 LiDAR elevation data, Google Earth 2009 aerial imagery and USDA 2005 aerial photography. Using these data sets, the model maps the distribution of suitable vernal pool tadpole shrimp habitat in the Plan Area according to the species' two habitat types, vernal pool complex and degraded vernal pool complex habitat. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Vernal Pool Complex Habitat: High quality permanent habitat that consists of vernal pools and uplands that display characteristic vernal pool and swale visual signatures that have not been significantly impacted by agricultural or development practices. Vernal pool complex habitat for vernal pool tadpole shrimp includes the following vegetation subunits that were selected from the BDCP vernal pool complex natural community:

- Vernal pool complex – all vegetation types

Degraded Vernal Pool Complex Habitat: Low quality ephemeral habitat that ranges from areas with vernal pool and swale visual signatures that display clear evidence of significant disturbance due to plowing, disking, or leveling to areas with clearly artificial basins such as shallow agricultural ditches, depressions in fallow fields, and areas of compacted soils in pastures. The aquatic features in this habitat are more clearly classified as temporary waters *sensu lato* (Williams 2006) than intact and fully functional vernal pools. Because these features are inundated during the wet season and may have historically been located in or near areas with natural vernal pool complex, they may support individuals or small populations of species that are found in vernal pools and swales. However, they do not possess the full complement of ecosystem and community characteristics of natural vernal pools, swales and their associated uplands and they are generally ephemeral features that are eliminated during the course of normal agricultural practices. Degraded vernal pool complex habitat for vernal pool tadpole shrimp includes the following vegetation subunits that were selected from the BDCP other natural seasonal wetlands and grasslands communities:

- Grasslands
  - Degraded vernal pool complex – California annual grasslands;
  - Degraded vernal pool complex – Ruderal herbaceous grasses and forbs;
  - Degraded vernal pool complex – Italian rye-grass (*Lolium multiflorum*); and
  - Degraded vernal pool complex – Rabbitsfoot grass (*Polygpogon maritimus*).
- Other natural seasonal wetlands
  - Degraded vernal pool complex - vernal pools.

Potential habitat without concave surfaces was removed from the model. LiDAR elevation data was then visually inspected in four general areas to further assess specific locations that had been identified by the habitat selection process. These areas were selected based both on *a priori* knowledge of the region and because they were identified by the intersection of the selected vegetation types and soils. The analysis of the LiDAR data further refined the habitat model and provided a more accurate demarcation of suitable habitat. The GIS habitat model was then compared against field data from surveys conducted by the California Department of Water Resources in 2009. Land uses that are incompatible with the species' habitat requirements, for example, potential habitat polygons falling on leveled or developed lands were removed from the model.

Assumptions. Historical and current records of this species in the Plan Area indicate that it occurs in appropriate habitat along the perimeter of the Plan Area (Figure A-37b) (Witham 2002, 2003, 2006, ESA 2005, Barona et al. 2007, CNDDB 2010). The vegetation cover of the alkaline soils is typically a combination of vernal pool adapted species and annual ryegrass (Witham 2002, 2003, 2006, CNDDB 2010).

A37.8 RECOVERY GOALS

A general statement for recovery of vernal pool tadpole shrimp is presented in the USFWS (2005) Recovery Plan: to ensure protection of the full geographic, genetic, and ecological extent of this species and to improve the circumstances that caused it to be listed in the first place. Interim goals are to (1) stabilize and protect populations, (2) conduct research to refine reclassification and recovery criteria, and (3) downlist endangered species to threatened. Vernal pool habitats used by the species, as well as historical and potential habitats, need to be protected; and habitat management plans for these habitats need to be developed and implemented. Recovery criteria have been established in the Recovery Plan (USFWS 2005).

The criteria to downlist the species are to protect 80 percent of this species' existing occurrences and 85 to 95 percent of this species' suitable habitat within 13 Core Areas, including: Chico, Oroville and Vina Plains, Grasslands Ecological Area, Davis Communications Annex, Jepson Prairie, Collinsville, Sacramento National Wildlife Refuge (NWR), Cosumnes/Rancho Seco, Mather, Madera, Merced, and Table Mountain. A total of 85 percent of suitable habitat is to be protected within 11 Core Areas, including: SE San Francisco Bay, Dales, Doe Mill, Red Bluff, Redding, Cross Creek, Dolan, Beale, Western Placer County, Cottonwood Creek, and Turlock. The criteria to delist the species are: protect 100 percent of newly discovered/reintroduced populations and reintroduce the species into vernal pool regions and soil types from which surveys indicate that it has been extirpated (USFWS 2005).

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APPENDIX A38. CONSERVANCY FAIRY SHRIMP (*BRANCHINECTA CONSERVATIO*)

A38.1 LEGAL STATUS

Conservancy fairy shrimp (*Branchinecta conservatio*) was listed as endangered throughout its range under the federal Endangered Species Act on September 19, 1994 (59 FR 48136). In September 2007, U.S. Fish and Wildlife Services (USFWS) published a 5-year review recommending that the species remain listed as endangered. Revised critical habitat was designated on February 10, 2006 (71 FR 7118), although none of the critical habitat units are within the Plan Area. This species is covered by the December 15, 2005, Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon. Conservancy fairy shrimp has no state regulatory status.

A38.2 SPECIES DISTRIBUTION AND STATUS

A38.2.1 Range and Status

The historical distribution of Conservancy fairy shrimp is not known, but the distribution of vernal pool habitats in the areas where the species is now known to occur was once more continuous and larger in area than today (USFWS 2005). The species is currently found in disjunct and fragmented habitats across the Central Valley of California from Tehama County to Merced County and at two southern California locations on the Los Padres National Forest in Ventura County (Figure A-38a) (USFWS 2005, 2007, CNDDB 2010).

A38.2.2 Distribution and Status in the BDCP Plan Area

Conservancy fairy shrimp is known to occur at three locations within the Plan Area (Figure A-38b) (USFWS 2007). In general, within the Plan Area, turbid-water playas and vernal pools that may support the species occur on alkaline soils from the Department of Fish and Game (DFG) Tule Ranch Unit of the Yolo Bypass Wildlife Area southwest to the Montezuma Wetlands Mitigation Projects and from the Byron Airport to Discovery Bay.

A38.3 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

As with other vernal pool crustacean species, Conservancy fairy shrimp is sporadic in its distribution, often inhabiting only one or a few vernal pools in otherwise more widespread pool complexes. Pools within a complex typically are separated by distances on the order of five or more feet (1.5 meters) and may form dense mosaics of small pools or a sparser scattering of larger pools (USFWS 2005). Conservancy fairy shrimp have been found in vernal pools ranging

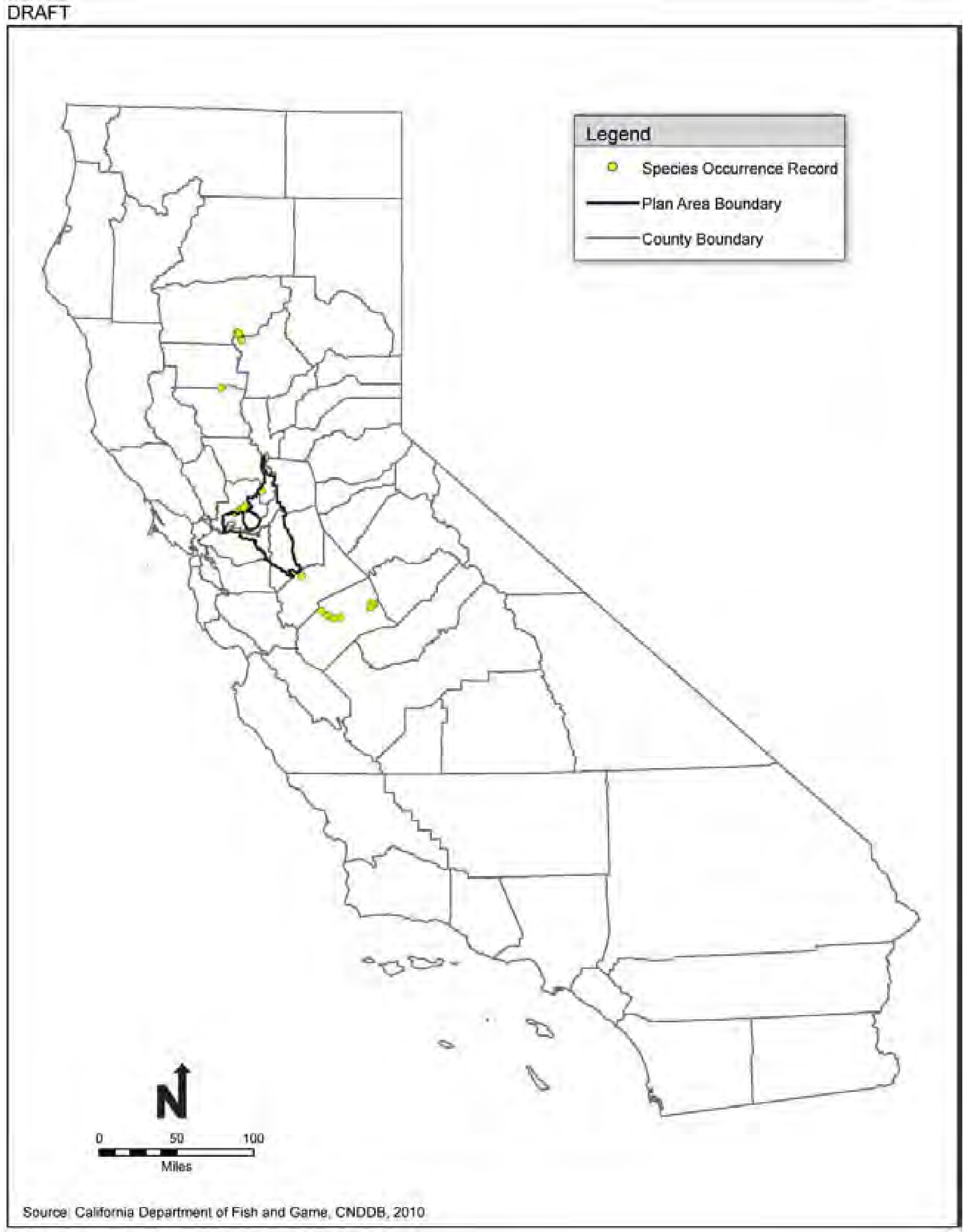

Figure A-38a. Conservancy Fairy Shrimp Statewide Recorded Occurrences

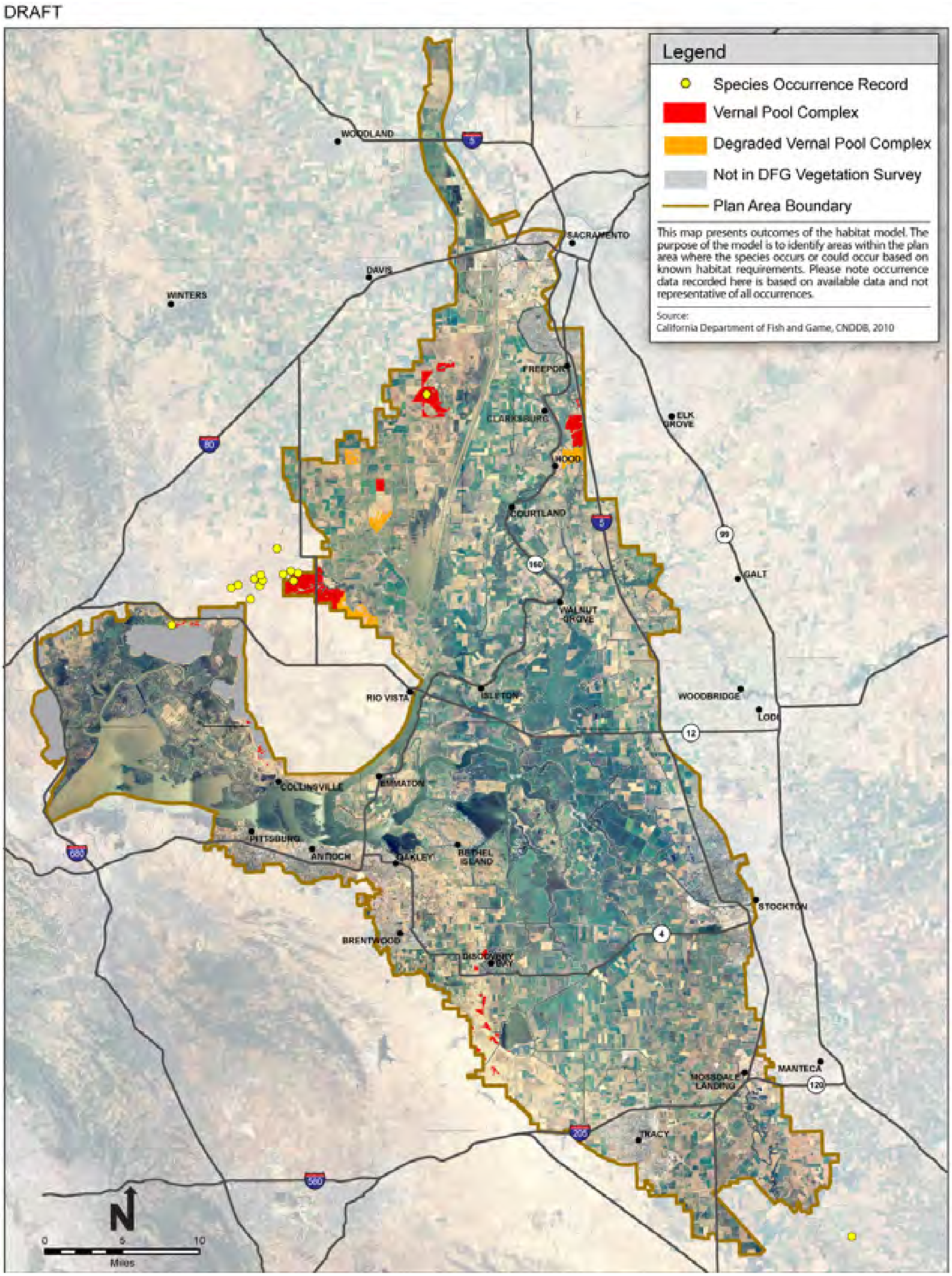

Figure A-38b. Conservancy Fairy Shrimp Habitat Model and Recorded Occurrences

in size from 323 square feet to 88 acres (30 m^2 to 35.6 hectares) at elevations ranging from 16 to 5,577 feet (5 to 1,700 meters) (USFWS 2005, 2007).

This species is entirely dependent on the aquatic environment provided by the temporary waters of natural vernal pool and playa pool ecosystems as well as the artificial environments of ditches and tire ruts (King et al. 1996, Helm 1998, Eriksen and Belk 1999). The temporary waters in which Conservancy fairy shrimp inhabits fill in the fall and winter during the beginning of the wet season and dry in late-spring at the beginning of the dry season and remain desiccated throughout the summer (Helm 1998, Eriksen and Belk 1999). The temporary waters fill directly from precipitation as well as from runoff from their watersheds (Williamson et al. 2005, Rains et al. 2006, 2008, O'Geen et al. 2008). The watershed extent that is necessary for maintaining the hydrological functions of the temporary waters depends on a number of complex factors including the hydrologic conductivity of the surface soil horizons, the continuity and extent of hard-pans and clay-pans underlying non-clay soils, the existence of a perched aquifer overlying the pans, slope, effects of vegetation on evapotranspiration rates, compaction of surface soils by grazing animals, and other factors (Marty 2004, Pyke and Marty 2005, Williamson et al. 2005, Rains et al. 2006, 2008, O'Geen et al. 2008).

Typical turbid-water habitats for Conservancy fairy shrimp in California are large, playa-type vernal pools or long inundation smaller vernal pools (Eng et al. 1990, USFWS 2007). Common wetland plant species that co-occur with Conservancy fairy shrimp include toad rush (*Juncus bufonius*), coyote thistle (*Eryringium* spp.), downingia (*Downingia ornatissma* or *D. bicornuta*), goldfields (*Lasthenia* spp.), woolly marbles (*Psilocarphus* spp.), and hair grass (*Deschampsia* spp.) (King et al. 1996, Alexander and Schlising 1997, 1998, Helm 1998, Plattencamp 1998, Eriksen and Belk 1999, Alexander 2007).

A38.4 Life History

Description. Conservancy fairy shrimp is a typical Branchinectid anostracan. They are typically off-white to grey, although the brood patch may be green or yellow. Depending on the rapidity of development, mature animals may vary in length from 3 to 38 millimeters (0.12 to 1.50 inches). Like other fairy shrimp, they are entirely aquatic with delicate elongate bodies, large stalked compound eyes, no carapaces, and eleven pairs of swimming legs. Males and females are generally differentiated on the basis of antennae development, thoracic projections, and brood pouch development.

Reproduction and Growth. Conservancy fairy shrimp is adapted to the environmental conditions of their ephemeral habitats. One adaptation is the ability of Conservancy fairy shrimp eggs, or cysts, to remain dormant in the soil when their vernal pool habitats are dry. The cysts survive the hot, dry summers and cold, wet winters that follow until the vernal pools and swales fill with rainwater and conditions are right for hatching. When the pools refill in the same or subsequent seasons some, but not all, of the eggs may hatch. The egg bank in the soil may comprise eggs from several years of breeding (USFWS 2005, 2007).

In a study using large plastic pools to simulate natural vernal pools, Helm found no difference in the time to reproduce among California linderiella, Conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, midvalley fairy shrimp, and vernal pool tadpole shrimp (46 days) (Helm 1998). However, that experiment supplemented by field data (Gallagher 1996, Alexander 2007) suggests that the average time to reproduce for California linderiella, Conservancy fairy shrimp, longhorn fairy shrimp, and vernal pool fairy shrimp is approximately 8 weeks, while that for midvalley fairy shrimp is approximately 2 weeks. No data were reported regarding pool fertility or the impacts of predation on the time to reproduce. These reproduction periods may be shortened or lengthened by warmer or colder water temperatures (Helm 1998).

Feeding. Conservancy fairy shrimp is an omnivorous filter-feeder. In general, all fairy shrimp species indiscriminately filter particles that include bacteria, unicellular algae, and micrometazoa (Eriksen and Belk 1999). The precise size of items these fairy shrimp are capable of filtering is currently unknown. However, fairy shrimp species will attempt to consume whatever material they can fit into their feeding groove and do not discriminate based upon taste, as do other crustacean groups (Eriksen and Belk 1999).

Predation and Dispersal. Planktonic Crustacea are important in the food web, as they represent a high-fat, high-protein resource for migratory waterfowl. Mallard (*Anas platyrhynchos*), green-winged teal (*A. crecca*), bufflehead (*Bucephala albeola*), greater yellowlegs (*Tringa melanoleuca*), and killdeer (*Charadrius vociferus*) all forage actively in Central Valley vernal pools on the invertebrate and amphibian fauna during the winter months (Silveira 1996, Bogiatto and Karnegis 2006).

Predator consumption of fairy shrimp cysts aids in distributing populations of fairy shrimp. Predators (e.g., birds and amphibians) expel viable cysts in their excrement, often at locations other than where they were consumed. If conditions are suitable, these transported cysts may hatch at the new location and potentially establish a new population. Cysts are also transported by wind and in mud carried on the feet of animals, including livestock that may wade through fairy shrimp habitat. This type of dispersal aids ephemeral pool crustaceans in exploiting a wide variety of ephemeral habitats (Erickson and Belk 1999).

A38.5 Threats and Stressors

Threats to vernal pool habitat and species in general, including Conservancy fairy shrimp, were identified in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (USFWS 2005). In addition, the Recovery Plan identified several threats specific to the Conservancy fairy shrimp.

Habitat Loss and Fragmentation. Habitat loss and fragmentation were identified as the largest threats to the survival and recovery of vernal pool species. Habitat loss generally is a result of agricultural conversion from rangelands to intensive farming, urbanization, aggregate mining, infrastructure projects (such as roads and utility projects), and recreational activities (such as off-highway vehicles and hiking) (USFWS 2005, 2007). Habitat fragmentation occurs when vernal pool complexes are broken into smaller groups or individual vernal pools and become isolated from each other as a result of activities such as road development and other infrastructure projects (USFWS 2005, 2007).

Agricultural Conversion. Conversion of land use, such as from grasslands or pastures to more intensive agricultural uses (e.g., croplands) or from one crop type to another, has contributed and continues to contribute to the decline of vernal pools in general (USFWS 2005, 2007).

Invasive Species. The invasions of vernal pools by waxy mannagrass (*Glyceria declinata*), an invasive aquatic grass (Gerlach et al. 2009), greatly increases the amount of decomposing biomass in vernal pools and may result in higher respiratory oxygen consumption relative to photosynthetic oxygen generation (Rogers 1998). Also, upland biomass of invasive species such as medusahead (*Taeniatherum caput-medusae*) can produce dense vegetation and thatch, shortening the ponding duration of some vernal pools (Marty 2004, Pyke and Marty 2005). Italian ryegrass (*Lolium multiflorum*) has rapidly become a dominant invasive species of the uppermost zone of vernal pools and appears to have undergone rapid adaptation to alkaline clay soils (Dawson et al. 2007).

Altered Hydrology. Human disturbances can alter the hydrology of temporary waters and result in a change in the timing, frequency, or duration of inundation in vernal pools, which can create conditions that render existing vernal pools unsuitable for vernal pool species (USFWS 2005, 2007).

A38.6 RELEVANT CONSERVATION EFFORTS

Conservancy fairy shrimp was listed as endangered and critical habitat was designated as noted above. Critical habitat unit 3 includes an area north of the Potrero Hills that is within the Plan Area. Throughout the range of the species, vernal pool habitats supporting populations of Conservancy fairy shrimp have been protected through a variety of other means, including preserves, refuges, and protections on private lands. Within the Solano-Colusa Vernal Pool Region, Conservancy fairy shrimp is protected on the DFG Tule Ranch Reserve, the proposed Burke Ranch mitigation bank, in the Jepson Prairie Preserve system, and in the Montezuma Wetlands Mitigation site (Witham 2003, 2006, USFWS 2007).

Conservancy fairy shrimp is covered under the approved San Joaquin County Multi-species Habitat Conservation and Open Space Plan, and is proposed for coverage under the Solano County Multispecies Habitat Conservation Plan, the Yolo County Natural Heritage Program Plan, and the Butte Regional Conservation Plan.

A38.7 SPECIES HABITAT SUITABILITY MODEL

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below and in Section 2.3.1, *Data Sources and Natural Community Classification*). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as vernal pools, individual trees, or small groups of trees. It is also possible, as with some vernal pool invertebrates that are restricted to seasonally ponded habitats, to underestimate potentially-occupied habitat due to the lack of information on small, degraded or artificially-created seasonal wetland habitats.

Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The Conservancy fairy shrimp model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), DWR 2007 LiDAR elevation data, Google Earth 2009 aerial imagery and United States Department of Agriculture (USDA) 2005 aerial photography. Using these data sets, the model maps the distribution of suitable Conservancy fairy shrimp habitat in the Plan Area according to the species' two habitat types, vernal pool complex and degraded vernal pool complex habitat. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Vernal Pool Complex Habitat: High quality permanent habitat that consists of vernal pools and uplands that display characteristic vernal pool and swale visual signatures that have not been significantly impacted by agricultural or development practices. Vernal pool complex habitat for Conservancy fairy shrimp includes the following vegetation subunits that were selected from the BDCP vernal pool complex natural community:

- Vernal pool complex – all vegetation types

Degraded Vernal Pool Complex Habitat: Low quality ephemeral habitat that ranges from areas with vernal pool and swale visual signatures that display clear evidence of significant disturbance due to plowing, disking, or leveling to areas with clearly artificial basins such as shallow agricultural ditches, depressions in fallow fields, and areas of compacted soils in pastures. The aquatic features in this habitat are more clearly classified as temporary waters *sensu lato* (Williams 2006) than intact and fully functional vernal pools. Because these features are inundated during the wet season and may have historically been located in or near areas with natural vernal pool complex, they may support individuals or small populations of species that are found in vernal pools and swales. However, they do not possess the full complement of ecosystem and community characteristics of natural vernal pools, swales and their associated uplands and they are generally ephemeral features that are eliminated during the course of normal agricultural practices. Degraded vernal pool complex habitat for Conservancy fairy shrimp includes the following vegetation subunits that were selected from the BDCP other natural seasonal wetlands and grasslands communities:

- Grasslands
    - Degraded vernal pool complex – California annual grasslands;
    - Degraded vernal pool complex – Ruderal herbaceous grasses and forbs;
    - Degraded vernal pool complex – Italian rye-grass (*Lolium multiflorum*); and
    - Degraded vernal pool complex – Rabbitsfoot grass (*Polygpogon maritimus*).
- Other natural seasonal wetlands
    - Degraded vernal pool complex – Vernal pools.

Potential habitat without concave surfaces was removed from the model. LiDAR elevation data was then visually inspected in four general areas to further assess specific locations that had been identified by the habitat selection process. These areas were selected based both on *a priori* knowledge of the region and because they were identified by the intersection of the selected vegetation types and soils. The analysis of the LiDAR data further refined the habitat model and provided a more accurate demarcation of suitable habitat. The GIS habitat model was then compared against field data from surveys conducted by the California Department of Water Resources in 2009. Land uses that are incompatible with the species' habitat requirements, for example, potential habitat polygons falling on leveled or developed lands were removed from the model.

Assumptions. Historical and current records of this species in the Plan Area indicate that its current distribution is limited to the northwestern perimeter of the Plan Area (Figure A-38b) (Witham 2002, 2003, 2006, CNDDB 2010). However, because the Plan Area has not been completely surveyed, its potential distribution was increased to the southwestern and eastern perimeter of the Plan Area as well. The vegetation cover of the alkaline soils is typically a combination of vernal pool adapted species and annual ryegrass (Witham 2002, 2003, 2006, CNDDB 2010).

A38.8 Recovery Goals

The recovery goal of Conservancy fairy shrimp is to delist the species and ensure its long-term conservation (USFWS 2005). Interim goals are to: (1) stabilize and protect populations, (2) conduct research to refine reclassification and recovery criteria, and (3) downlist endangered species to threatened. Vernal pool habitats used by the species as well as historical and potential habitats need to be protected, and habitat management plans for these habitats need to be developed and implemented. Recovery criteria have been established in the Recovery Plan (USFWS 2005). The criteria to downlist the species are: protect 100 percent of the present occurrences and protect 95 percent of its suitable habitat in the Vina Plains, Caswell, Grassland Ecological Area, Ventura County, Jepson Prairie, Sacramento National Wildlife Refuge (NWR), Collinsville, and Madera Core Areas. The criteria to delist the species are: protect 100 percent of newly discovered/reintroduced populations and regions and soil types from which surveys indicate the species has been extirpated and reintroduce the species into vernal pool regions and soil types from which surveys indicate that it has been extirpated (USFWS 2005).

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APPENDIX A39. LONGHORN FAIRY SHRIMP (*BRANCHINECTA LONGIANTENNA*)

A39.1 LEGAL STATUS

The longhorn fairy shrimp (*Branchinecta longiantenna*) was federally listed as endangered by the U.S. Fish and Wildlife Service (USFWS) on September 19, 1994 (59 FR 48136). On October 9, 2007, the USFWS published a 5-year review recommending that the species remain listed as endangered (USFWS 2007). Revised critical habitat was designated on February 10, 2006 (71 FR 7118) and critical habitat unit designations were published for Contra Costa, Alameda, Merced, and San Luis Obispo counties on February 10, 2006 (71 FR 7118). This species is covered by the December 15, 2005, Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (USFWS 2005). The longhorn fairy shrimp has no state regulatory status.

A39.2 SPECIES DISTRIBUTION AND STATUS

A39.2.1 Range and Status

The historical distribution of the longhorn fairy shrimp is not known, but probably did not extend into the northern portion of the Central Valley or into southern California (USFWS 2005, 2007). Currently, populations are known from Concord in Contra Costa County in the north to Soda Lake in San Luis Obispo County in the south (Figure A-39a), including populations in Alameda and Merced counties (USFWS 2007). The Contra Costa and Alameda County populations are located within the Livermore Vernal Pool Region, while known populations in Merced County are at the Kesterson National Wildlife Refuge and in a roadside ditch just north of Los Banos in the San Joaquin Vernal Pool Region (USFWS 2005, 2007). Those in San Luis Obispo County are adjacent to Soda Lake in the Carrizo Vernal Pool Region (both immediately outside and within the Carrizo Plain National Monument). Occurrences are rare and highly disjunct with specific pool characteristics largely unknown (USFWS 2005, 2007). The Altamont Pass subunits of the species (Contra Costa and Alameda counties) occur within clear-water depression pools in sandstone outcrops (Eng et al. 1990, Eriksen and Belk 1999, CNDDB 2010).

A39.2.2 Distribution and Status in the Plan Area

The species is not known to occur in the Plan Area (Figure A-39b) (CNDDB 2010). The closest populations are in Contra Costa County (Vasco Caves Preserve) and Alameda County (Brushy Peak Preserve) just southwest of the Plan Area. These occurrences are in seasonal pools within sandstone depressions in rocky outcrops which are not present anywhere within the Plan Area.

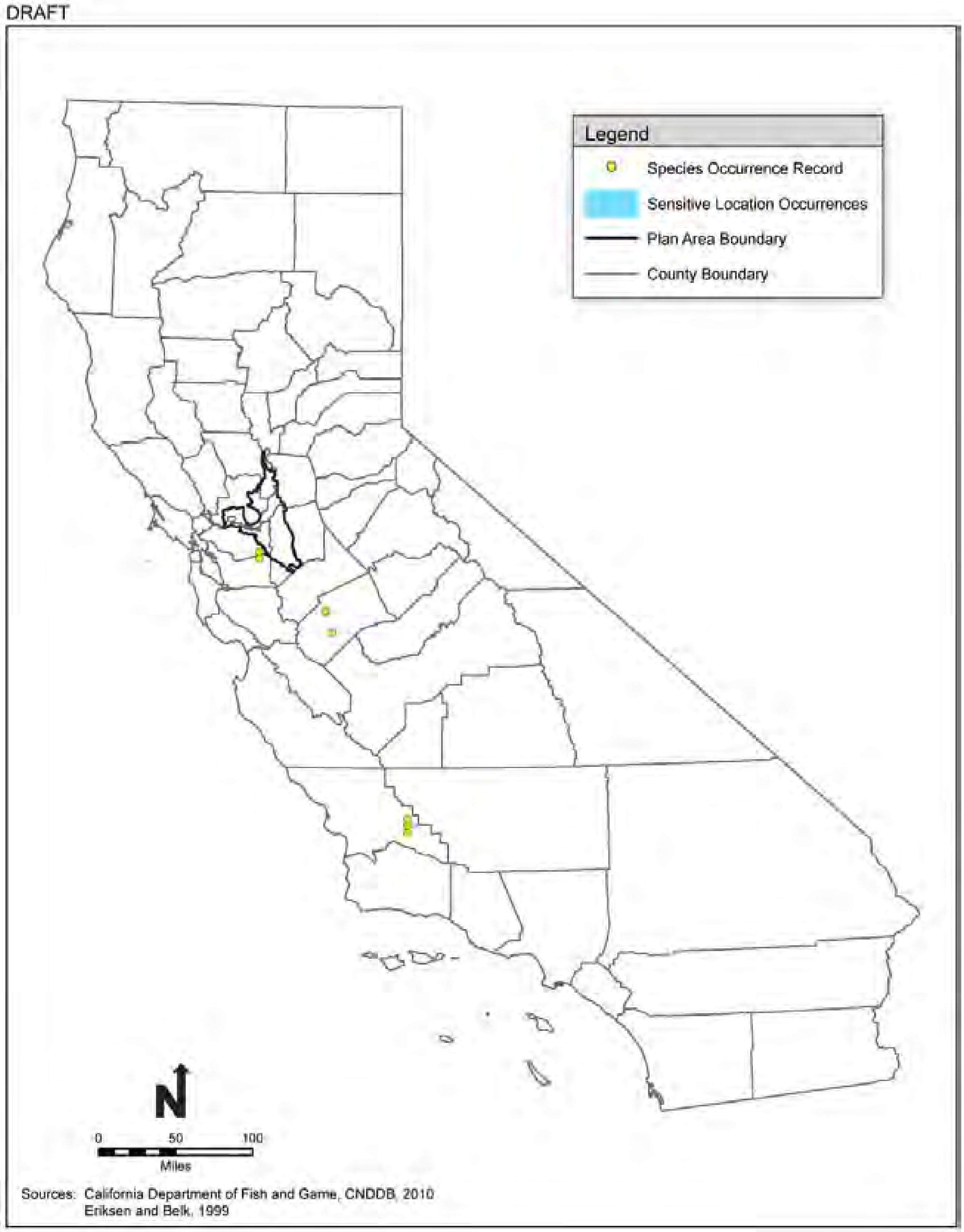

Figure A-39a. Longhorn Fairy Shrimp Statewide Recorded Occurrences

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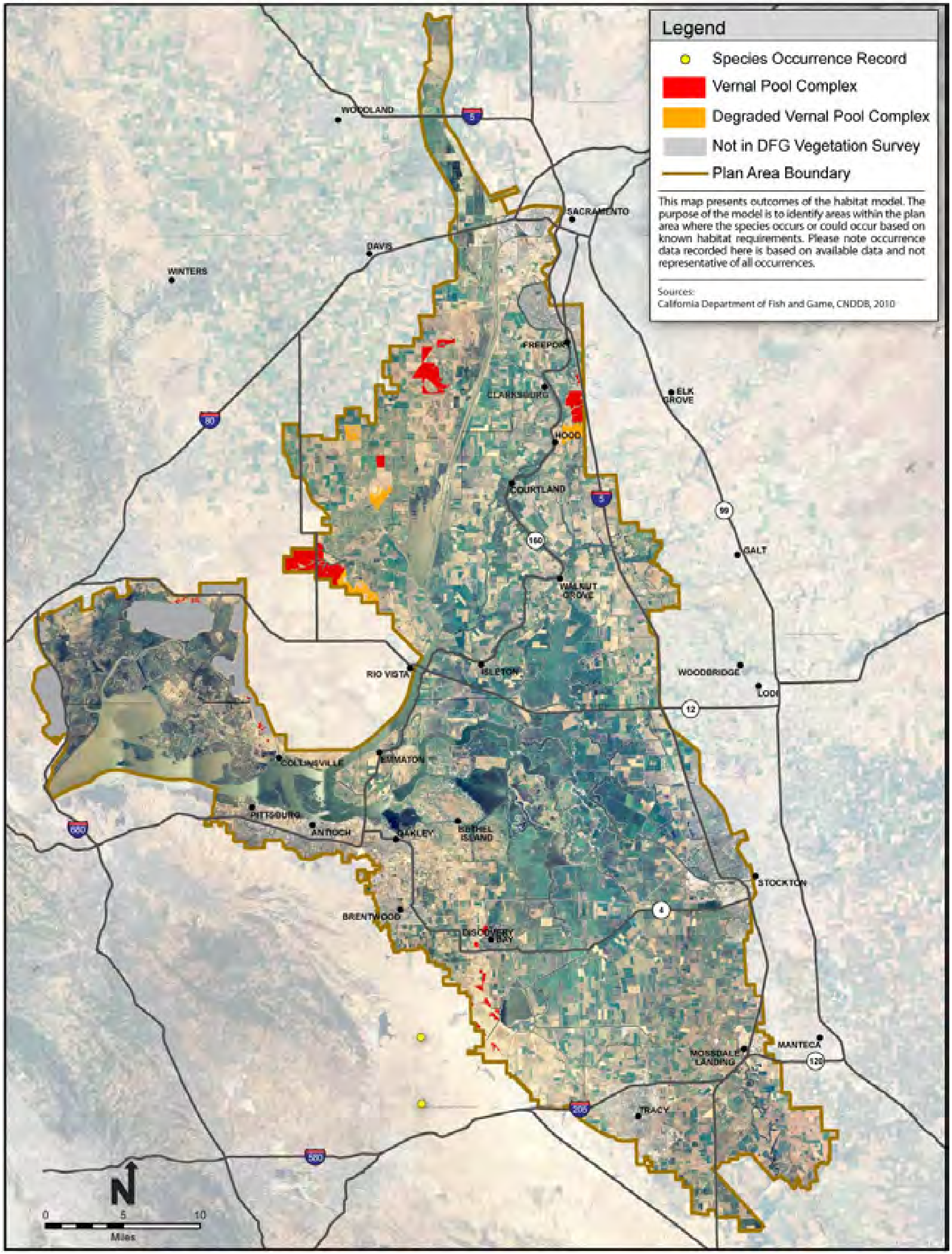

Figure A-39b. Longhorn Fairy Shrimp Habitat Model and Recorded Occurrences

This species also occurs in pools within alkali sink vegetation in other parts of its known range (USFWS 2005, 2007, CNDDB 2010), but it has not been detected in similar pools in the Plan Area despite at least 14 years of extensive vernal pool surveys (USFWS 2005, 2007). While it has not been detected in the Plan Area, vernal pools that may support the species occur on alkaline soils from the Tule Ranch Unit of the California Department of Fish and Game (DFG) Yolo Bypass Wildlife Area southwest to the Montezuma Wetlands Mitigation Projects and from the Byron Airport to Discovery Bay.

A39.3 Habitat Requirements and Special Conditions

Longhorn fairy shrimp in Contra Costa and Alameda counties are primarily reported from small (less than one meter diameter) water-filled sandstone depressions while those in the San Joaquin Valley and Carrizo Plain are found in shallow vernal pools within alkali sink vegetation in water with neutral potential of hydrogen (pH) (7.2) and a low chloride concentration (Helm 1998, USFWS 2005, 2007, CNDDB 2010). These vernal pool habitats are subject to seasonal variations including duration of ponding. This species has likely evolved adaptations to these variations (59 FR 48136). The longhorn fairy shrimp is capable of living in vernal pools of relatively short duration (ponding six to seven weeks in winter and three weeks in spring) (Eriksen and Belk 1999).

A39.4 Life History

Description. Longhorn fairy shrimp are generally similar to other fairy shrimp species with delicate elongate bodies, large stalked compound eyes, no carapaces, and eleven pairs of swimming legs. Longhorn fairy shrimp is distinguished from other species by its elongated second antennae, which is twice the length, relative to its body, of that of other Branchinecta species. Size ranges from approximately 12 to 21 millimeters (0.5 to 0.8 inches). Males and females are differentiated primarily on the basis of the length of the second antennae, but also by thoracic projections and brood pouch development.

Reproduction and Growth. Longhorn fairy shrimp is a component of the planktonic crustacea within seasonal temporary pools, but nothing is known about its role in foodwebs. Beyond inundation, the specific cues for cyst hatching are unknown (Eriksen and Belk 1999), although temperature is believed to play a large role. When reared in plastic pools, with their bottoms lined with soil excavated from vernal pools and without supplemental food, some individuals of this species completed their lifecycle in 23 days but the average time was 43 days (Helm 1998). Longhorn fairy shrimp have been reported to co-occur in the same general area with the vernal pool fairy shrimp (*Branchinecta lynchi*), but the species did not occupy the same vernal pools (Eng et al. 1990).

Feeding. Longhorn fairy shrimp is an omnivouous filter-feeder. In general, all fairy shrimp species indiscriminately filter particles that include bacteria, unicellular algae, and micrometazoa

(Eriksen and Belk 1999). The precise size of items these fairy shrimp are capable of filtering is currently unknown. However, fairy shrimp species will attempt to consume whatever material they can fit into their feeding groove and do not discriminate based upon taste, as do some other crustacean groups (Eriksen and Belk 1999).

Predation and Dispersal. Planktonic Crustacea are important in the food web, as they represent a high-fat, high-protein resource for migratory waterfowl. Mallard (*Anas platyrhynchos*), green-winged teal (*A. crecca*), bufflehead (*Bucephala albeola*), greater yellowlegs (*Tringa melanoleuca*), and killdeer (*Charadrius vociferus*) all forage actively in Central Valley vernal pools on the invertebrate and amphibian fauna during the winter months (Silveira 1996, Bogiatto and Karnegis 2006).

Predator consumption of fairy shrimp cysts aids in distributing populations of fairy shrimp. Predators (e.g., birds and amphibians) expel viable cysts in their excrement, often at locations other than where they were consumed. If conditions are suitable, these transported cysts may hatch at the new location and potentially establish a new population. Cysts are also transported by wind and in mud carried on the feet of animals, including livestock that may wade through fairy shrimp habitat. This type of dispersal aids ephemeral pool crustaceans in exploiting a wide variety of ephemeral habitats (Erickson and Belk 1999).

A39.5 THREATS AND STRESSORS

The primary disturbance to longhorn fairy shrimp occurring in the vicinity of the Plan Area (i.e., Altamont Pass area) is from habitat disturbances caused by the construction and operation of wind energy equipment and related activities (USFWS 2007). Within this area, habitat loss or disturbance from urbanization and agricultural development and impacts related to these activities are of less concern compared with other vernal pool types in locations more vulnerable to these activities.

A39.6 RELEVANT CONSERVATION EFFORTS

The species was listed as endangered and critical habitat was designated as noted above. Vernal pool habitat on the Carrizo Plain has been partially protected in the Carrizo National Monument (USFWS 2007). Habitats in the San Joaquin Vernal Pool region are protected at the Kesterson National Wildlife Refuge (USFWS 2005, 2007). Known occurrences in sandstone depression pools in the Altamont area are protected in the Brushy Peak and Vasco Caves preserves which are on property owned and managed by the East Bay Regional Parks District (USFWS 2007).

The longhorn fairy shrimp is covered under the approved San Joaquin County Multi-species Habitat Conservation and Open Space Plan and East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan.

A39.7 SPECIES HABITAT SUITABILITY MODEL

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below and in Section 2.3.1, *Data Sources and Natural Community Classification*). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as vernal pools, individual trees, or small groups of trees. It is also possible, as with some vernal pool invertebrates that are restricted to seasonally ponded habitats, to underestimate potentially-occupied habitat due to the lack of information on small, degraded or artificially-created seasonal wetland habitats.

Still, for most species the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The longhorn fairy shrimp model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), DWR 2007 LiDAR elevation data, Google Earth 2009 aerial imagery and United States

Department of Agriculture (USDA) 2005 aerial photography. Using these data sets, the model maps the distribution of suitable longhorn fairy shrimp habitat in the Plan Area according to the species' two habitat types, vernal pool complex and degraded vernal pool complex habitat. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Vernal Pool Complex Habitat: High quality permanent habitat that consists of vernal pools and uplands that display characteristic vernal pool and swale visual signatures that have not been significantly impacted by agricultural or development practices. Vernal pool complex habitat for longhorn fairy shrimp includes the following vegetation subunits that were selected from the BDCP vernal pool complex natural community:

- Vernal pool complex – all vegetation types

Degraded Vernal Pool Complex Habitat: Low quality ephemeral habitat that ranges from areas with vernal pool and swale visual signatures that display clear evidence of significant disturbance due to plowing, disking, or leveling to areas with clearly artificial basins such as shallow agricultural ditches, depressions in fallow fields, and areas of compacted soils in pastures. The aquatic features in this habitat are more clearly classified as temporary waters *sensu lato* (Williams 2006) than intact and fully functional vernal pools. Because these features are inundated during the wet season and may have historically been located in or near areas with natural vernal pool complex, they may support individuals or small populations of species that are found in vernal pools and swales. However, they do not possess the full complement of ecosystem and community characteristics of natural vernal pools, swales and their associated uplands and they are generally ephemeral features that are eliminated during the course of normal agricultural practices. Degraded vernal pool complex habitat for longhorn fairy shrimp includes the following vegetation subunits that were selected from other natural seasonal wetlands and grasslands communities:

- Grasslands
    - Degraded vernal pool complex – California annual grasslands;
    - Degraded vernal pool complex – Ruderal herbaceous grasses and forbs;
    - Degraded vernal pool complex – Italian rye-grass (*Lolium multiflorum);* and
    - Degraded vernal pool complex – Rabbitsfoot grass (*Polygpogon maritimus*).
- Other natural seasonal wetlands
    - Degraded vernal pool complex – Vernal pools.

Potential habitat without concave surfaces was removed from the model. LiDAR elevation data was then visually inspected in four general areas to further assess specific locations that had been identified by the habitat selection process. These areas were selected based both on *a priori* knowledge of the region and because they were identified by the intersection of the selected vegetation types and soils. The analysis of the LiDAR data further refined the habitat model and provided a more accurate demarcation of suitable habitat. The GIS habitat model was then compared against field data from surveys conducted by the California Department of Water Resources in 2009. Land uses that are incompatible with the species' habitat requirements, for example, potential habitat polygons falling on leveled or developed lands were removed from the model.

Assumptions. Longhorn fairy shrimp is not known to occur in the Plan Area. The Plan Area does not support rock outcrops with seasonal pools, which is the primary habitat type this species is known to use in the region. However, because this species is known to occur in vernal pools in alkali sink vegetation in San Joaquin County and the Carrizo Plain, identifying potential habitat for this species was conducted similarly to other covered vernal pool invertebrates. Potential habitat is limited to alkaline soil areas with vernal pool and swale microtopography within the Plan Area (Figure A-39b) (Witham 2002, 2003, 2006, CNDDB 2010). The vegetation cover of the alkaline soils is typically a combination of vernal pool adapted species and annual ryegrass (Witham 2002, 2003, 2006, CNDDB 2010).

A39.8 Recovery Goals

The Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon was finalized by the USFWS in 2005. With an overall recovery goal to delist the species and ensure its long-term conservation, interim goals include: (1) stabilize and protect populations, (2) conduct research to refine reclassification and recovery criteria, and (3) downlist endangered species to threatened. Vernal pool habitats used by the species as well as historical and potential habitats need to be protected, and habitat management plans for these habitats need to be developed and implemented. Recovery criteria have been established in the Recovery Plan. The criteria to downlist the species are: protect 100 percent of the present occurrences and protect 95 percent of its suitable habitat in the North Carrizo Plain, South Carrizo Plain, Altamont Hills, and Grassland Ecological Area Core Areas. The criteria to delist the species are: protect 100 percent of newly discovered/reintroduced populations, reintroduce the species into vernal pool regions and soil types from which surveys indicate the species has been extirpated, and discover or establish additional populations (USFWS 2005).

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A39.9.2 Federal Register Notices Cited

59 FR 48136. 1994. Final Rule: Endangered and Threatened Wildlife and Plants: Determination of endangered status for the conservancy fairy shrimp, longhorn fairy shrimp, and the vernal pool tadpole shrimp; and threatened status for the vernal pool fairy shrimp. Federal Register 59: 48136.

71 FR 7118. 2006. Final Rule: Endangered and Threatened Wildlife and Plants: Designation of critical habitat for four vernal pool crustaceans and eleven vernal pool plants. Federal Register 71: 7118.

APPENDIX A40. VERNAL POOL FAIRY SHRIMP (*BRANCHINECTA LYNCHI*)

A40.1 LEGAL STATUS

Vernal pool fairy shrimp (*Branchinecta lynchi*) is listed as threatened under the federal Endangered Species Act throughout its range (59 FR 48136). In September 2007, the U.S. Fish and Wildlife Service (USFWS) published a 5-year review recommending that the species remain listed as threatened. Revised critical habitat was designated on February 10, 2006 (71 FR 7118). This species is covered by the December 15, 2005, Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (USFWS 2005). Only one unit, 19B, is partially within the Plan Area boundary. Vernal pool fairy shrimp has no state regulatory status.

A40.2 SPECIES DISTRIBUTION AND STATUS

A40.2.1 Range and Status

Vernal pool fairy shrimp was identified in 1990 (Eng et al. 1990) and there is little information on the historical range of the species. It has the largest geographical range of listed fairy shrimp in California, but is seldom abundant (Eng et al. 1990). The species is currently found in disjunct and fragmented habitats across the Central Valley of California from Shasta County to Tulare County and the central and southern Coast Ranges from northern Solano County to Ventura County, California (Figure A-40a) (USFWS 2005, 2007, CNDDB 2010). Additional disjunct occurrences have been identified in southern California and in Jackson County, Oregon. In California, it occurs in a wide range of vernal pools, and in the Altamont Pass area (Contra Costa and Alameda counties) it occurs in clear-water depression pools in sandstone outcrops (Eng et al 1990, Eriksen and Belk 1999, CNDDB 2010).

A40.2.2 Distribution and Status in the Plan Area

Vernal pool fairy shrimp has been reported from several locations within the Plan Area (Figure A-40b) (USFWS 2005, 2007, CNDDB 2010). In general, within the Plan Area, vernal pools that may support the species occur on alkaline soils from the California Department of Fish and Game (DFG) Tule Ranch Reserve southwest to the Montezuma Wetlands Mitigation Projects and from the Byron Airport to Discovery Bay. Other potential vernal pool habitat occurs along the eastern boundary of the Plan Area near Stone Lakes (Figure A-40b). Seven additional occurrences were discovered in the south Stone Lakes area during 2009 surveys conducted by the California Department of Water Resources (DWR). A comprehensive survey of vernal pools or habitat for vernal pool fairy shrimp has not been conducted in the Plan Area.

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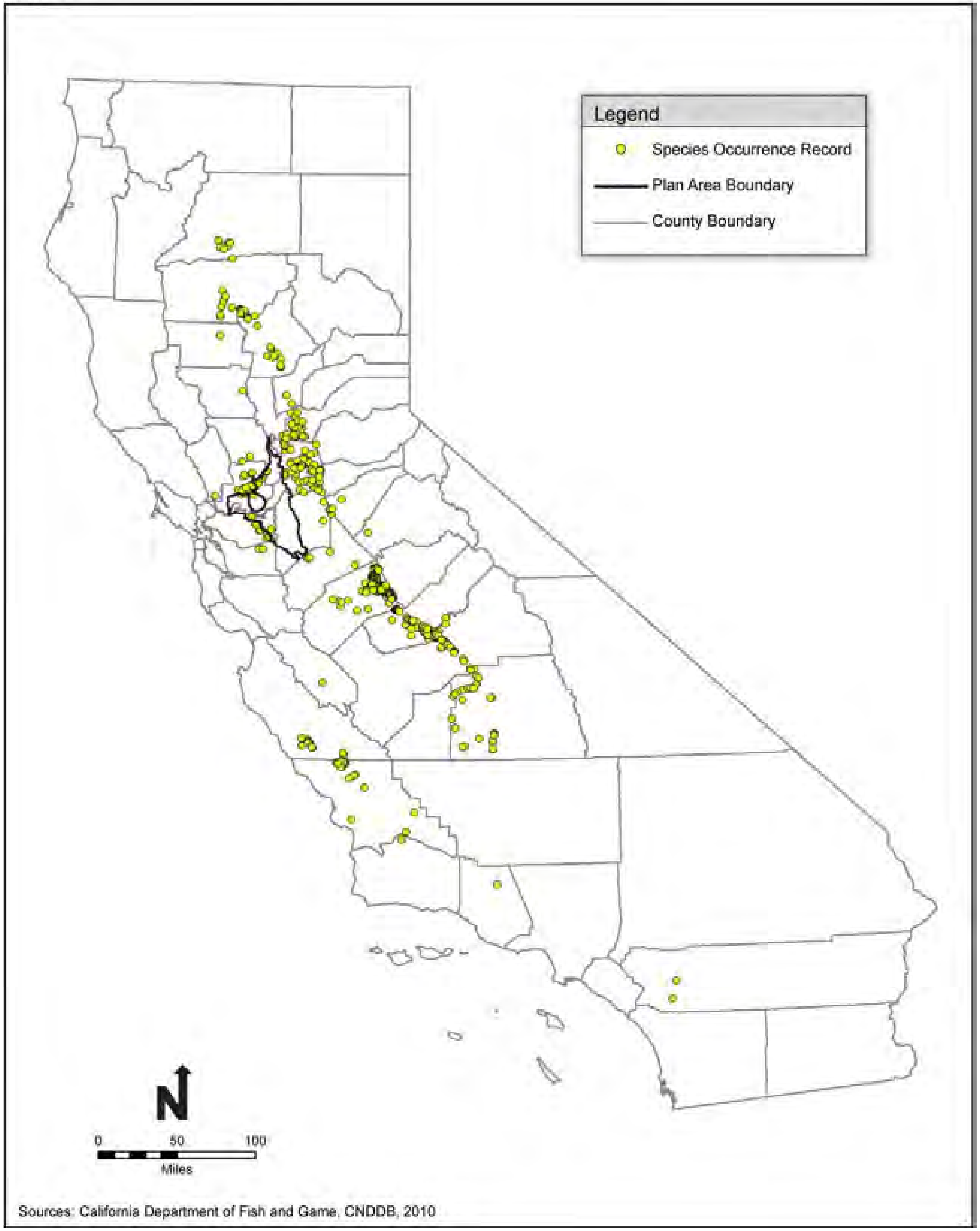

Figure A-40a. Vernal Pool Fairy Shrimp Statewide Recorded Occurrences

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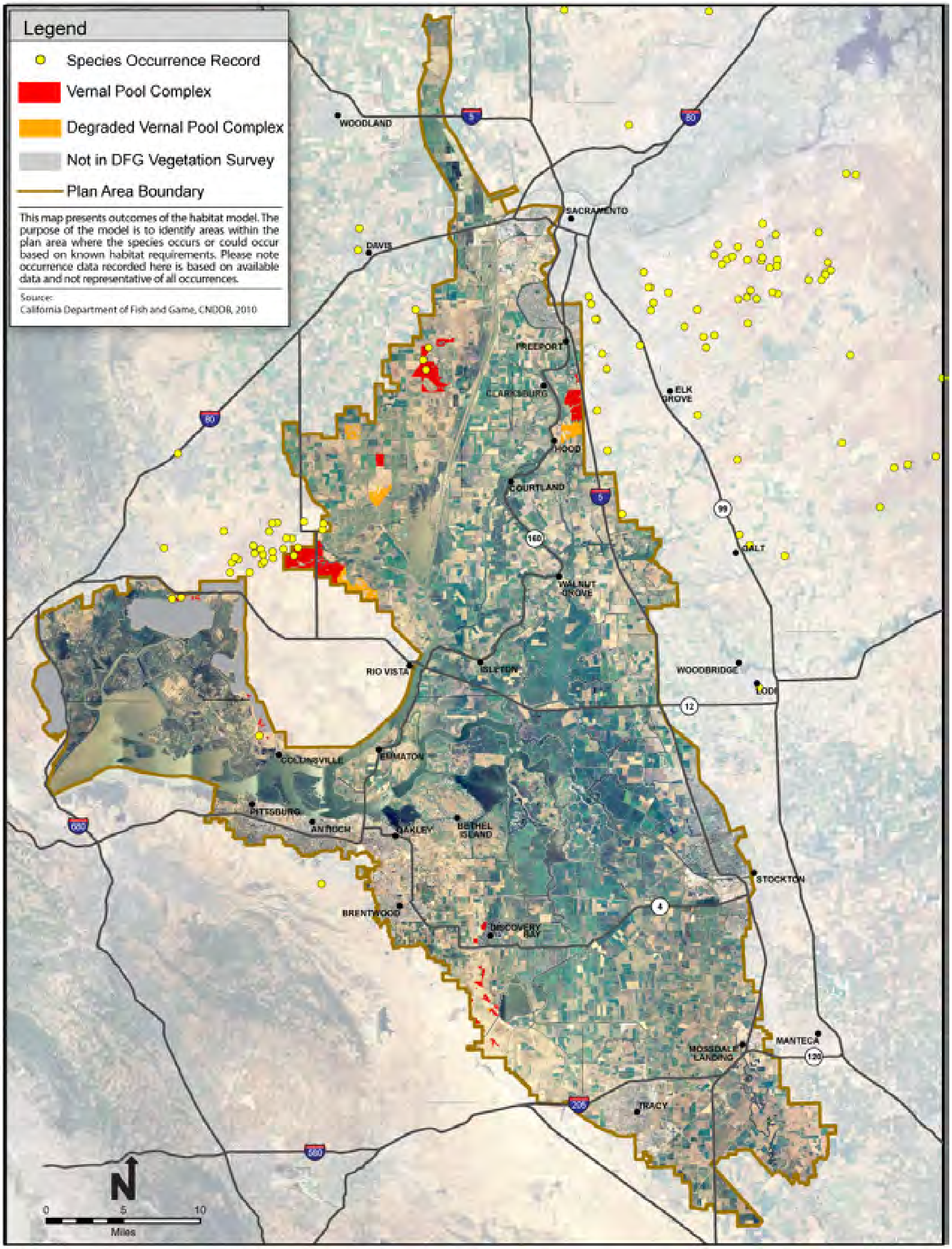

Figure A-40b. Vernal Pool Fairy Shrimp Habitat Model and Recorded Occurrences

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A40.3 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

This species is entirely dependent on the aquatic environment provided by the temporary waters of natural vernal pool and playa pool ecosystems as well as the artificial environments of ditches and tire ruts (King et al. 1996, Helm 1998, Eriksen and Belk 1999). The temporary waters in which vernal pool tadpole shrimp inhabits fill in the fall and winter during the beginning of the wet season and dry in late-spring at the beginning of the dry season and remain desiccated throughout the summer (Helm 1998, Eriksen and Belk 1999). The temporary waters fill directly from precipitation as well as from runoff from their watersheds (Williamson et al. 2005, Rains et al. 2006, 2008, O'Geen et al. 2008). The watershed extent that is necessary for maintaining the hydrological functions of the temporary waters depends on a number of complex factors including the hydrologic conductivity of the surface soil horizons, the continuity and extent of hard-pans and clay-pans underlying non-clay soils, the existence of a perched aquifer overlying the pans, slope, effects of vegetation on evapotranspiration rates, compaction of surface soils by grazing animals, and other factors (Marty 2004, Pyke and Marty 2005, Williamson et al. 2005, Rains et al. 2006, 2008, O'Geen et al. 2008).

The temporary waters that are habitat for vernal pool fairy shrimp are extremely variable and range from clear sandstone pools with little alkalinity to turbid vernal pools on clay soils with moderate alkalinity (King et al. 1996, Eriksen and Belk 1999). Common wetland plant species that co-occur with vernal pool fairy shrimp include toad rush (*Juncus bufonius*), coyote thistle (*Eryringium* spp.), downingia (*Downingia ornatissma* or *D. bicornuta*), goldfields (*Lasthenia* spp.), woolly marbles (*Psilocarphus* spp.), and hair grass (*Deschampsia* spp.) (King et al. 1996, Alexander and Schlising 1997, 1998, Helm 1998, Plattencamp 1998, Eriksen and Belk 1999, Alexander 2007). Vernal pool fairy shrimp have also occasionally been found in degraded vernal pool habitats and artificially-created seasonal pools (Helm 1998). Vernal pool fairy shrimp commonly co-occur with the fairy shrimp (*Linderiella occidentalis*, *Branchinecta conservatio*, *B. lindahli*, *B. coloradensis*) and vernal pool tadpole shrimp (*Lepidurus packardi*). The midvalley shrimp (*B. mesovallensis*) and *B. longiantenna* both occur within the range of vernal pool tadpole shrimp but are typically found in different habitats (USFWS 2005, 2007).

A40.4 LIFE HISTORY

Description. Vernal pool fairy shrimp is a typical Branchinectid anostracan. They are typically off-white to grey. Depending on the rapidity of development, mature animals may vary in length from 3 to 38 millimeters (0.12 to 1.50 inch). Like other fairy shrimp, they are entirely aquatic with delicate elongate bodies, large stalked compound eyes, no carapaces, and eleven pairs of swimming legs. Males and females are generally differentiated on the basis of antennae development, thoracic projections, and brood pouch development.

Reproduction and Growth. Vernal pool fairy shrimp are adapted to the environmental conditions of their ephemeral habitats. One adaptation is the ability of vernal pool fairy shrimp eggs, or cysts, to remain dormant in the soil when their vernal pool habitats are dry. The cysts survive the hot, dry summers and cold, wet winters that follow until vernal pools and swales fill with rainwater and conditions are right for hatching. When the pools refill in the same or subsequent seasons some, but not all, of the eggs may hatch. The egg bank in the soil may comprise eggs from several years of breeding (USFWS 2005, 2007). Beyond inundation of the habitat, the specific cues for hatching are unknown, although temperature and conductivity (solute concentration) are believed to play a large role (Helm 1998, Eriksen and Belk 1999).

In a study using large plastic pools to simulate natural vernal pools, Helm found no difference in the time to reproduce among California linderiella, Conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, midvalley fairy shrimp, and vernal pool tadpole shrimp (46 days) (Helm 1998). However, that experiment supplemented by field data (Gallagher 1996, Alexander 2007) suggests that the average time to reproduce for California linderiella, Conservancy fairy shrimp, longhorn fairy shrimp, and vernal pool fairy shrimp is approximately 8 weeks, while that for midvalley fairy shrimp is approximately 2 weeks. No data were reported regarding pool fertility or the impacts of predation on the time to reproduce. These reproduction periods may be shortened or lengthened by warmer or colder water temperatures (Helm 1998).

Feeding. Vernal pool fairy shrimp is an omnivorous filter-feeder. In general, all fairy shrimp species indiscriminately filter particles that include bacteria, unicellular algae, and micrometazoa (Eriksen and Belk 1999). The precise size of items these fairy shrimp are capable of filtering is currently unknown. However, fairy shrimp species will attempt to consume whatever material they can fit into their feeding groove and do not discriminate based upon taste, as do some other crustacean groups (Eriksen and Belk 1999).

Predation and Dispersal. Planktonic Crustacea are important in the food web, as they represent a high-fat, high-protein resource for migratory waterfowl. Mallard (*Anas platyrhynchos*), green-winged teal (*A. crecca*), bufflehead (*Bucephala albeola*), greater yellowlegs (*Tringa melanoleuca*), and killdeer (*Charadrius vociferus*) all forage actively in Central Valley vernal pools on the invertebrate and amphibian fauna during the winter months (Silveira 1996, Bogiatto and Karnegis 2006).

Predator consumption of fairy shrimp cysts aids in distributing populations of fairy shrimp. Predators (e.g., birds and amphibians) expel viable cysts in their excrement, often at locations other than where they were consumed. If conditions are suitable, these transported cysts may hatch at the new location and potentially establish a new population. Cysts are also transported by wind and in mud carried on the feet of animals, including livestock that may wade through fairy shrimp habitat. This type of dispersal aids ephemeral pool crustaceans in exploiting a wide variety of ephemeral habitats (Erickson and Belk 1999).

A40.5 THREATS AND STRESSORS

Threats to vernal pool habitat and species in general, including vernal pool fairy shrimp, were identified in the Recovery Plan (USFWS 2005, 2007). In addition, the Recovery Plan identified several threats specific to vernal pool fairy shrimp. Within the entire range of the species, more than half of the known populations of vernal pool fairy shrimp are threatened by development or agricultural conversion. Several populations are found on military bases, and although not an immediate threat, military activities can result in alteration of pool characteristics, including introduction of non-native plant species (USFWS 2005, 2007).

Habitat Loss and Fragmentation. Habitat loss and fragmentation were identified as the largest threats to the survival and recovery of vernal pool species. Habitat loss generally is a result of agricultural conversion from rangelands to intensive farming, urbanization, aggregate mining, infrastructure projects (such as roads and utility projects), and recreational activities (such as off-highway vehicles and hiking) (USFWS 2005, 2007). Habitat fragmentation occurs when vernal pool complexes are broken into smaller groups or individual vernal pools and become isolated from each other as a result of activities such as road development and other infrastructure projects (USFWS 2005, 2007).

Agricultural Conversion. Conversion of land use, such as from grasslands or pastures to more intensive agricultural uses (e.g., croplands) or from one crop type to another has contributed and continues to contribute to the decline of vernal pools in general (USFWS 2005, 2007).

Invasive Species. The invasions of vernal pools by waxy mannagrass (*Glyceria declinata*), an invasive aquatic grass (Gerlach et al. 2009), greatly increases the amount of decomposing biomass in vernal pools and may result in higher respiratory oxygen consumption relative to photosynthetic oxygen generation (Rogers 1998). Also, upland biomass of invasive species such as medusahead (*Taeniatherum caput-medusae*) can produce dense vegetation and thatch, shortening the ponding duration of some vernal pools (Marty 2004, Pyke and Marty 2005). Italian ryegrass (*Lolium multiflorum*) has rapidly become a dominant invasive species of the uppermost zone of vernal pools and appears to have undergone rapid adaptation to alkaline clay soils (Dawson et al. 2007).

Altered Hydrology. Human disturbances can alter the hydrology of temporary waters and result in a change in the timing, frequency, or duration of inundation in vernal pools, which can create conditions that render existing vernal pools unsuitable for vernal pool species (USFWS 2005, 2007).

Habitat alteration may also occur due to large-scale climate and environmental changes, such as global climate change, which lead to changes in precipitation patterns and atmospheric conditions. Most of the populations of vernal pool fairy shrimp are isolated from other populations and are distributed in discontinuous vernal pool systems. Small, isolated populations are vulnerable, which could result in extirpation from a particular area (USFWS 2005, 2007).

A40.6 RELEVANT CONSERVATION EFFORTS

A total of 597,821 acres, occupying 30 units, has been designated as critical habitat within the state of California (71 FR 7118). Critical habitat unit 16A, which is immediately north of the Potrero Hills, and units 19A and 19B in east Contra Costa County are partially within the Plan Area. In addition, approximately 13,000 acres of vernal pool habitats, including mitigation banks, have been set aside for vernal pool fairy shrimp specifically as terms and conditions of Section 7 consultations. These areas are scattered throughout the Central Valley and represent important building blocks toward recovery of vernal pool fairy shrimp. Throughout the range of the species, vernal pool habitats supporting populations of vernal pool fairy shrimp have been protected through a variety of other means, including preserves, refuges, and protections on private lands. In the Solano-Colusa Vernal Pool Region, vernal pool fairy shrimp are protected in the Jepson Prairie Ecosystem, including the Tule Ranch unit of the DFG Yolo Bypass Wildlife Area (Tule Ranch, DFG Calhoun Cut Ecological Reserve, Burke Ranch, Jepson Prairie Preserve, and Montezuma Wetlands Mitigation owned by the Solano County Open Space and Farmland Conservancy (USFWS 2005, 2007). Known occurrences in sandstone depression pools in the Altamont area are protected in the Brushy Peak and Vasco Caves preserves that are on property owned and managed by the East Bay Regional Parks District (USFWS 2007).

Vernal pool fairy shrimp is covered under the approved San Joaquin County Multi-species Habitat Conservation and Open Space Plan, Natomas Basin Habitat Conservation Plan, and East Contra Costa Habitat Conservation Plan/Natural Community Conservation Plan. In addition, the species is proposed for coverage under the Solano County Multispecies Habitat Conservation Plan, South Sacramento County Habitat Conservation Plan, the Yolo County Natural Heritage Program Plan that are under development, and the Butte Regional Conservation Plan.

A40.7 SPECIES HABITAT SUITABILITY MODEL

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing GIS data sources (described below and in Section 2.3.1, *Data Sources and Natural Community Classification*). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as vernal pools, individual trees, or small groups of trees. It is also possible, as with vernal pool fairy shrimp, to underestimate potentially-occupied habitat due to the lack of information on small, degraded or artificially-created seasonal wetland habitats.

Still, for most species the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

For each model, the mapping data sets and each vegetation type or association is identified. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. Vernal pool fairy shrimp model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), DWR 2007 LiDAR elevation data, Google Earth 2009 aerial imagery and USDA 2005 aerial photography. Using these data sets, the model maps the distribution of suitable vernal pool fairy shrimp habitat in the Plan Area according to the species' two habitat types, vernal pool complex and degraded vernal pool complex habitat. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Vernal Pool Complex Habitat: High quality permanent habitat that consists of vernal pools and uplands that display characteristic vernal pool and swale visual signatures that have not been significantly impacted by agricultural or development practices. Vernal pool complex habitat for vernal pool fairy shrimp includes the following vegetation subunits that were selected from the BDCP vernal pool complex natural community:

- Vernal pool complex – all vegetation types

Degraded Vernal Pool Complex Habitat: Low quality ephemeral habitat that ranges from areas with vernal pool and swale visual signatures that display clear evidence of significant disturbance due to plowing, disking, or leveling to areas with clearly artificial basins such as shallow agricultural ditches, depressions in fallow fields, and areas of compacted soils in pastures. The aquatic features in this habitat are more clearly classified as temporary waters sensu lato (Williams 2006) than intact and fully functional vernal pools. Because these features are inundated during the wet season and may have historically been located in or near areas with natural vernal pool complex, they may support individuals or small populations of species that are found in vernal pools and swales. However, they do not posses the full complement of ecosystem and community characteristics of natural vernal pools, swales and their associated uplands and they are generally ephemeral features that are eliminated during the course of normal agricultural practices. Degraded vernal pool complex habitat for vernal pool fairy shrimp includes the following vegetation subunits that were selected from the BDCP other natural seasonal wetlands and grasslands communities:

- Grasslands
    - Degraded vernal pool complex – California annual grasslands;
    - Degraded vernal pool complex – Ruderal herbaceous grasses and forbs;
    - Degraded vernal pool complex – Italian rye-grass (*Lolium multiflorum*); and
    - Degraded vernal pool complex – Rabbitsfoot grass (*Polygpogon maritimus*).
- Other natural seasonal wetlands
    - Degraded vernal pool complex- Vernal pools.

Potential habitat without concave surfaces was removed from the model. LiDAR elevation data was then visually inspected in four general areas to further assess specific locations that had been identified by the habitat selection process. These areas were selected based both on *a priori* knowledge of the region and because they were identified by the intersection of the selected vegetation types and soils. The analysis of the LiDAR data further refined the habitat model and provided a more accurate demarcation of suitable habitat. The GIS habitat model was then compared against field data from surveys conducted by the DWR in 2009. Land uses that are incompatible with the species' habitat requirements, for example, potential habitat polygons falling on leveled or developed lands were removed from the model.

Assumptions. Historical and current records of this species in the Plan Area indicate that it occurs in appropriate habitat along the perimeter of the Plan Area (Figure A-40b) (Witham 2002, 2003, 2006, ESA 2005, Barona et al. 2007, CNDDB 2010).

A40.8 RECOVERY GOALS

A general statement for recovery of vernal pool fairy shrimp is presented in the USFWS (2005) Recovery Plan: to ensure protection of the full geographic, genetic, and ecological extent of this species and to improve the circumstances that caused it to be listed in the first place. Accomplishment of this goal would be achieved by protecting 80 percent of species occurrences throughout its range, including 85 percent of its suitable habitat in 38 core areas. In addition, the species would be reintroduced into vernal pool regions and soil types from which surveys indicate that it has been eradicated.

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APPENDIX A 41. MIDVALLEY FAIRY SHRIMP (*BRANCHINECTA MESOVALLENSIS*)

A41.1 LEGAL STATUS

Midvalley fairy shrimp (*Branchinecta mesovallensis*) currently has no legal status under either the state or federal endangered species acts. It was petitioned for listing under the federal Endangered Species Act in 2001. In 2003, the U.S. Fish and Wildlife Service (USFWS) published a finding (68 FR 22724) that the petition provided substantial evidence to indicate that listing may be warranted. However, in 2004 the USFWS determined, following a review of available scientific and commercial information, that listing was not warranted (69 FR 3592).

A41.2 SPECIES DISTRIBUTION AND STATUS

A41.2.1 Range and Status

Distribution. Midvalley fairy shrimp is endemic to California Central Valley grassland vernal pools (Belk and Fugate 2000). All known occurrences are between central Sacramento County and northern Fresno County (Figure A-41a). Reported occurrences include scattered occurrences from the Mather Field area of Sacramento, south through Galt from Sacramento County; two locations in the Yolo Bypass southwest of Saxon in Yolo County; Jepson Prairie, Travis Air Force Base, and Vacaville areas in Solano County; from Lodi, north to the county border in San Joaquin County; the Byron Airport in Contra Costa County; the Virginia Smith Trust (Haystack Mountain), and Arena Plains National Wildlife Reserve (NWR) in Merced County; one location in central Madera County; and one in northern Fresno County (Eriksen and Belk 1999, Belk and Fugate 2000).

Population Trends. There is no reliable information on population trends for this species due to its recent description (Belk and Fugate 2000), lack of information on its historical distribution, and the extent of loss of vernal pool habitats in the Central Valley.

An unknown amount of vernal pool habitat and midvalley fairy shrimp occurrences have been lost. Attempts have been made to calculate lost vernal pool acreages (Holland 1978, 1988, 1998, Bauder and McMillan 1998). Due to increasing pressures of human populations in California and Oregon, more vernal pool habitat is being encroached upon and affected throughout the species' range.

Adequate determination of remaining midvalley fairy shrimp occurrences throughout the animal's range, as well as population trends, remains largely incomplete. Eriksen and Belk (1999) present a map of localities for the midvalley fairy shrimp with less than 30 localities represented; the greatest density of occurrences is in southern Sacramento County.

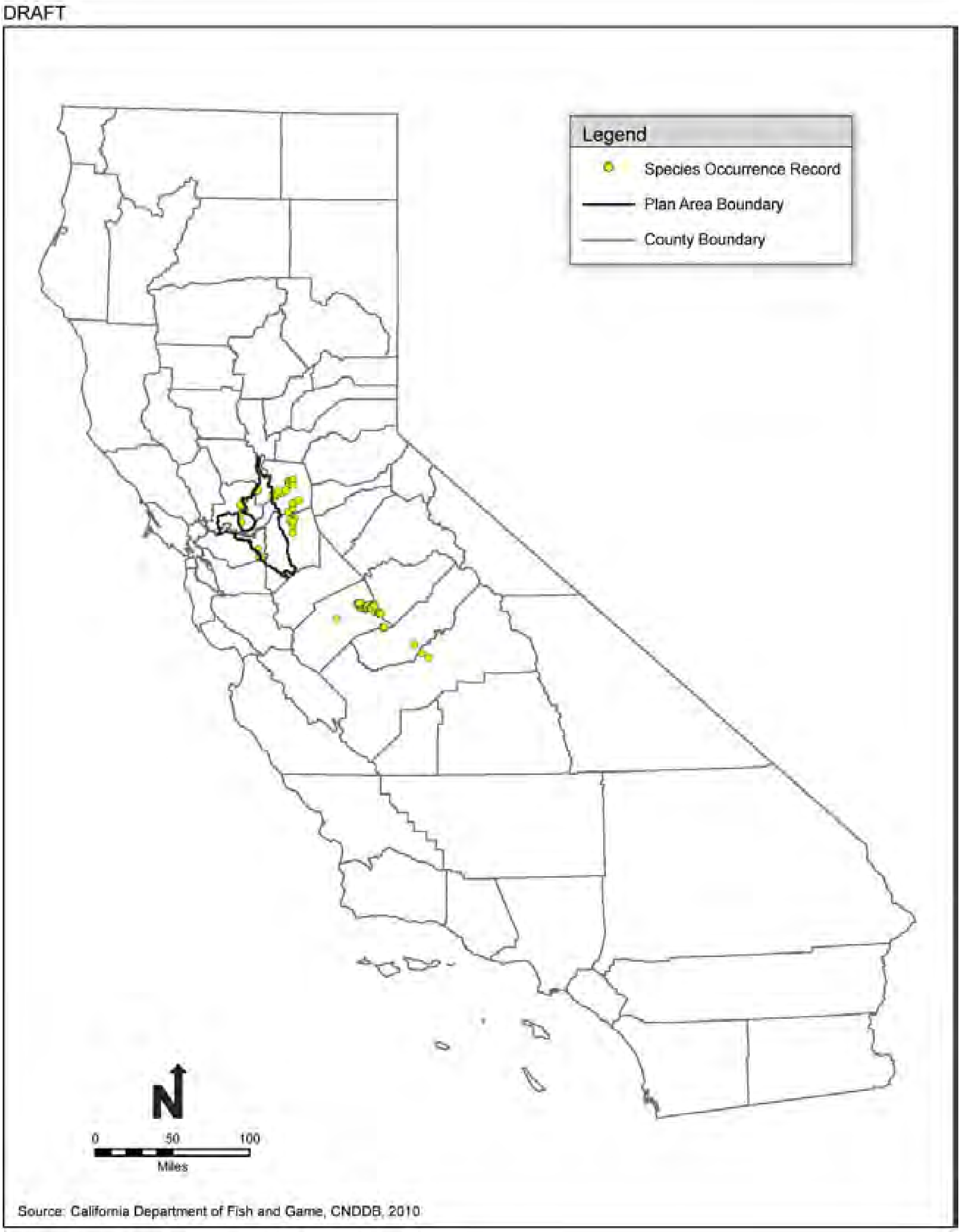

Figure A-41a. Midvalley Fairy Shrimp Statewide Recorded Occurrences

This generally corresponds with the current distribution as derived from California Natural Diversity Database (CNDDB) occurrences (CNDDB 2010). A further complication may be that midvalley fairy shrimp possibly escape early detection particularly during dry years or during the dry season because they inhabit swales and short-lived pools to a greater extent relative to other species (Helm 1998, Belk and Fugate 2000).

A41.2.2 Distribution and Status in the Plan Area

Distribution and status in the Plan Area is largely unknown and based primarily on CNDDB records, which provide an incomplete and inconsistent record of occurrence for this species. Recorded locations from the Plan Area include several occurrences in the vicinity of the Cosumnes River Preserve and two locations in the Yolo Bypass, both in small vernal pools southwest of Saxon (CNDDB 2010) (Figure A-41b). Based on existing knowledge of the species' requirements, the species could potentially occur in shallow grassland vernal pools and similar seasonal wetlands wherever they occur in the Plan Area. More complete systematic surveys would be required to more accurately determine the distribution of this species in the Plan Area.

A41.3 Habitat Requirements and Special Conditions

This species is entirely dependent on the aquatic environment provided by the temporary waters of natural vernal pool and playa pool ecosystems as well as the artificial environments of ditches and tire ruts (King et al. 1996, Helm 1998, Eriksen and Belk 1999). The temporary waters in which vernal pool tadpole shrimp inhabits fill in the fall and winter during the beginning of the wet season and dry in late-spring at the beginning of the dry season and remain desiccated throughout the summer (Helm 1998, Eriksen and Belk 1999). The temporary waters fill directly from precipitation as well as from runoff from their watersheds (Williamson et al. 2005, Rains et al. 2006, 2008, O'Geen et al. 2008). The watershed extent that is necessary for maintaining the hydrological functions of the temporary waters depends on a number of complex factors including the hydrologic conductivity of the surface soil horizons, the continuity and extent of hard-pans and clay-pans underlying non-clay soils, the existence of a perched aquifer overlying the pans, slope, effects of vegetation on evapotranspiration rates, compaction of surface soils by grazing animals, and other factors (Marty 2004, Pyke and Marty 2005, Williamson et al. 2005, Rains et al. 2006, 2008, O'Geen et al. 2008).

The temporary waters that are habitat for midvalley fairy shrimp are extremely variable and range from clear sandstone pools with little alkalinity to turbid vernal pools on clay soils with moderate alkalinity (King et al. 1996, Eriksen and Belk 1999).

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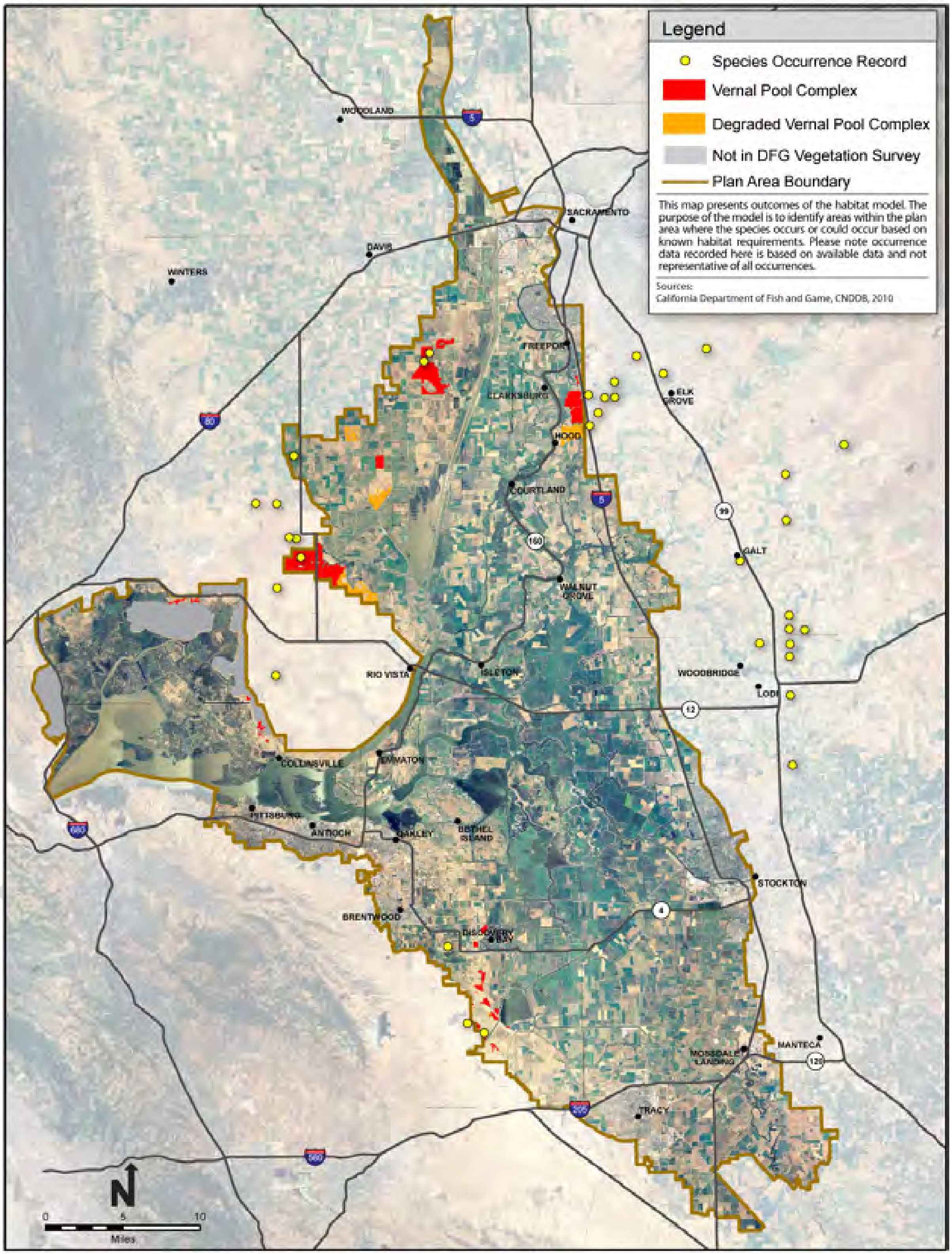

Figure A-41b. Midvalley Fairy Shrimp Habitat Model and Recorded Occurrences

Common wetland plant species that co-occur with midvalley shrimp include toad rush (*Juncus bufonius*), coyote thistle (*Eryringium* spp.), downingia (*Downingia ornatissma* or *D. bicornuta*), goldfields (*Lasthenia* spp.), woolly marbles (*Psilocarphus* spp.), and hair grass (*Deschampsia* spp.) (King et al. 1996, Alexander and Schlising 1997, 1998, Helm 1998, Plattencamp 1998, Eriksen and Belk 1999, Alexander 2007).

Vernal pools that support these fairy shrimp are often grass or mud-bottomed, with clear to tea-colored water, and are often in basalt flow depression pools in grasslands (Eriksen and Belk 1999). Midvalley fairy shrimp have been found in habitats ranging from 0.0004 to 0.2 hectares (0.001 to 0.5 acre) and typically are found in smaller, short-lived pools and other seasonal wetlands compared with other species within the same genus (Eriksen and Belk 1999).

Midvalley fairy shrimp commonly co-occur with California fairy shrimp (*Linderiella occidentalis*) (Eriksen and Belk 1999, Rogers in review). This species has also been reported co-occurring with the vernal pool fairy shrimp (*Branchinecta lynchi*) (Eng et al. 1990) on three occasions, where midvalley fairy shrimp was probably washed into the vernal pool fairy shrimp habitat by abnormally high rainfall (Eriksen and Belk 1999).

A41.4 LIFE HISTORY

Description. Midvalley fairy shrimp is a typical branchinectid anostracan. Live animals are typically off-white to grey, although the brood pouch may be green or yellow. Depending upon the rapidity of development, mature animals may vary in length from 3 to 38 millimeters (0.12 to 1.5 inch). Like other fairy shrimp, they are entirely aquatic with delicate elongate bodies, large stalked compound eyes, no carapaces, and eleven pairs of swimming legs. Males and females are generally differentiated on the basis of antennae development, thoracic projections, and brood pouch development.

Reproduction and Growth. During the dry phase of their habitat, the anostracans survive as diapausing cysts (resting eggs) in and on the substrate (Sars 1896, 1898, Eriksen and Belk 1999, Rogers and Fugate 2001). When the habitat inundates from seasonal rainfall, some of the cysts hatch, and the nauplii (early larval form of anostraca) swim into the upper water column (Eriksen and Belk 1999). The cysts lie dormant in the substrate until the pool dries and re-inundates during the subsequent rains. Beyond inundation of the habitat, the specific cues for hatching are unknown, although temperature and conductivity (solute concentration) are believed to play a large role (Helm 1998, Eriksen and Belk 1999).

In a study using large plastic pools to simulate natural vernal pools, Helm found no difference in the time to reproduce among California linderiella, Conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, midvalley fairy shrimp, and vernal pool tadpole shrimp (46 days) (Helm 1998). However, that experiment supplemented by field data (Gallagher 1996, Alexander 2007) suggests that the average time to reproduce for California linderiella, Conservancy fairy shrimp, longhorn fairy shrimp, and vernal pool fairy shrimp is approximately

8 weeks, while that for midvalley fairy shrimp is approximately 2 weeks. No data were reported regarding pool fertility or the impacts of predation on the time to reproduce. These reproduction periods may be shortened or lengthened by warmer or colder water temperatures (Helm 1998).

Predation and Dispersal. Planktonic Crustacea are important in the food web, as they represent a high-fat, high-protein resource for migratory waterfowl. Mallard (*Anas platyrhynchos*), green-winged teal (*A. crecca*), bufflehead (*Bucephala albeola*), greater yellowlegs (*Tringa melanoleuca*), and killdeer (*Charadrius vociferus*) all forage actively in Central Valley vernal pools on the invertebrate and amphibian fauna during the winter months (Silveira 1996, Bogiatto and Karnegis 2006).

Predator consumption of fairy shrimp cysts aids in distributing populations of fairy shrimp. Predators (e.g., birds and amphibians) expel viable cysts in their excrement, often at locations other than where they were consumed. If conditions are suitable, these transported cysts may hatch at the new location and potentially establish a new population. Cysts are also transported by wind and in mud carried on the feet of animals, including livestock that may wade through fairy shrimp habitat. This type of dispersal aids ephemeral pool crustaceans in exploiting a wide variety of ephemeral habitats (Erickson and Belk 1999).

A41.5 Threats and Stressors

Threats to vernal pool habitat and species in general, including midvalley fairy shrimp, were identified in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (USFWS 2005). In addition, the Recovery Plan identified several threats specific to midvalley fairy shrimp.

Habitat Loss and Fragmentation. Habitat loss and fragmentation were identified as the largest threats to the survival and recovery of vernal pool species. Habitat loss generally is a result of agricultural conversion from rangelands to intensive farming, urbanization, aggregate mining, infrastructure projects (such as roads and utility projects), and recreational activities (such as off-highway vehicles and hiking) (USFWS 2005). Habitat fragmentation occurs when vernal pool complexes are broken into smaller groups or individual vernal pools and become isolated from each other as a result of activities such as road development and other infrastructure projects (USFWS 2005).

Agricultural Conversion. Conversion of land use, such as from grasslands or pastures, to more intensive agricultural uses (e.g., croplands) or from one crop type to another, has contributed and continues to contribute to the decline of vernal pools in general (USFWS 2005).

Competition from Invasive Species. Vernal pool plant species have declined due to the introduction of invasive non-native plant and animal species. Changes in hydrology and poor grazing management has contributed to increasing dominance by invasive plants, which affects habitat suitability for midvalley fairy shrimp (Marty 2004).

Invasive Species. The invasions of vernal pools by waxy mannagrass (*Glyceria declinata*), an invasive aquatic grass (Gerlach et al. 2009), greatly increases the amount of decomposing biomass in vernal pools and may result in higher respiratory oxygen consumption relative to photosynthetic oxygen generation (Rogers 1998). Also, upland biomass of invasive species such as medusahead (*Taeniatherum caput-medusae*) can produce dense vegetation and thatch, shortening the ponding duration of some vernal pools (Marty 2004, Pyke and Marty 2005). Italian ryegrass (*Lolium multiflorum*) has rapidly become a dominant invasive species of the uppermost zone of vernal pools and appears to have undergone rapid adaptation to alkaline clay soils (Dawson et al. 2007).

Altered Hydrology. Human disturbances can alter the hydrology of temporary waters and result in a change in the timing, frequency, or duration of inundation in vernal pools, which can create conditions that render existing vernal pools unsuitable for vernal pool species (USFWS 2005).

A41.6 Relevant Conservation Efforts

Midvalley fairy shrimp is not listed; however, it may be protected through conservation efforts for vernal pool ecosystems in general. USFWS (2005) reports that of 53 midvalley fairy shrimp locations (as of 2003) 22 (41.5 percent) are on protected lands, including two National Wildlife Refuges (NWRs), several vernal pool mitigation banks, a DFG Ecological Reserve, and several Nature Conservancy conservation easements.

Midvalley fairy shrimp is covered under the approved Natomas Basin Habitat Conservation Plan, San Joaquin County Multi-species Habitat Conservation and Open Space Plan, and East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan. Further, the species is proposed for coverage under the Solano County Multispecies Habitat Conservation Plan, Yolo County Natural Heritage Program Plan, and South Sacramento County Habitat Conservation Plan.

A41.7 Species Habitat Suitability Model

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below and in section 2.3.1, *Data Sources and Natural Community Classification*). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as individual trees or small groups of trees. It is also possible, as with some vernal pool invertebrates that are restricted to seasonally ponded habitats, to underestimate potentially-occupied habitat due to the lack of information on small, degraded or artificially-created seasonal wetland habitats.

Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. Midvalley fairy shrimp model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), California Department of Water Resources (DWR) 2007 LiDAR elevation data, Google Earth 2009 aerial imagery and United States Department of Agriculture (USDA) 2005 aerial photography. Using these data sets, the model maps the distribution of suitable midvalley fairy shrimp habitat in the Plan Area according to the species' two habitat types, vernal pool complex and degraded vernal pool complex habitat. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Vernal Pool Complex Habitat: High quality permanent habitat that consists of vernal pools and uplands that display characteristic vernal pool and swale visual signatures that have not been significantly impacted by agricultural or development practices. Vernal pool complex habitat for midvalley fairy shrimp includes the following vegetation subunits that were selected from the BDCP vernal pool complex natural community:

- Vernal pool complex – all vegetation types

Degraded Vernal Pool Complex Habitat: Low quality ephemeral habitat that ranges from areas with vernal pool and swale visual signatures that display clear evidence of significant disturbance due to plowing, disking, or leveling to areas with clearly artificial basins such as shallow agricultural ditches, depressions in fallow fields, and areas of compacted soils in pastures. The aquatic features in this habitat are more clearly classified as temporary waters *sensu lato* (Williams 2006) than intact and fully functional vernal pools. Because these features are inundated during the wet season and may have historically been located in or near areas with natural vernal pool complex, they may support individuals or small populations of species that are found in vernal pools and swales. However, they do not possess the full complement of ecosystem and community characteristics of natural vernal pools, swales and their associated uplands and they are generally ephemeral features that are eliminated during the course of normal agricultural practices. Degraded vernal pool complex habitat for midvalley fairy shrimp includes the following vegetation subunits that were selected from the BDCP's other natural seasonal wetlands and grasslands communities:

- Grasslands
  - Degraded vernal pool complex – California annual grasslands;
  - Degraded vernal pool complex – Ruderal herbaceous grasses and forbs;
  - Degraded vernal pool complex – Italian rye-grass (*Lolium multiflorum*); and
  - Degraded vernal pool complex – Rabbitsfoot grass (*Polygpogon maritimus*).
- Other natural seasonal wetlands
  - Degraded vernal pool complex-vernal pools.

Potential habitat without concave surfaces was removed from the model. LiDAR elevation data was then visually inspected in four general areas to further assess specific locations that had been identified by the habitat selection process. These areas were selected based both on *a priori* knowledge of the region and because they were identified by the intersection of the selected vegetation types and soils. The analysis of the LiDAR data further refined the habitat model and provided a more accurate demarcation of suitable habitat. The GIS habitat model was then compared against field data from surveys conducted by the DWR in 2009. Land uses that are incompatible with the species' habitat requirements, for example, potential habitat polygons falling on leveled or developed lands were removed from the model.

Assumptions. Historical and current records of this species in the Plan Area indicate that it occurs in appropriate habitat along the perimeter of the Plan Area (Figure A-41b) (Witham 2002, 2003, 2006, CNDDB 2010). The vegetation cover of the alkaline soils is typically a combination of vernal pool adapted species and annual ryegrass (Witham 2002, 2003, 2006, CNDDB 2010).

A41.8 RECOVERY GOALS

A general statement for recovery of midvalley fairy shrimp is presented in the USFWS (2005) Recovery Plan: to achieve and protect, in perpetuity, self-sustaining populations throughout the full ecological, geographic, and genetic range of the species and to ameliorate or eliminate threats to the species. Interim goals are to stabilize and protect populations and conduct research to refine reclassification and recovery criteria. Vernal pool habitats used by the species as well as historical and potential habitats need to be protected, and habitat management plans for these habitats need to be developed and implemented. Recovery criteria have been established in the Recovery Plan (USFWS 2005).

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APPENDIX A42. CALIFORNIA LINDERIELLA *(LINDERIELLA OCCIDENTALIS)*

A42.1 LEGAL STATUS

California linderiella (*Linderiella occidentalis*) has no state or federal regulatory status. This species was addressed as a species of concern by the U.S. Fish and Wildlife Service (USFWS) in the December 15, 2005, Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (USFWS 2005).

A42.2 SPECIES DISTRIBUTION AND STATUS

A42.2.1 Range and Status

California linderiella is the most common fairy shrimp in California and is endemic to the state (Eriksen and Belk 1999). It has been reported in the Central Valley from Shasta County south to Fresno County and in the Coast and Transverse ranges from Mendocino County south to Ventura County (Figure A-42a) (Eriksen and Belk 1999, CNDDB 2010) and has been collected at elevations from near sea level to 1,159 meters (3,800 feet) (Eriksen and Belk 1999).

California linderiella co-occurs with 19 other large branchiopods including conservancy fairy shrimp (*Branchinecta conservatio*), longhorn fairy shrimp (*B. longiantenna*), vernal pool fairy shrimp (*B. lynchi*), mid-valley fairy shrimp (*B. mesovallensis*), and vernal pool tadpole shrimp (*Lepidurus packardi*) (Helm 1998, Eriksen and Belk 1999). It most often co-occurs in pools also inhabited by vernal pool fairy shrimp, in which case California linderiella is generally more numerous (Eriksen and Belk 1999).

A42.2.2 Distribution and Status in the Plan Area

California linderiella has been reported from several locations within the Plan Area (Figure A-42b) (USFWS 2005, CNDDB 2010). In general, within the Plan Area, vernal pools that may support the species occur on alkaline clay soils from the California Department of Fish and Game (DFG) Tule Ranch Reserve southwest to the Montezuma Wetlands Mitigation Projects and from the Byron Airport to Discovery Bay. Other potential vernal pool habitat occurs on clay-pan soils along the eastern boundary of the Plan Area near Stone Lakes. California linderiella was not found during 2009 surveys conducted by the California Department of Water Resources (DWR) in the Stone Lakes and Clifton Court Forebay areas.

DRAFT

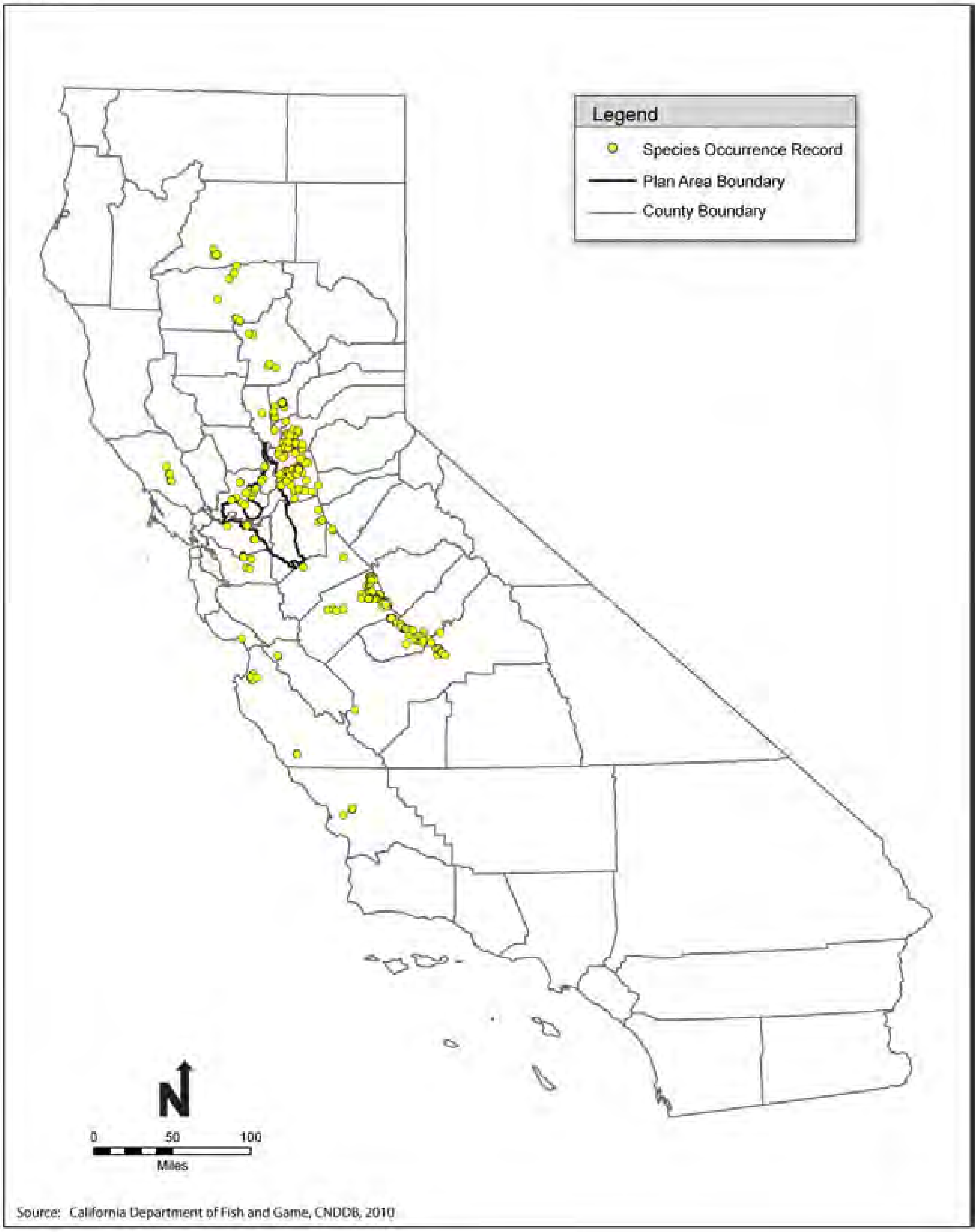

Figure A-42a. California Linderiella Statewide Recorded Occurrences

DRAFT

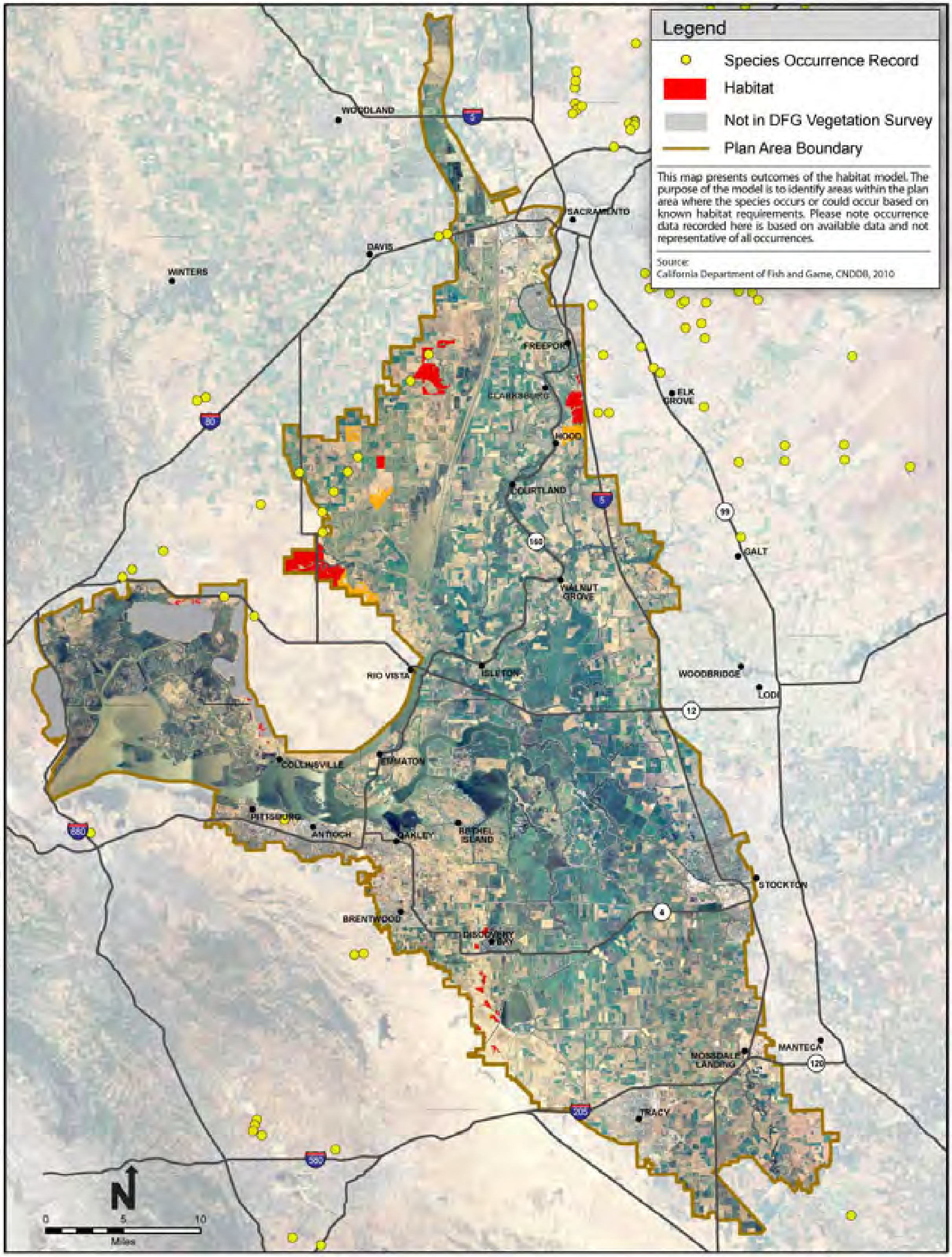

Figure A-42b. California Linderiella Habitat Model and Recorded Occurrences

A42.3 HABITAT REQUIREMENTS AND SPECIAL CONDITIONS

This species is entirely dependent on the aquatic environment provided by the temporary waters of natural vernal pool and playa pool ecosystems as well as the artificial environments of ditches and tire ruts (King et al. 1996, Helm 1998, Eriksen and Belk 1999). The temporary waters in which California linderiella inhabits fill in the fall and winter during the beginning of the wet season and dry in late spring at the beginning of the dry season and remain desiccated throughout the summer (Eriksen and Belk 1999). The temporary waters fill directly from precipitation as well as from runoff from their watersheds (Williamson et al. 2005, Rains et al. 2006, 2008, O'Geen et al. 2008). The watershed extent that is necessary for maintaining the hydrological functions of the temporary waters depends on a number of complex factors including the hydrologic conductivity of the surface soil horizons, the continuity and extent of hard-pans and clay-pans underlying non-clay soils, the existence of a perched aquifer overlying the pans, slope, effects of vegetation on evapotranspiration rates, compaction of surface soils by grazing animals, and other factors (Marty 2004, Pyke and Marty 2005, Williamson et al. 2005, Rains et al. 2006, 2008, O'Geen et al. 2008).

The temporary waters that are habitat for California linderiella are extremely variable and range from clear sandstone pools with little alkalinity to turbid vernal pools on clay soils with moderate alkalinity (King et al. 1996, Eriksen and Belk 1999, CNDDB 2010). Common wetland plant species that co-occur with California linderiella include toad rush (*Juncus bufonius*), coyote thistle (*Eryringium* spp.), downingia (*Downingia ornatissma* or *D. bicornuta*), goldfields (*Lasthenia* spp.), woolly marbles (*Psilocarphus* spp.), and hair grass (*Deschampsia* spp.) (King et al. 1996, Alexander and Schlising 1997, 1998, Helm 1998, Plattencamp 1998, Eriksen and Belk 1999, Alexander 2007).

California linderiella is a component of a larger invertebrate community (King et al. 1996, Rogers 1998, Eriksen and Belk 1999). This invertebrate community includes mostly planktonic Crustacea dependent on temporary waters, including copepods, cladocerans, and ostracodes—as well as flatworms and a suite of insect species, including vernal pool haliplid beetle (*Apterliplus parvulus*), scimitar backswimmers (*Buenoa scimitra*), Ricksecker's hydrochara (*Hydrochara rickseckeri*), and many others (Rogers 1998). These habitats are usually low in opportunistic species that include mosquitoes and chironomid midges in the genus *Chironomus* (Rogers 1998).

A42.4 LIFE HISTORY

Description. Like other fairy shrimp, California linderiella is entirely aquatic with delicate elongate bodies, large stalked compound eyes, no carapaces, and eleven pairs of swimming legs. Males and females are generally differentiated on the basis of antennae development, thoracic projections, and brood pouch development. Live animals are off-white to grayish in color and are translucent, but unlike similar fairy shrimp in the genus Branchinecta, California linderiella tend to be slightly smaller and have distinctive red eyes (Eriksen and Belk 1999).

Reproduction and Growth. Like other fairy shrimp species, California linderiella are adapted to the environmental conditions of their ephemeral habitats. One adaptation is the ability of the eggs, or cysts, to remain dormant in the soil when their vernal pool habitats are dry. The cysts survive the hot, dry summers and cool, wet winters that follow until the vernal pools and swales fill with rainwater and conditions are right for hatching. When the pools refill in the same or subsequent seasons some, but not all, of the eggs may hatch. The egg bank in the soil may include eggs from several years of breeding (USFWS 2005).

Beyond inundation of the habitat, the specific cues for hatching are unknown, although temperature and conductivity (solute concentration) are believed to play a large role (Helm 1998, Eriksen and Belk 1999).

In a study using large plastic pools to simulate natural vernal pools, Helm found no difference in the time to reproduce among California linderiella, conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, mid-valley fairy shrimp, and vernal pool tadpole shrimp (Helm 1998). However, that experiment supplemented by field data (Gallagher 1996, Alexander 2007) suggests that the average time to reproduce for California linderiella, conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp is approximately 8 weeks, while that for mid-valley fairy shrimp is approximately 2 weeks. No data were reported regarding pool fertility or the impacts of predation on the time to reproduce. These reproduction periods may be shortened or lengthened by warmer or colder water temperatures as the minimum time to reproduce for California linderiella is in the range of 2-4 weeks (Helm 1998).

Feeding. California linderiella is an omnivorous filter-feeder. In general, all fairy shrimp species indiscriminately filter particles that include bacteria, unicellular algae, and micrometazoa (Eriksen and Belk 1999). The precise size of items these fairy shrimp are capable of filtering is currently unknown. However, fairy shrimp species will attempt to consume whatever material they can fit into their feeding groove and apparently do not discriminate based upon taste, as do some other crustacean groups (Eriksen and Belk 1999).

Predation and Dispersal. Planktonic Crustacea are important in the food web, as they represent a high-fat, high-protein resource for migratory waterfowl. Mallard (*Anas platyrhynchos*), green-winged teal (*A. crecca*), bufflehead (*Bucephala albeola*), greater yellowlegs (*Tringa melanoleuca*), and killdeer (*Charadrius vociferus*) all forage actively in Central Valley vernal pools on the invertebrate and amphibian fauna during the winter months (Silveira 1996, Bogiatto and Karnegis 2006).

Predator consumption of fairy shrimp cysts aids in distributing populations of fairy shrimp. Predators (e.g., birds and amphibians) expel viable cysts in their excrement, often at locations other than where they were consumed. If conditions are suitable, these transported cysts may hatch at the new location and potentially establish a new population. Cysts are also transported by wind and in mud carried on the feet of animals, including livestock that may wade through fairy shrimp habitat. This type of dispersal aids ephemeral pool crustaceans in exploiting a wide variety of ephemeral habitats (Erickson and Belk 1999).

A42.5 THREATS AND STRESSORS

Threats to vernal pool habitat and California linderiella were identified in the Recovery Plan (USFWS 2005). These threats include the following:

Habitat Loss and Fragmentation. Habitat loss and fragmentation were identified as the largest threats to the survival and recovery of vernal pool species. Habitat loss generally is a result of agricultural conversion from rangelands to intensive farming, urbanization, aggregate mining, infrastructure projects (such as roads and utility projects), and recreational activities (such as off-highway vehicles and hiking) (USFWS 2005). Habitat fragmentation occurs when vernal pool complexes are broken into smaller groups or individual vernal pools and become isolated from each other as a result of activities such as road development and other infrastructure projects (USFWS 2005).

Agricultural Conversion. Conversion of land use, such as from grazed grasslands to more intensive agricultural uses (e.g., rice, vineyards, and orchards) has contributed and continues to contribute to the decline of vernal pools in general (USFWS 2005).

Invasive Species. The invasions of vernal pools by waxy mannagrass (*Glyceria declinata*), a non-native invasive aquatic grass (Gerlach et al. 2009), greatly increases the amount of decomposing biomass in vernal pools and may result in higher respiratory oxygen consumption relative to photosynthetic oxygen generation (Rogers 1998). Also, upland biomass of non-native invasive species such as medusahead (*Taeniatherum caput-medusae*) can produce dense vegetation and thatch, shortening the ponding duration of some vernal pools (Marty 2004, Pyke and Marty 2005). Italian ryegrass (*Lolium multiflorum*) has rapidly become a dominant non-native invasive species of the uppermost zone of vernal pools and appears to have undergone rapid adaptation to alkaline clay soils (Dawson et al. 2007).

Altered Hydrology. Human disturbances can alter the hydrology of temporary waters and result in a change in the timing, frequency, or duration of inundation in vernal pools, which can create conditions that render existing vernal pools unsuitable for vernal pool species (USFWS 2005).

Mosquito Control. Experiments have shown that mosquito fish (*Gambusia affinis*) that are sometimes introduced into ponds for mosquito control can have a negative impact on California linderiella (Leyse et al. 2004).

A42.6 RELEVANT CONSERVATION EFFORTS

California linderiella is proposed for coverage under the Solano County Multispecies Habitat Conservation Plan and the Yolo County Natural Heritage Program Plan.

A42.7 SPECIES HABITAT SUITABILITY MODEL

Model Approach. BDCP Species Habitat Suitability Models are formulated primarily using vegetation data from existing GIS data sources (described below and in Section 2.3.1, *Data Sources and Natural Community Classification*). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as vernal pools, individual trees, or small groups of trees. It is also possible, as with the California linderiella, to underestimate potentially-occupied habitat due to the lack of information on small, degraded or artificially-created seasonal wetland habitats.

Still, for most species the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lower probability of species occurrence compared with areas identified as suitable habitat.

For each model, the mapping data sets and each vegetation type or association is identified. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the BDCP Plan Area.

GIS Model Data Sources. The California linderiella model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), DWR 2007 LiDAR elevation data, Google Earth 2009 aerial imagery and United States Department of Agriculture (USDA) 2005 aerial photography. Using these data sets, the model maps the distribution of suitable California linderiella habitat in the Plan Area according to the species' two habitat types, vernal pool complex and degraded vernal pool complex habitat.

Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Vernal Pool Complex Habitat. High quality permanent habitat that consists of vernal pools and uplands that display characteristic vernal pool and swale visual signatures that have not been significantly impacted by agricultural or development practices. Vernal pool complex habitat for California linderiella includes the following vegetation subunits that were selected from the BDCP vernal pool complex natural community:

- Vernal pool complex – all vegetation types

Degraded Vernal Pool Complex Habitat: Low quality ephemeral habitat that ranges from areas with vernal pool and swale visual signatures that display clear evidence of significant disturbance due to plowing, disking, or leveling to areas with clearly artificial basins such as shallow agricultural ditches, depressions in fallow fields, and areas of compacted soils in pastures. The aquatic features in this habitat are more clearly classified as temporary waters *sensu lato* (Williams 2006) than intact and fully functional vernal pools. Because these features are inundated during the wet season and may have historically been located in or near areas with natural vernal pool complex, they may support individuals or small populations of species that are found in vernal pools and swales. However, they do not possess the full complement of ecosystem and community characteristics of natural vernal pools, swales and their associated uplands and they are generally ephemeral features that are eliminated during the course of normal agricultural practices. Degraded vernal pool complex habitat for California linderiella includes the following vegetation subunits that were selected from the BDCP other natural seasonal wetlands and grasslands communities:

- Grasslands
    - Degraded vernal pool complex – California annual grasslands;
    - Degraded vernal pool complex – Ruderal herbaceous grasses and forbs;
    - Degraded vernal pool complex – Italian rye-grass (*Lolium multiflorum*); and
    - Degraded vernal pool complex – Rabbitsfoot grass (*Polygpogon maritimus*).
- Other natural seasonal wetlands
    - Degraded vernal pool complex – Vernal pools.

Potential habitat without concave surfaces was removed from the model. LiDAR elevation data was then visually inspected in four general areas to further assess specific locations that had been identified by the habitat selection process. These areas were selected based both on *a priori* knowledge of the region and because they were identified by the intersection of the selected vegetation types and soils. The analysis of the LiDAR data further refined the habitat model and provided a more accurate demarcation of suitable habitat. The GIS habitat model was then compared against field data from surveys conducted by the California Department of Water Resources in 2009. Land uses that are incompatible with the species' habitat requirements, for example, potential habitat polygons falling on leveled or developed lands were removed from the model.

Assumptions. Historical and current records of this species in the Plan Area indicate that it occurs in appropriate habitat along the perimeter of the Plan Area (Figure A-42b) (Witham 2002, 2003, 2006, ESA 2005, CNDDB 2010).

A42.8 RECOVERY GOALS

A general statement for recovery of California linderiella is presented in the USFWS (2005) Recovery Plan: to achieve and protect, in perpetuity, self-sustaining populations throughout the full ecological, geographic, and genetic range of the species and to ameliorate or eliminate threats to the species. Interim goals are to stabilize and protect populations and conduct research to refine reclassification and recovery criteria. Vernal pool habitats used by the species as well as historical and potential habitats need to be protected, and habitat management plans for these habitats need to be developed and implemented. Species-specific recovery criteria are to conserve 80 percent of its occurrences and 95 percent of suitable vernal pool habitat in the Jepson Prairie and Cosumnes-Rancho Seco recovery core areas.

A42.9 REFERENCES

A42.9.1 Literature Cited

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APPENDIX A43. ALKALI MILK-VETCH (*ASTRAGALUS TENER* VAR. *TENER*)

A43.1 LEGAL STATUS

Alkali milk-vetch (*Astragalus tener* var. *tener*) is not listed under either federal or California Endangered Species Acts. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G1T1/S1.1 which means that globally (G) and within the state (S) both the species and variety have either less than six viable element occurrences, less than 1,000 individuals, or less than 2,000 acres (809 hectares) of occupied habitat. Its state threat level rank is "very threatened."

The California Native Plant Society (CNPS) List ranking of 1B.2 for alkali milk-vetch indicates that it is rare, threatened, or endangered in California and elsewhere, and is considered by CNPS to be fairly endangered in California with between 20 to 80 percent of occurrences threatened. Plants with a CNPS List rank of 1B are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

A43.2 SPECIES DISTRIBUTION AND STATUS

A43.2.1 Range and Status

The range of alkali milk-vetch extends from Sonoma, Napa, Solano, and Yolo counties in the north, to Monterey and San Benito counties in the south, to San Francisco, Contra Costa, Alameda, and Santa Clara counties in the west, and San Joaquin, Stanislaus, and Merced counties in the east (Figure A-43a). Alkali milk-vetch was widely distributed around the San Francisco Bay region and in the Sacramento and northern San Joaquin valleys 100 years ago (Barneby 1964), but by 1989 only a few populations remained (Liston 1992). A 2002 survey concluded that 25 of the 65 known occurrences should be considered extirpated (Witham 2002). Sixteen of the known extant occurrences are in the Solano-Colusa Vernal Pool Region of Solano County (Keeler-Wolf et al. 1998), and another five are located in an area between Newman, Merced, and Los Banos in the San Joaquin Vernal Pool Region of Merced County (Silveira 1996 as cited in USFWS 2005, CNDDB 2008). In Yolo County, Crampton (1979) noted the presence of this species near the City of Woodland on the Maupin property. A 1990 survey of historical collection sites in Yolo and Solano counties found six plants at the City of Woodland Preserve and six small populations at the Jepson Prairie Preserve (Witham 1990).

DRAFT

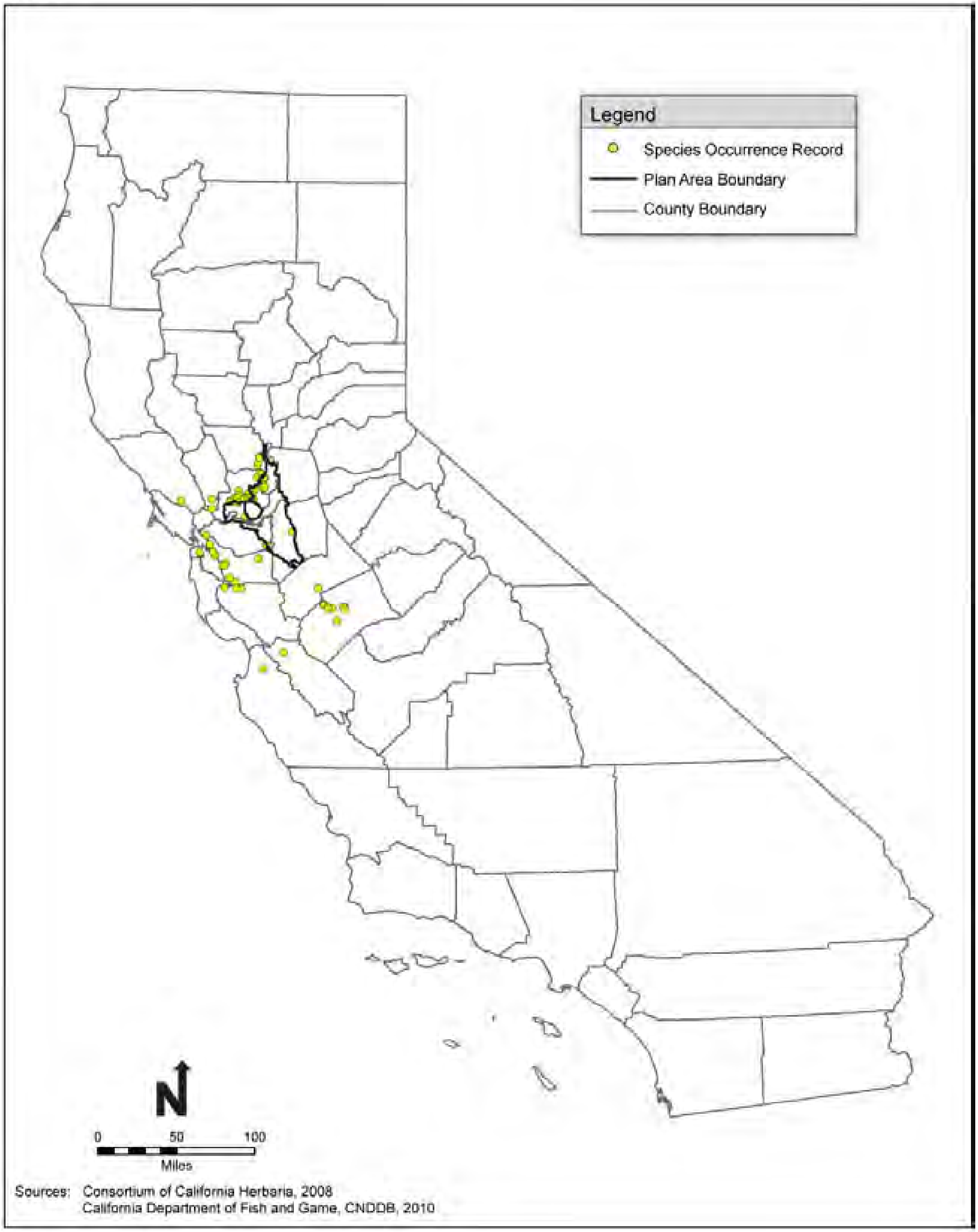

Figure A-43a. Alkali Milk-Vetch Statewide Recorded Occurrences

Currently, the Yolo County distribution of adult plants of this species includes the City of Woodland Preserve, the Woodland Regional Park, the Brauner and Maupin (near the Road 25 and 103 intersection) properties, the Yolo Grasslands Park, the Tule Ranch unit of the California Department of Fish and Game (DFG) Yolo Bypass Wildlife Area (Tule Ranch), and the Willow Slough Bypass (Showers 1996, EIP Associates 1998, Foothill Associates 2002, Witham 2003, University of California Davis Herbarium 2004, ESA 2005, A. Shapiro pers. comm. 2005).

A43.2.2 Distribution and Status in the Plan Area

Within the Plan Area are several reported occurrences (Figure A-43b). Small groups of up to 20 plants are found on suitable habitat on the Tule Ranch (Witham 2003). It has been observed 1/4 mile south of Saxon Station on the western edge of the Yolo Bypass on the Yolo Bypass Wildlife Area. To the west, it was reported as observed growing in clay soils west of Bunker Station. To the south, multiple sightings have been observed in vernally wet grassland in the Jepson Prairie Preserve. Further south in the Suisun Marsh area, it was observed in an alkaline vernal pool in the Montezuma Wetlands Restoration Project. On the southwest edge of the Plan Area, it has been observed in alkaline grassland vegetation northwest of the junction of Byron Hot Springs Road and Armstrong Road (CNDDB 2008). A previous instance observed in the Stockton area near Smith Canal is believed to be extirpated (CNDDB 2008).

A43.3 HABITAT REQUIREMENTS AND SPECIAL CONSIDERATIONS

Little is known about the ecology of alkali milk-vetch. In the Central Valley, it appears to be restricted to alkaline soils in areas that are, or were historically subject to flooding and overland flows (Silveira 2000, Witham 2003, ESA 2005). At the McClellan Air Force Base Davis Communications Facility site in Yolo County, it is found growing on the annual ryegrass (*Lolium multiflorum*) dominated floodplains above the upper margins of vernal pools and swales that contain Solano grass (*Tuctoria mucronata*) and Colusa grass (*Neostapfia colusiana*) (ESA 2005). All individuals at that site were found in areas that had been subjected to a prescribed burn and which subsequently flooded briefly in February (ESA 2005). In two subsequent years, the same area burned due to arson-caused fires and also flooded during the winter, but only a few individuals were detected during the following springs in contrast to the large population that established after the prescribed burn (J. Gerlach unpubl. data). At the Tule Ranch site in the Yolo Bypass, it is found in vernally mesic grasslands dominated by annual ryegrass and associated with alkaline vernal pools (Witham 2003). It is also found near the City of Woodland and along the Willow Slough Bypass in Yolo County in areas that were once alkali sink vegetation, but which were converted to rice fields and then fallowed for many years or which were converted into a levee system (Andrews 1970, Crampton 1979, Showers 1988, 1996, EIP Associates 1998, Foothill Associates 2002). There were historical occurrences along the railroad tracks north of the City of Davis and on the Hunt and Wesson tomato canning plant property (CNDDB 2008), but no individuals were located during surveys of those areas in 2006 (J. Gerlach unpubl. data).

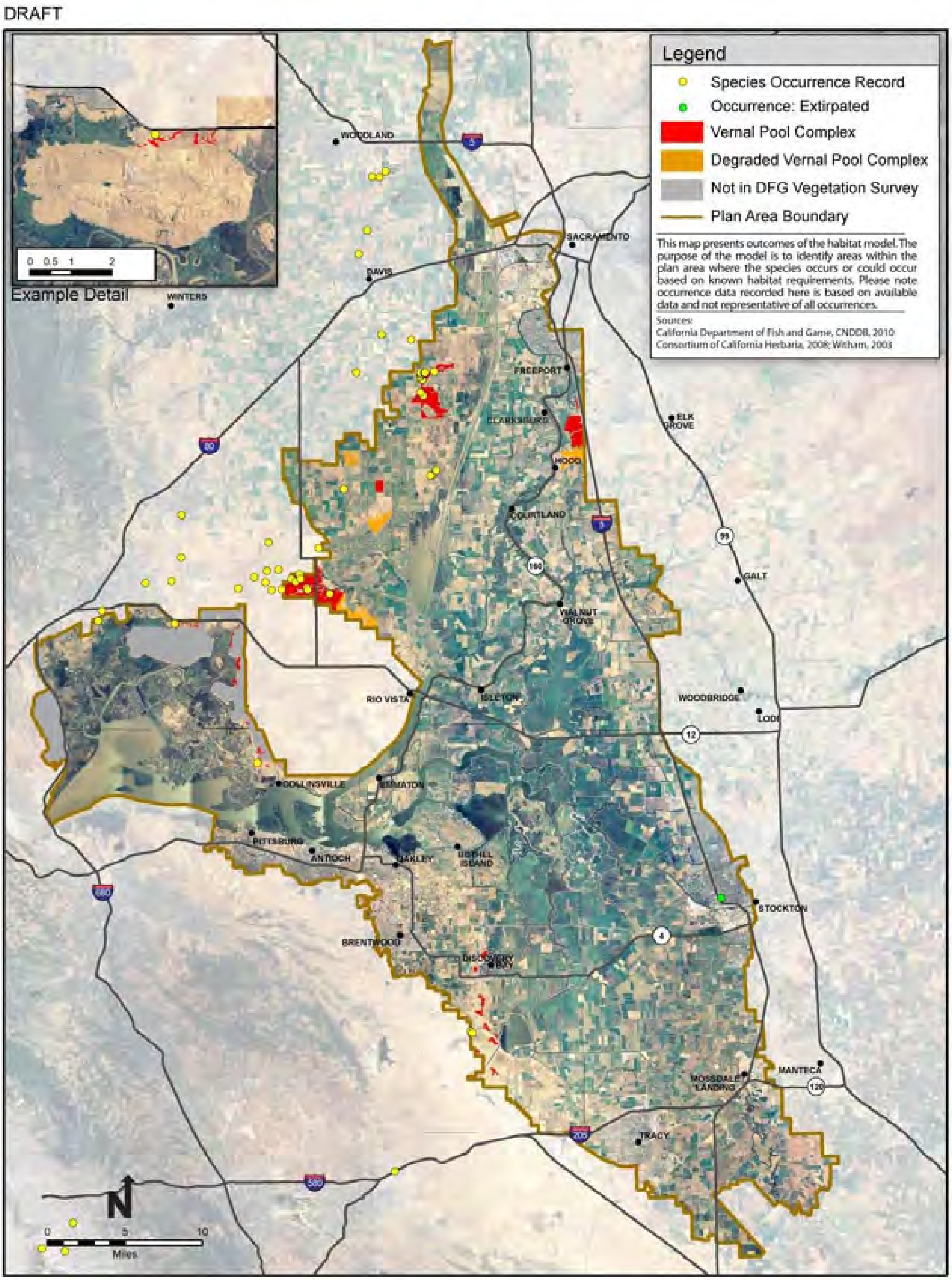

Figure A-43b. Alkali Milk-Vetch Habitat Model and Recorded Occurrences

The canning plant has been closed for several years and the alkaline soil areas are no longer farmed and are now densely vegetated with annual ryegrass (J. Gerlach unpubl. data). In the greater Jepson Prairie area it grows in vernal pool grassland that is dominated by annual ryegrass (Witham 2006).

The populations southeast of the City of Woodland and north of the City of Davis are in a heavily human-impacted area of what historically was alkaline sink vegetation lying along both sides of the north channel of Putah Creek and Willow Slough and above the Yolo Basin (U. S. Bureau of Soils 1909a, 1909b, Mann et al. 1911). The hydrology, salts, and clay soils that created and maintained the alkaline sink vegetation were deposited when floodwaters from Putah Creek flowed northward from the area near the City of Davis and emptied into Willow Slough. That flow was also supplemented when the combined floodwaters of Putah Creek, Cache Creek, and all of the drainages of the Blue Ridge filled the Cache/Putah Basin, drained eastward through a gap in the Plainfield Ridge, and flowed into the Yolo Basin through Willow Slough (Graymer et al. 2002). This area has also been heavily invaded by annual ryegrass (Dawson et al. 2007).

Laguna Callé, as Willow Slough was previously known, was a unique perennial stream (Eliason 1850, Anonymous 1870) that during the dry season originated from a series of pond-like springs approximately 9 miles (14.5 kilometers [km]) southwest of Woodland on the eastern edge of the Plainfield Ridge. As the slough approached the area of Merritt, south of the City of Woodland, it transformed into a 2.5-mile (4 km) long, gravel-bottomed, linear lake, with an average width of 150 feet (46 meters) and a maximum depth of 75 feet (23 meters). Approximately 1 mile (1.6 km) east of County Road 103, the stream flowing from the lake branched as it dropped over the edge of the alluvial deposits into the Yolo Basin, where it flowed another 2.5 miles northeastward until it emptied into a tule marsh. Large floods from Cache Creek and Putah Creek have flowed through Willow Slough as recently as 1942, but gravel mining in Cache Creek, dam building on both Cache and Putah creeks, and the construction of the Willow Slough Bypass have drastically altered the hydrology, salt budgets, and clay deposition patterns in the area of the alkali sink vegetation. Aerial photographs show that all of the alkaline sink vegetation was converted into various kinds of agricultural fields, ditched for drainage (USDA 1952), or subsequently developed as the cities expanded. Given the intensity and extent of the agricultural impacts to the entire alkali sink area and the irreversible changes in hydrology, those areas do not currently support alkali sink vegetation, and it would be very difficult to replicate the natural hydrological regimes that would allow that type of vegetation to be successfully restored in the area.

There are few data documenting the population trends of alkali milk-vetch. Because most of the recent observations of individuals have been at sites where it was considered extirpated, it appears that those individuals have established from pre-existing long-lived seed banks. Witham's observation that recruitment increased in a population near the Jepson Prairie Preserve after pipeline construction (CNDDB 2008) appears to confirm the importance of the seed bank. More recently, a large multi-year survey of California's vernal pool vegetation found that alkali milk-vetch was the most variable rare taxon and only occurred once during the 5-year study at a very low cover value (1 percent) (Buck 2004, Barbour et al. 2007).

A43.4 LIFE HISTORY

Alkali milk-vetch is a 2- to 16-inch (4- to 40-centimeter [cm]) tall herbaceous annual plant in the pea family (Fabaceae) (Hickman 1993) that has been differentiated from Ferris' milk-vetch (*Astragalus tener* var. *ferrisiae*) based on the morphology of its fruits (Liston 1990, 1992). Alkali milk-vetch has short, stout, strongly curved pods (Witham 2003). The leaves of alkali milk-vetch are 1 to 3 inches (2 to 9 cm) long, with 7 to 17 pinnately compound, well-separated leaflets. Three to 12 pink-purple, pea-like flowers comprise a dense inflorescence.

A protein electrophoresis analysis of two populations, one from Jepson Prairie in Solano County and the other from northern Merced County, found very little genetic differentiation between the populations and high levels of genetic diversity within each population (Liston 1992). This technique uses allozymes or slight alterations in plant proteins as indicators or markers. Because small mutations in the genetic code results in markers that are generally invisible to the forces of natural selection, these allozyme markers are classified as neutral markers. Therefore, because the neutral markers used in the study have not been shown to be correlated with any traits that might provide an adaptive advantage, Liston's results provide no information concerning the extent of local adaptation or other measures of the "genetic health" of the populations and no information regarding the amount of variation for adaptive traits (McKay et al. 2001, Latta and McKay 2002, McKay and Latta 2002, Wayne and Morin 2004).

Based on a crossing study by Liston (1992), the species was found to be self-compatible, and the inbreeding coefficients for the two populations were not significantly different from the expected value for a randomly mating population. Therefore, Liston concluded that insect pollinators are responsible for maintaining high levels of outcrossing within the populations. Liston also concluded that the recent dramatic range and population reductions experienced by alkali milk-vetch might explain the lack of neutral marker differentiation between the two populations and that the lack of inter-population neutral marker differentiation might also be attributed to a seed bank, as milk-vetch species are known to produce long-lived seed banks. Liston indicated that the unique morphology of the plant's flower suggested that alkali milk-vetch is pollinated by butterflies, which is rare for a species in the pea family (Liston 1992).

It is not known when or under which environmental conditions germination of alkali milk-vetch seeds occurs (USFWS 2005). Skinner and Pavlik (1994) indicate the flowering period to be March through June. Witham observed that recruitment increased in a population near the Jepson Prairie Preserve after pipeline construction (Witham 1990). Alkali milk-vetch was also observed in an artificially constructed vernal pool near Albrae at a site where no observations had been recorded since 1923 (USFWS 2005). These observations indicate the importance of a long-lived soil seed bank and suggest that viable seed may exist in the soil seed bank in areas where mature plants have not been observed for many years. This importance of a long-lived seed bank is also supported by studies that have found that this species persists across multiple seasons despite the absence of reproductive plants (Buck 2004, Barbour et al. 2007).

A43.5 Threats and Stressors

Development, intensive agriculture, and exotic plant species (especially annual ryegrass) are considered the primary threats to alkali milk-vetch (Showers 1996, Witham 2003, ESA 2005, Dawson et al. 2007).

A43.6 Relevant Conservation Efforts

Alkali milk-vetch is included in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (USFWS 2005). Alkali milk-vetch is a covered species under the permitted San Joaquin County Multi-species Habitat Conservation and Open Space Plan and is proposed for coverage under the Solano County Multi-species Habitat Conservation Plan and the Yolo County Natural Heritage Program Plan.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for alkali milk-vetch is "Contribute to Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its control and within its scope that are necessary to contribute to the recovery of the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

A43.7 Species Habitat Suitability Model

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below and in Section 2.3.1, *Data Sources and Natural Community Classification*). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as vernal pools, individual trees, or small groups of trees. It is also possible, as with some vernal pool invertebrates that are restricted to seasonally ponded habitats, to underestimate potentially-occupied habitat due to the lack of information on small, degraded or artificially-created seasonal wetland habitats.

Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The alkali milk-vetch model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), DWR 2007 LiDAR elevation data, Google Earth 2009 aerial imagery and USDA 2005 aerial photography. Using these data sets, the model maps the distribution of suitable alkali milk-vetch habitat in the Plan Area according to the species' two habitat types, vernal pool complex and degraded vernal pool complex habitat. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Vernal Pool Complex Habitat: High quality permanent habitat that consists of vernal pools and uplands that display characteristic vernal pool and swale visual signatures that have not been significantly impacted by agricultural or development practices. Vernal pool complex habitat for alkali milk-vetch includes the following vegetation subunits that were selected from the BDCP vernal pool complex natural community:

- Vernal pool complex – all vegetation types

Degraded Vernal Pool Complex Habitat: Low quality ephemeral habitat that ranges from areas with vernal pool and swale visual signatures that display clear evidence of significant disturbance due to plowing, disking, or leveling to areas with clearly artificial basins such as shallow agricultural ditches, depressions in fallow fields, and areas of compacted soils in pastures. The aquatic features in this habitat are more clearly classified as temporary waters sensu lato (Williams 2006) than intact and fully functional vernal pools. Because these features are inundated during the wet season and may have historically been located in or near areas with natural vernal pool complex, they may support individuals or small populations of species that are found in vernal pools and swales. However, they do not posses the full complement of ecosystem and community characteristics of natural vernal pools, swales and their associated uplands and they are generally ephemeral features that are eliminated during the course of normal agricultural practices. Degraded vernal pool complex habitat for alkali milk-vetch includes the following vegetation subunits that were selected from the BDCP other natural seasonal wetlands and grasslands communities:

- Grasslands
  - Degraded vernal pool complex – California annual grasslands;
  - Degraded vernal pool complex – Ruderal herbaceous grasses and forbs;
  - Degraded vernal pool complex – Italian rye-grass (*Lolium multiflorum*); and
  - Degraded vernal pool complex – Rabbitsfoot grass (*Polygpogon maritimus*).
- Other natural seasonal wetlands
  - Degraded vernal pool complex-vernal pools.

Potential habitat without concave surfaces (except for seeps along Suisun Marsh) was removed from the model. LiDAR elevation data was then visually inspected in four general areas to further assess specific locations that had been identified by the habitat selection process. These areas were selected based both on *a priori* knowledge of the region and because they were identified by the intersection of the selected vegetation types and soils. The analysis of the LiDAR data further refined the habitat model and provided a more accurate demarcation of suitable habitat. The GIS habitat model was then compared against field data from surveys conducted by the California Department of Water Resources/Delta Habitat Conservation and Conveyance Program (DWR/DHCCP) for the Bay Delta Conservation Plan (BDCP) in 2009. Land uses that are incompatible with the species' habitat requirements (for example, potential habitat polygons falling on leveled or developed lands) were removed from the model.

Assumptions. Historical and current records of this species in the Plan Area indicate that its current distribution is limited to alkaline soil areas with vernal pool and swale microtopography along the western border of the Plan Area (Figure A-43b) (Witham 2002, 2003, 2006, ESA 2005, Barona et al. 2007, CNDDB 2010). The vegetation cover of the alkaline soils is typically a combination of vernal pool adapted species and annual ryegrass (Witham 2002, 2003, 2006, CNDDB 2010). Because alkali milk-vetch also frequently occurs in the same habitats as Heckard's peppergrass (Witham 2002, 2003, 2006, CNDDB 2010) and Heckard's peppergrass was discovered in the Stone Lakes area by DWR/DHCCP field survey teams, its habitat range was extended into areas with vernal pool and swale microtopography along the eastern border of the Plan Area.

A43.8 Recovery Goals

Although alkali milk-vetch is not a federally listed taxon, it is included in the Draft Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (USFWS 2005). The Recovery Plan explicitly states that its goal is to ensure the long-term conservation of this variety and 32 other taxa by using an ecosystem level strategy that is based on: current knowledge of the existing conditions of vernal pool communities, the distribution and status of the populations of each of the species, and current and anticipated process that impact vernal pool ecosystems. Because the goal of the Recovery Plan is primarily directed at habitat preservation, its implementation program specifically addresses factors that relate to habitat acquisition and management: (1) habitat protection; (2) adaptive habitat management and monitoring; (3) status surveys; (4) research; and (5) public participation.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designates the alkali milk-vetch as "Contribute to Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its control and within its scope that are necessary to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

A43.9 References

A43.9.1 Literature Cited

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A43.9.2 Personal Communication

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APPENDIX A44. HEARTSCALE (*ATRIPLEX CORDULATA*)

A44.1 LEGAL STATUS

Heartscale (*Atriplex cordulata*) is not listed under either federal or California endangered species acts. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G2?/S2.2? which means that globally (G) and within the state (S) there are either between six to 20 viable element occurrences of this species, 1,000 to 3,000 individuals of this species, or 2,000 to 10,000 acres (809 to 4,047 hectares) where this species occurs; and the state threat level rank is "threatened." The "?" portion of the rank indicates that there is uncertainty about the rank.

The California Native Plant Society (CNPS) List ranking of 1B.2 for heartscale indicates that it is rare, threatened, or endangered. It is endemic to California and is considered by CNPS to be fairly endangered with between 20 to 80 percent of occurrences threatened. Plants with a CNPS List rank of 1B are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

A44.2 SPECIES DISTRIBUTION AND STATUS

A44.2.1 Range and Status

Heartscale is endemic to California, and its reported range extends through the Central Valley from Glenn County in the north to Kern County in the south, and in valleys of the inner Coast Range in Alameda and San Luis Obispo counties (Figure A-44a) (CNPS 2009). Many of the reported occurrences are 70 years old or older and in areas that are now under more intensive agriculture (CNDDB 2009).

A44.2.2 Distribution and Status in the Plan Area

Heartscale is found in meadows, seeps, riparian wetlands, chenopod scrub, and valley and foothill grasslands in a variety of soils that are either saline or alkaline (CNDDB 2009, CNPS 2009) (Figure A-44b). The populations in the Plan Area are generally small and often subjected to prolonged grazing by sheep (CNDDB 2009) which may have both positive and negative impacts on this species.

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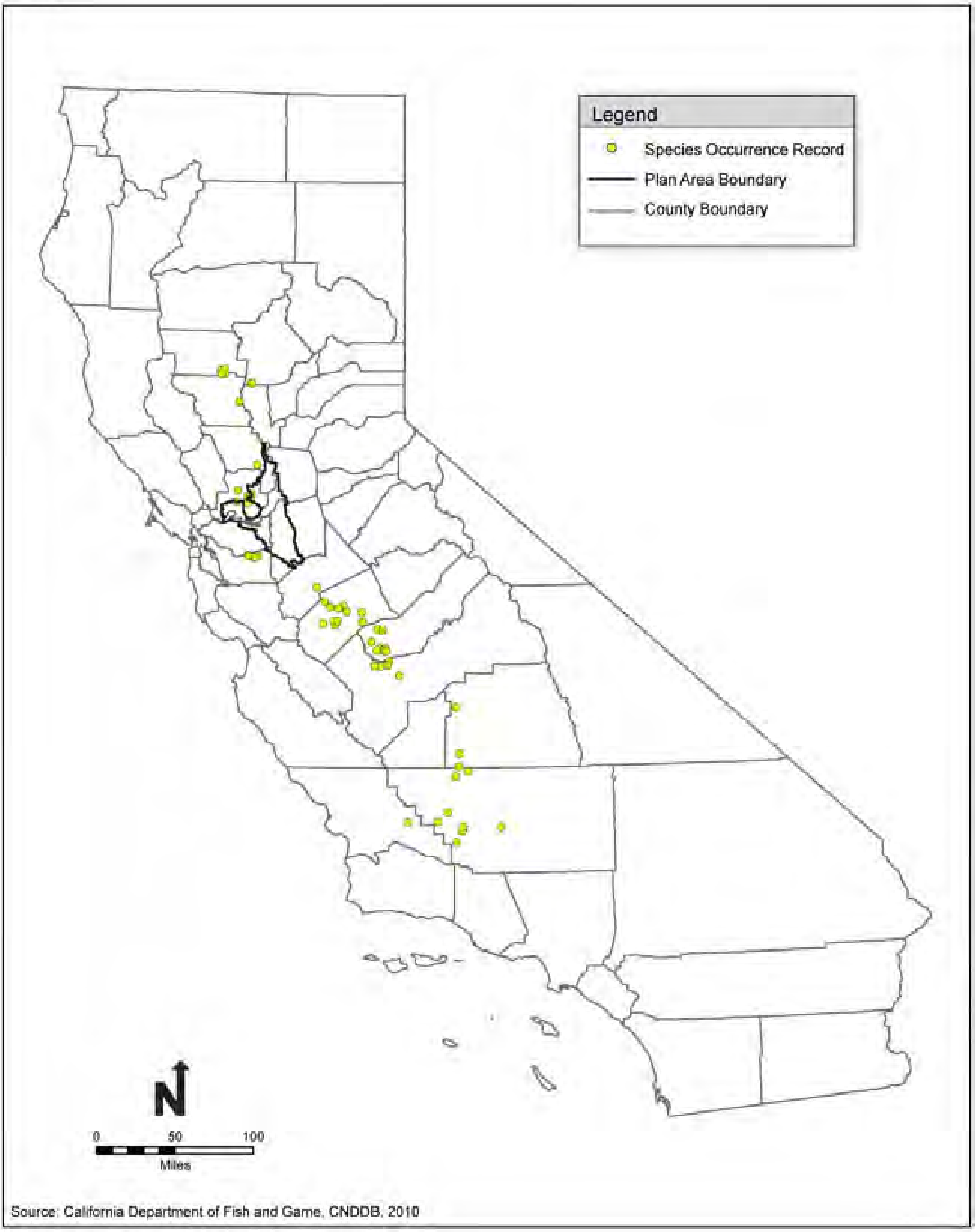

Figure A-44a. Heartscale Statewide Recorded Occurrences

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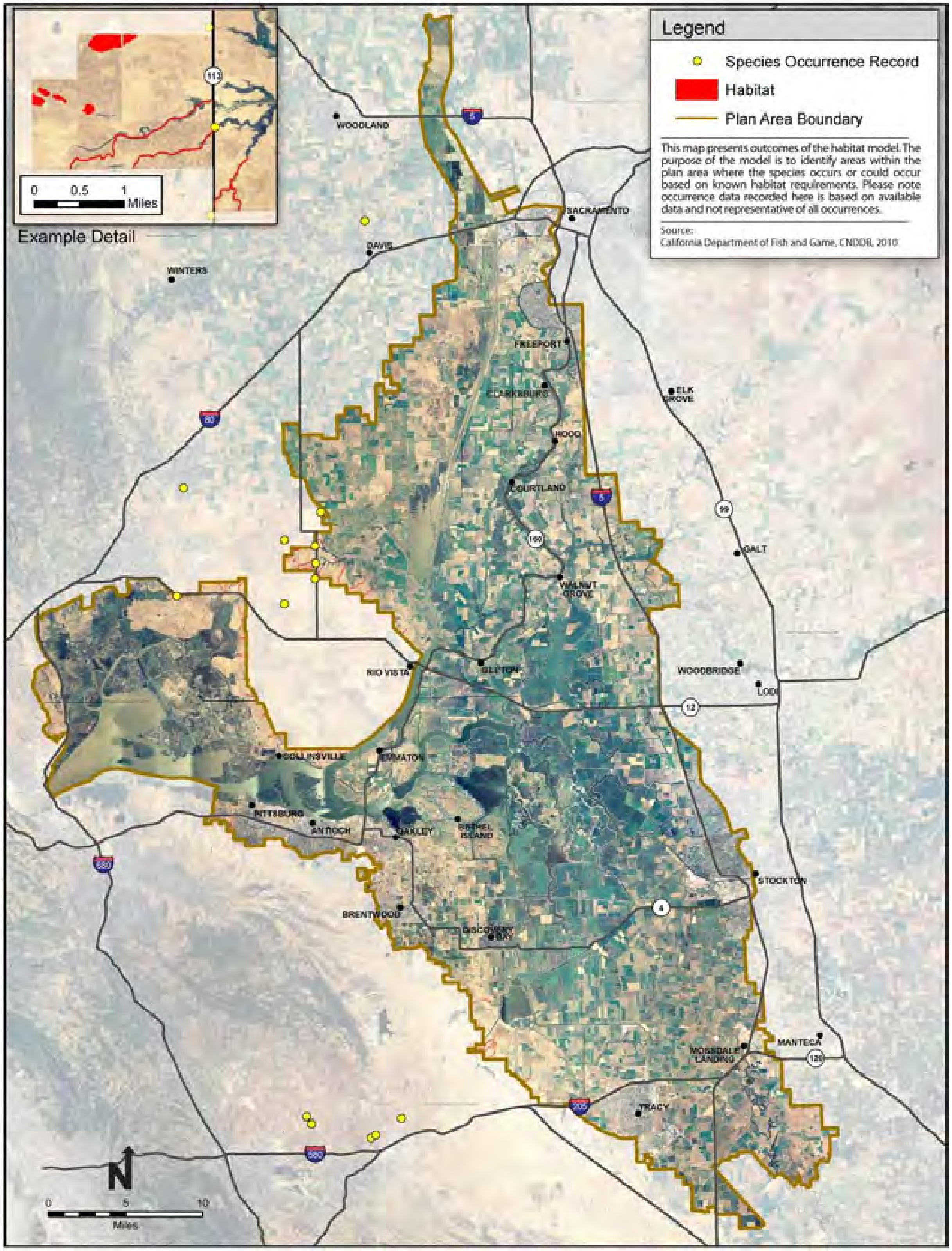

Figure A-44b. Heartscale Habitat Model and Recorded Occurrences

A44.3 Habitat Requirements and Special Considerations

In the Plan Area, heartscale is found in meadows, seeps, drainage corridors, and vernal pools, underlain by alkaline clay soils (CNPS 2009). Species associated with heartscale can include common spikeweed (*Centromadia pungens*), saltgrass (*Distichlis spicata*), alkali heath (*Frankenia salina*), low barley (*Hordeum depressum*), bush seepweed (*Suaeda moquinii*), brittlescale (*Atriplex depressa*), and San Joaquin spearscale (*Atriplex joaquiniana*) (CNDDB 2009, CNPS 2009). The reported CNDDB occurrences in Solano and east Contra Costa counties are in close proximity to hydrological features such as stream corridors and playas pools. It is not known whether this association with hydrological features is a strict habitat requirement or a legacy of land management practices, such as extensive dry-farmed grain and other intensive agriculture that avoid planting and cultivation of hydrological features, continuing to the present (John Gerlach, personal observation on May 30, 2009).

A44.4 Life History

Heartscale is a small to medium-sized 4- to 20-inch (10- to 50-centimeter [cm]) tall annual herb of the goosefoot family (Chenopodiaceae) that blooms from April to October (Hickman 1993, CNPS 2009). It produces one or more erect stems with branches ascending to scaly gray tips with woolly fibers. The leaves are grayish-green, scaly, egg-shaped, and from 0.25-0.5 inch (0.6 to 1.5 cm) in length. Lower leaf bases are heart-shaped while upper leaf bases are rounded. Plant inflorescences are small dense clusters of flowers, and seeds are reddish brown and about 0.1 inch (2 millimeters) wide (Hickman 1993). Heartscale can be found at elevations of 3.3 to 1,230 feet (1 to 375 meters) (CNPS 2009).

A44.5 Threats and Stressors

Reported threats to heartscale include agriculture intensification, development, nonnative plants, overgrazing, and trampling (CNDDB 2009, CNPS 2009).

A44.6 Relevant Conservation Efforts

Heartscale is a covered species under the San Joaquin County Multi-species Habitat Conservation and Open Space Plan and is proposed for coverage under the Solano County Multispecies Habitat Conservation Plan. In the Plan Area, occurrences are generally protected on the Greater Jepson Prairie Ecosystem Management Plan (Witham 2006) while many of the other occurrences are located on wildlife refuges (CNDDB 2009).

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for heartscale is "Maintain" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions to maintain the species by avoiding, minimizing, and compensating for any adverse effects to the species created by ERP restoration actions. To the extent practicable, the ERP will improve species habitat conditions.

A44.7 Species Habitat Suitability Model

Heartscale occurrences in the Plan Area are all in close proximity to hydrological features such as stream corridors and playa pools which are located on either alluvium associated with the Montezuma Block along the western boundary of the Plan Area (Band 1998, Graymer et al. 2002), or on alluvium associated with tertiary formations located along the southwest boundary of the Plan Area (Schruben et al. 1998).

Stream corridors (intermittent and perennial) that intersected these geologic units were selected and truncated at the point at which they encountered the upper elevation of intertidal marsh (Siegel 2007). The corridors were buffered 50 feet (15.2 meters) on either side of their centerlines to capture the estimated maximum extent of alluvium deposits in close proximity to the streams. Field reconnaissance on the Montezuma Block area on May 30, 2009, found that this buffering width is liberal and tends to overpredict potential habitat (J. Gerlach, pers. obs.).

The identified potential habitat was then overlaid on National Agricultural Imagery Program (NAIP) aerial imagery (USDA 2005) to visually assess whether estimated habitat agreed with current land use practices (i.e., to ensure that habitat was not currently impacted by urban or agricultural uses). Predicted habitat that was impacted by urban or intensive agricultural uses was removed from the model.

A44.8 Recovery Goals

A USFWS recovery plan has not been prepared for this species and no recovery goals have been established.

A44.9 References

A44.9.1 Literature Cited

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APPENDIX A45. BRITTLESCALE (*ATRIPLEX DEPRESSA*)

A45.1 LEGAL STATUS

Brittlescale (*Atriplex depressa*) is not listed under either federal or California endangered species acts. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G2Q/S2.2 which means that globally (G) and within the state (S) there are either between six to 20 viable element occurrences of this species, 1,000 to 3,000 individuals of this species, or 2,000 to 10,000 acres (809 to 4,047 hectares) where this species occurs; and the state threat level rank is "threatened." The "Q" portion of the rank indicates that unresolved taxonomic questions remain for this rare species (CNDDB Special Vascular Plants, Bryophytes, and Lichens List).

The California Native Plant Society (CNPS) List ranking of 1B.2 for brittlescale indicates that it is rare, threatened, or endangered. It is endemic to California and is considered by CNPS to be fairly endangered with between 20 to 80 percent of occurrences threatened. Plants with a CNPS List rank of 1B are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

A45.2 SPECIES DISTRIBUTION AND STATUS

A45.2.1 Range and Status

Brittlescale is endemic to California, and its distribution is based on 58 observations (Figure A-45a). There has been confusion in identifying this species correctly and some of the occurrences are lesser saltscale (*Atriplex minuscula*) (Preston 2003). There is also disagreement regarding the morphological characteristics that separate these species (Preston 2009, pers. comm.). The range of brittlescale extends from Colusa and Glenn counties in the north, to Fresno, Merced, Stanislaus, and Tulare counties in the south and east, to Alameda, Contra Costa, Solano, and Yolo counties in the west (CNDDB 2009, CNPS 2009). It is found on a range of alkaline or saline soils in the Sacramento Valley and in the inner North Coast Ranges (CNDDB 2009).

A45.2.2 Distribution and Status in the Plan Area

Brittlescale has been reported from Solano County: at Olcott Lake on Jepson Prairie; between Bird's Landing and Montezuma Slough; south of Cement Road; along Creed Road; in the mitigation area for the access to Potrero Hills Landfill; and the Elsie Gridley Mitigation Bank (AMEC&FA 2001, CNDDB 2009) (Figure A-45b). Population sizes are reported for two of them: the Bird's Landing population had approximately 300 plants in 1991; and the Potrero Hills population had 213 plants in 1996 (CNDDB 2009). It is also found in and along drainages and alkaline seeps in eastern Contra Costa County and near alkaline seeps (CNDDB 2009).

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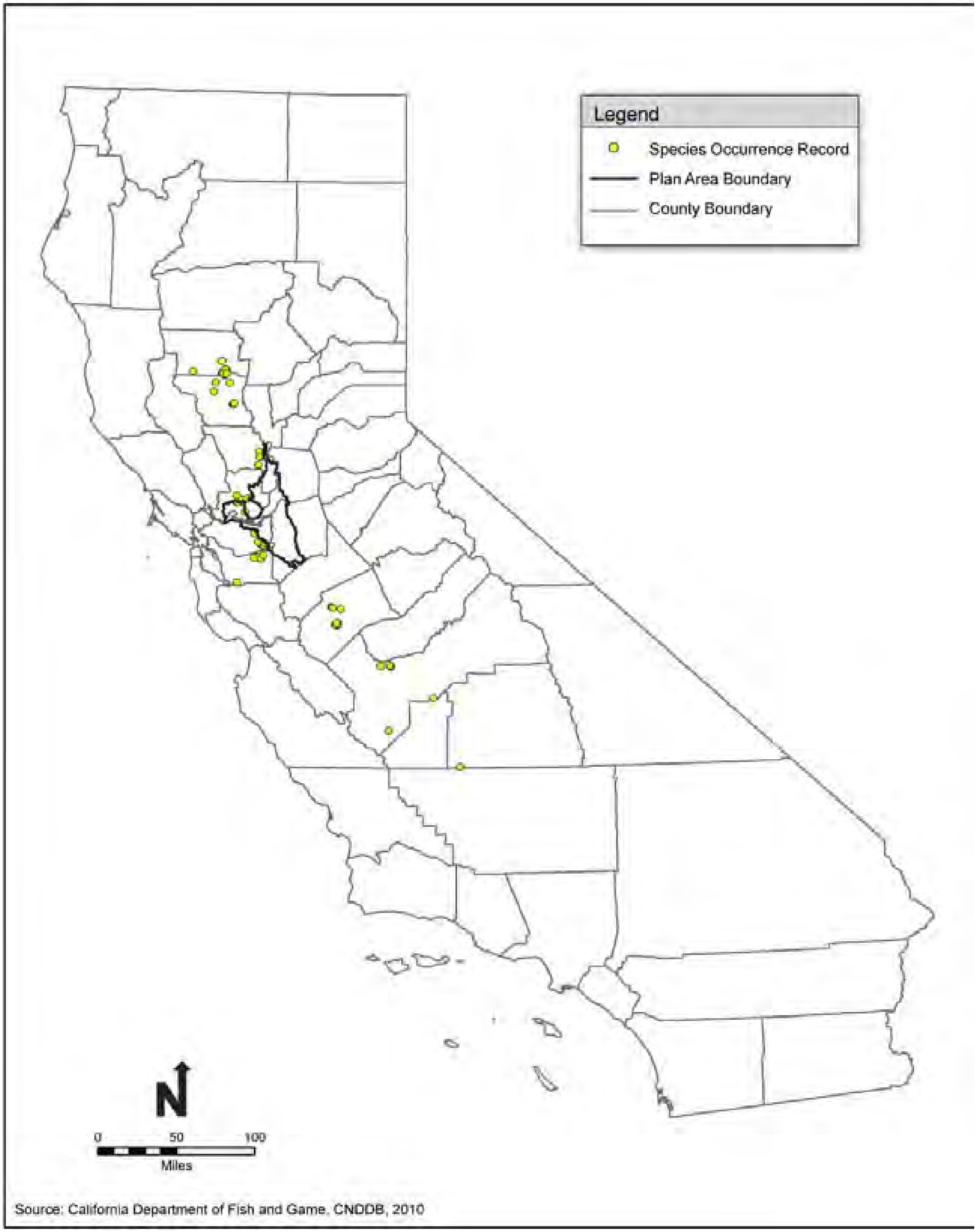

Figure A-45a. Brittlescale Statewide Recorded Occurrences

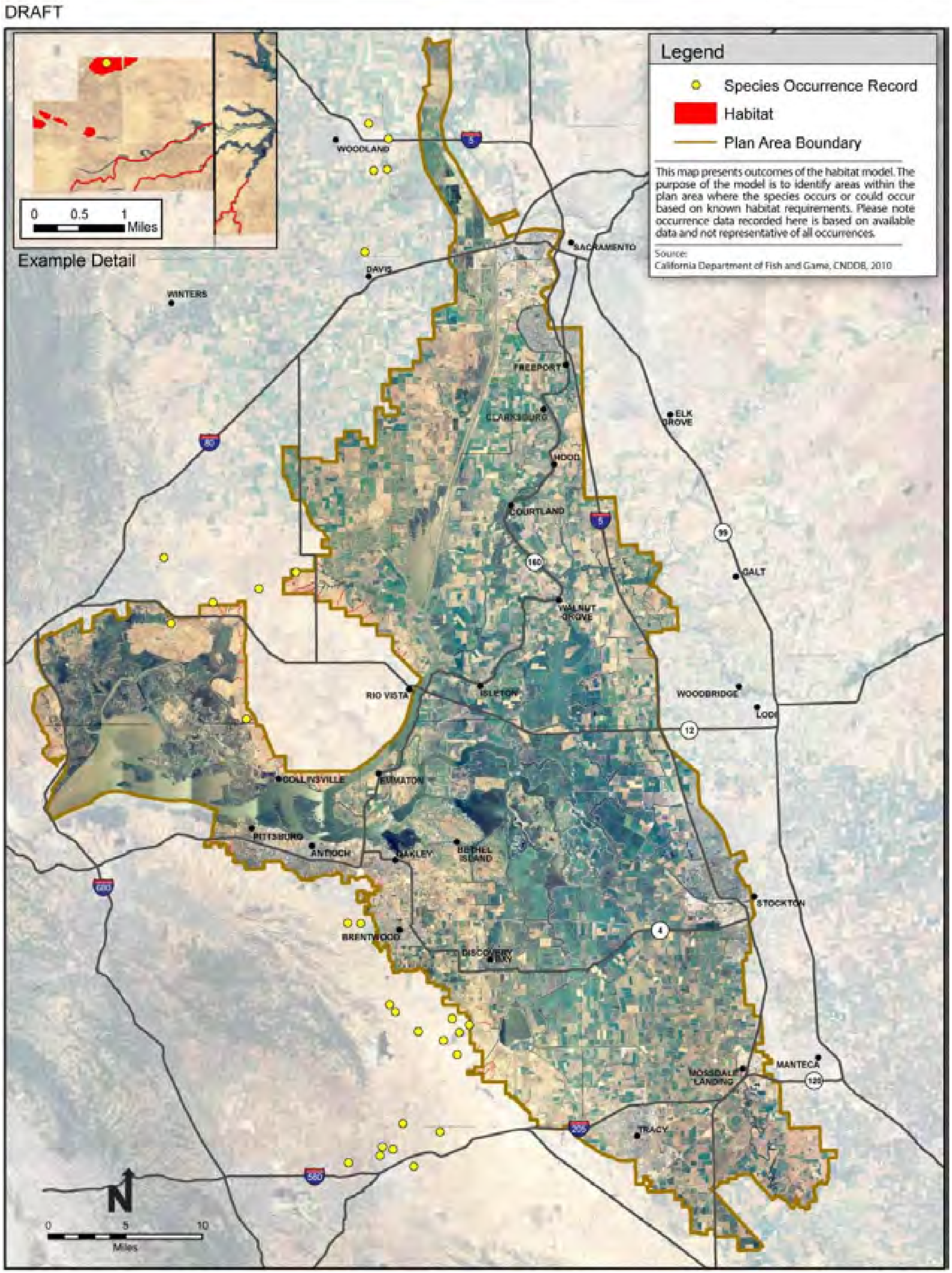

Figure A-45b. Brittlescale Habitat Model and Recorded Occurrences

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A45.3 Habitat Requirements and Special Considerations

Brittlescale is found in meadows, seeps, and vernal pools, with alkaline clay soils (CNPS 2009). Species associated with brittlescale can include common spikeweed (*Centromadia pungens*), saltgrass (*Distichlis spicata*), alkali heath (*Frankenia salina*), low barley (*Hordeum depressum*), Mediterranean barley (*Hordeum marinum* ssp. *gussoneanum*), western niterwort (*Nitrophila occidentalis*), Parish's pickleweed (*Salicornia subterminalis*[1]), bush seepweed (*Suaeda moquinii*), heartscale (*Atriplex cordulata*), and San Joaquin spearscale (*Atriplex joaquiniana*) (CNDDB 2009, CNPS 2009). The reported CNDDB occurrences in Solano and east Contra Costa counties are in close proximity to hydrological features such as stream corridors and playa pools. It is not known whether this association with hydrological features is a strict habitat requirement or a legacy of land management practices such as extensive dry-farmed grain and other intensive agriculture that avoid planting and cultivation of hydrological features, continuing to the present (John Gerlach, personal observation on May 30, 2009).

A45.4 Life History

Brittlescale is a small (< 20-centimeter [cm] [8-inch]) annual herb of the goosefoot family (Chenopodiaceae) that blooms from April to October (Hickman 1993, CNPS 2009). Its stems grow flat along the ground and turn upwards near their tips and are white, scaly and brittle (Hickman 1993). Leaf blades are small (0.2-0.3 inch [4-8 millimeters {mm}]), egg-shaped to heart-shaped, with entire margins, are generally densely white-scaly, and can be opposite unlike many other *Atriplex* species (Hickman 1993). Brittlescale can be found at elevations of 3 to 1,050 feet (1 to 320 meters) (CNPS 2009). It is closely related to *Atriplex minuscula* (lesser saltscale) and *Atriplex parishii* (Parish's brittlescale) and has, in the past, been described as a synonym for *Atriplex parishii* (Parish's brittlescale) (CNPS 2009). Its reddish seeds are 0.04 to 0.06 inch (1 to 1.5 mm) long (Hickman 1993).

A45.5 Threats and Stressors

The primary threat to brittlescale is the loss of suitable habitat within the range of the species (CNDDB 2009). Other threats include invasive species and the creation of waterfowl habitat (Showers 1996).

A45.6 Relevant Conservation Efforts

Brittlescale is a covered species in the San Joaquin County Multi-species Habitat Conservation and Open Space Plan and the East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan; and it is proposed for coverage under the Yolo County Natural

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[1] Currently known as *Arthrocnemum subterminale.*

Heritage Program Plan and the Solano County Multi-species Habitat Conservation Plan. In the Plan Area, occurrences are generally protected on the Greater Jepson Prairie Ecosystem Management Plan (Witham 2006) while many of the other occurrences are located on wildlife refuges (CNDDB 2009).

A45.7 Species Habitat Suitability Model

Brittlescale occurrences in and near the Plan Area are all in close proximity to hydrological features such as stream corridors and playa pools which are located on either alluvium associated with the Montezuma Block along the western boundary of the Plan Area (Band 1998, Graymer et al. 2002) or on alluvium associated with tertiary formations located along the southwest boundary of the Plan Area (Schruben et al. 1998).

Stream corridors (intermittent and perennial) that intersected these geologic units were selected and truncated at the point at which they encountered the upper elevation of intertidal marsh (Siegel 2007). The corridors were buffered 50 feet (15.2 meters) on either side of their centerlines to capture the estimated maximum extent of alluvium deposits in close proximity to the streams. Field reconnaissance on the Montezuma Block area on May 30, 2009, found that this buffering width is liberal and tends to overpredict potential habitat (J. Gerlach, pers. obs.).

The identified potential habitat was then overlaid on National Agricultural Imagery Program (NAIP) aerial imagery (USDA 2005) to visually assess whether estimated habitat agreed with current land use practices (i.e. to ensure that habitat was not currently impacted by urban or agricultural uses). Predicted habitat that was impacted by urban or intensive agricultural uses was removed from the model.

A45.8 Recovery Goals

A United States Fish and Wildlife (USFWS) recovery plan has not been prepared for this species and no recovery goals have been established.

A45.9 References

A45.9.1 Literature Cited

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USDA (United States Department of Agriculture). 2005. National Agricultural Imaging Program.

Witham, C.W. 2006. Greater Jepson Prairie ecosystem regional management plan. Fairfield: Solano Land Trust.

A45.9.2 Personal Communications

Preston, R. 2009. (Botanist, Jones & Stokes, and Jepson Herbarium Volunteer). Email correspondence with John Gerlach on May 19, 2009.

APPENDIX A46. SAN JOAQUIN SPEARSCALE (*ATRIPLEX JOAQUINIANA*)

A46.1 LEGAL STATUS

San Joaquin spearscale (*Atriplex joaquiniana*) is not listed under either federal or California endangered species acts. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G2/S2.1 which means that globally (G) and within the state (S) there are either between six to 20 viable element occurrences of this species, 1,000 to 3,000 individuals of this species, or 2,000 to 10,000 acres (809 to 4,047 hectares) where this species occurs. Its state threat level rank is "very threatened."

The California Native Plant Society (CNPS) List ranking of 1B.2 indicates that it is rare, threatened, or endangered in California and elsewhere, and is considered by CNPS to be fairly endangered in California with between 20 to 80 percent of occurrences threatened. Plants with a CNPS List rank of 1B are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

A46.2 SPECIES DISTRIBUTION AND STATUS

A46.2.1 Range and Status

The range of San Joaquin spearscale includes Glenn, Colusa and Yolo counties to the north, Contra Costa, Santa Clara, San Benito, Napa, Solano, and Alameda counties to the west, Sacramento, Fresno, Merced, and San Joaquin counties to the south (Figure A-46a). Population trends of San Joaquin spearscale have not been documented. According to the CNPS (2008), occurrences of San Joaquin spearscale in California are limited and at risk throughout its range, although it may have been more abundant historically.

Endemic to California, San Joaquin spearscale historically has been collected in the Central Valley from Glenn County south to Merced County (Silveira 2000, CNDDB 2008). Specimens have also been collected in the inner North Coast Ranges in Glenn County and in the ranges of Alameda, Contra Costa and San Benito counties (Silveira 2000, CNDDB 2008). It has been collected in, or adjacent to, salt marshes in Napa, Sacramento, San Luis Obispo, and Solano counties and on the shore of a small lake in Solano County (CNDDB 2008). Populations remain extant at many of the collection sites. Of 94 observations of the distribution of San Joaquin spearscale in California, seven occurred in Yolo County (CalFlora 2000, CNDDB 2008).

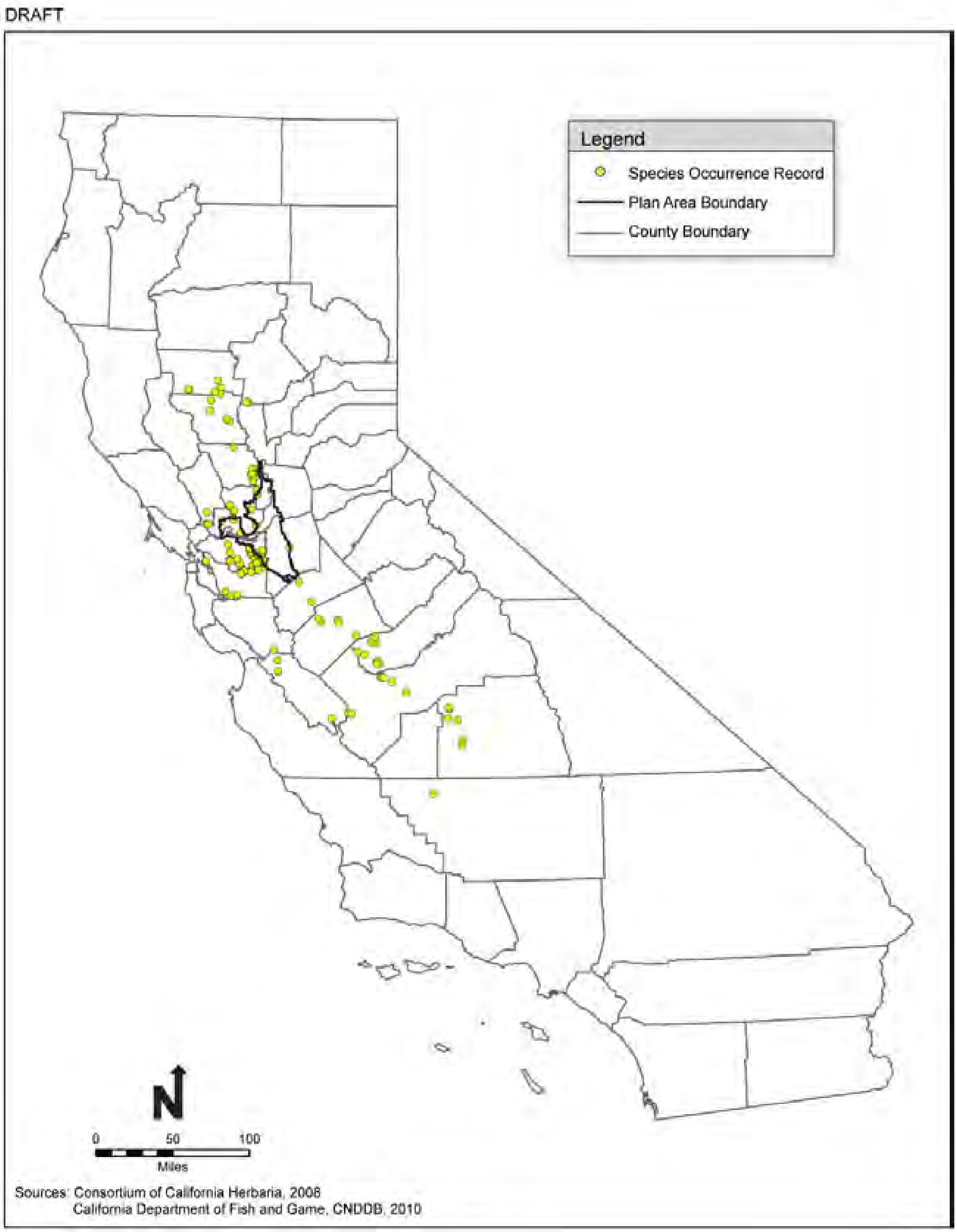

Figure A-46a. San Joaquin Spearscale Statewide Recorded Occurrences

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In Yolo County, San Joaquin spearscale has been collected on, and adjacent to, alkaline soils north of Davis, east of the City of Woodland, the McClellan Air Force Base Davis Communications Facility site, the California Department of Fish and Game (DFG) Tule Ranch Preserve, which is within the Plan Area, and near Dunnigan (Showers 1996, EDAW 2004, ESA 2005, Dean 2007, CNDDB 2008).

A46.2.2 Distribution and Status in the Plan Area

Within the Plan Area, San Joaquin spearscale generally occurs along the west side of the Sacramento Valley and adjacent to the San Joaquin River. It has been observed near Hass Slough, Orwood Tract, Byron Tract, Clifton Court Forebay, and northwest of Collinsville in the Suisun Marsh area (CNDDB 2008) (Figure A-46b).

A46.3 Habitat Requirements and Special Considerations

San Joaquin spearscale occurs in chenopod scrub and in meadows, playas, valley grassland, and foothill grassland vegetation growing on alkaline soils. In the Central Valley of California, it appears to be restricted to alkaline soils along the rims of alkaline basins and the edges of clay bottom vernal pools (CNDDB 2008). It is also found in alkaline and saline soils near creeks and seeps of the eastern flank of the inner North Coast Ranges (Taylor and Wilken 1993, CNDDB 2008). Similar soils occur in the alluvial fans of Brushy, Kellogg, and Marsh creeks along the northeastern edge of the San Joaquin Valley. In many instances the species occurs with or is found near populations of brittlescale (*Atriplex depressa*), a BDCP covered species, and palmate-bracted bird's-beak (*Cordylanthus palmatus*) (CNDDB 2008).

A46.4 Life History

San Joaquin spearscale was first described in 1904 by A. Nelson (Nelson 1904). It is a 4- to 39-inch (10- to 100-centimeter) tall herbaceous annual plant in the goosefoot family (Chenopodiaceae) (Taylor and Wilken 1993). The species is also known as San Joaquin saltbush and San Joaquin orache (Taylor and Wilken 1993, CalFlora 2000). It has erect stems, with many branches, which spread out as the plant ascends. The twigs are dense and finely scaled, becoming glabrous (hairless and smooth). The ovate to triangular-shaped leaves measure 0.4 to 2.8 inches (1 to 7 cm) (Taylor and Wilken 1993). The leaves are finely gray-scaled and may be green above. They are also generally irregularly wavy-toothed, with the base truncated and tapered in form (Taylor and Wilken 1993). The staminate inflorescence is spike- or panicle-like, which refers to branched clusters of flowers in which the branches are racemes. They are congested on the ends of the main stem and branches, resembling little "sausages." Species of *Atriplex* are most easily identified after flowering, based on fruiting bracts enclosing the seed (Hickman 1993). San Joaquin spearscale blooms from April through October, depending upon environmental conditions (CNPS 2008). The seeds are approximately 1 to 1.5 millimeters (0.04 to 0.06 inch) in length and are dark brown (Taylor and Wilken 1993).

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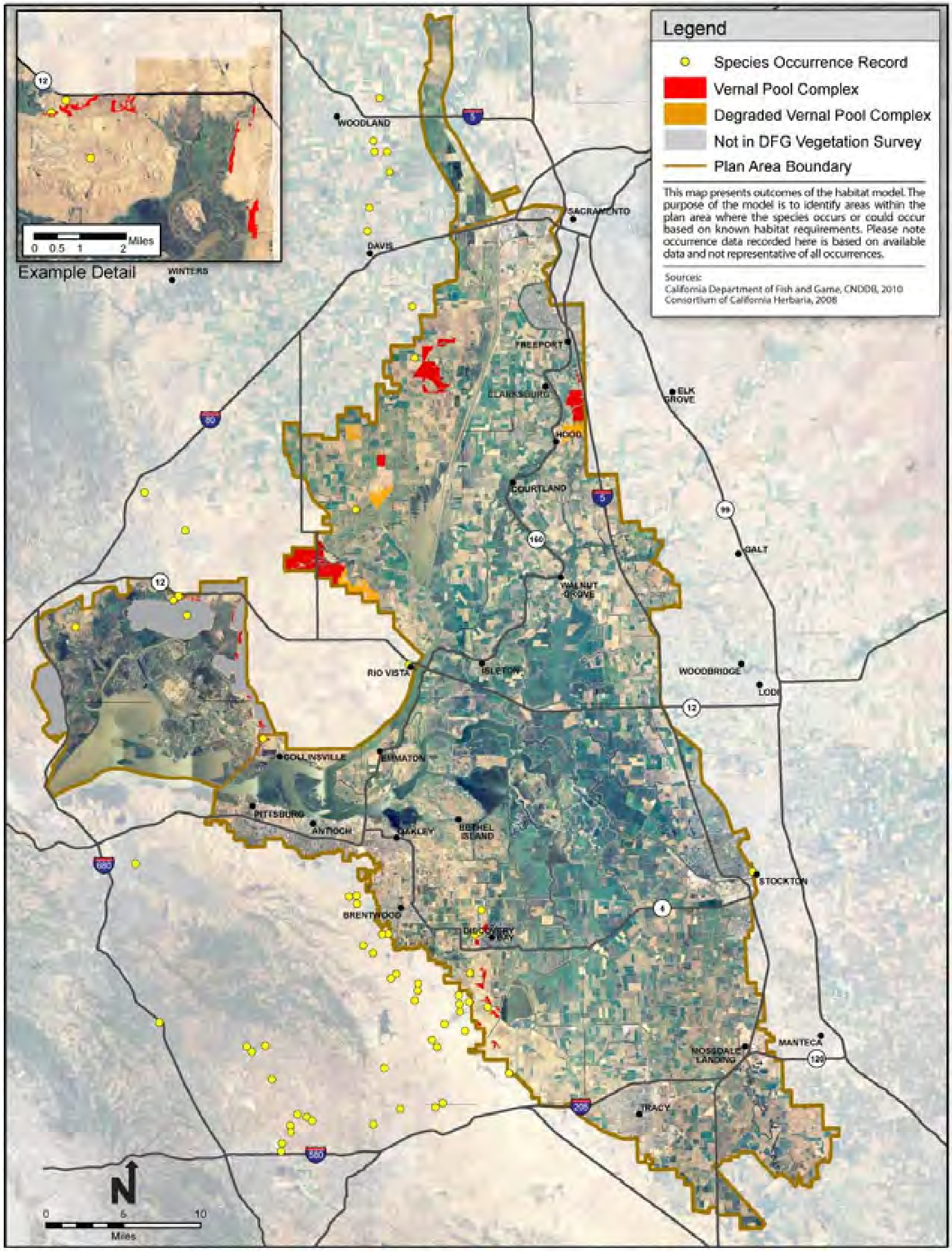

Figure A-46b. San Joaquin Spearscale Habitat Model and Recorded Occurrences

1

Very little is known about the biology and germination patterns of the species; however, spearscale is known to produce a long-lived seed bank that germinates in response to soil disturbances and can persist in weedy grasslands dominated by exotic species (EDAW 2004).

A46.5 Threats and Stressors

Development, intensive agriculture, waterfowl management, and exotic plant species are considered to be the primary threats to the species (Showers 1996, EDAW 2004, CNDDB 2008). All of these impacts lead to loss of habitat and degradation of the specific soils the plant requires to survive. Research should be directed towards invasive species control methods and techniques for establishing the appropriate hydrological regime to maintain the saline and alkaline soils.

A46.6 Relevant Conservation Efforts

San Joaquin spearscale is a covered species under the East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan which includes measures to protect populations and habitat. San Joaquin spearscale is proposed for coverage under the Solano County Multispecies Habitat Conservation Plan and the Yolo County Natural Heritage Program Plan.

A46.7 Species Habitat Suitability Model

Model Approach. BDCP Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below and in Section 2.3.1, *Data Sources and Natural Community Classification*). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as vernal pools, individual trees, or small groups of trees. It is also possible, as with some vernal pool invertebrates that are restricted to seasonally ponded habitats, to underestimate potentially-occupied habitat due to the lack of information on small, degraded or artificially-created seasonal wetland habitats.

Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The San Joaquin spearscale model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and

pool complex and degraded vernal pool complex habitat. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Vernal Pool Complex Habitat: High quality permanent habitat that consists of vernal pools and uplands that display characteristic vernal pool and swale visual signatures that have not been significantly impacted by agricultural or development practices. Vernal pool complex habitat for San Joaquin spearscale includes the following vegetation subunits that were selected from the vernal pool complex natural community:

- Vernal pool complex – all vegetation types

Degraded Vernal Pool Complex Habitat: Low quality ephemeral habitat that ranges from areas with vernal pool and swale visual signatures that display clear evidence of significant disturbance due to plowing, disking, or leveling to areas with clearly artificial basins such as shallow agricultural ditches, depressions in fallow fields, and areas of compacted soils in pastures. The aquatic features in this habitat are more clearly classified as temporary waters sensu lato (Williams 2006) than intact and fully functional vernal pools. Because these features are inundated during the wet season and may have historically been located in or near areas with natural vernal pool complex, they may support individuals or small populations of species that are found in vernal pools and swales. However, they do not possess the full complement of ecosystem and community characteristics of natural vernal pools, swales and their associated uplands and they are generally ephemeral features that are eliminated during the course of normal agricultural practices. Degraded vernal pool complex habitat for San Joaquin spearscale includes the following vegetation subunits that were selected from the BDCP other natural seasonal wetlands and grasslands communities:

- Grasslands
  - Degraded vernal pool complex – California annual grasslands;
  - Degraded vernal pool complex – ruderal herbaceous grasses and forbs;
  - Degraded vernal pool complex – Italian rye-grass (*Lolium multiflorum*); and
  - Degraded vernal pool complex – rabbitsfoot grass (*Polygpogon maritimus*).
- Other natural seasonal wetlands
  - Degraded vernal pool complex - vernal pools.

Potential habitat without concave surfaces (except for seeps along Suisun Marsh) was removed from the model. LiDAR elevation data was then visually inspected in four general areas to further assess specific locations that had been identified by the habitat selection process. These areas were selected based both on *a priori* knowledge of the region and because they were identified by the intersection of the selected vegetation types and soils. The analysis of the LiDAR data further refined the habitat model and provided a more accurate demarcation of suitable habitat. The GIS habitat model was then compared against field data from surveys conducted by the California Department of Water Resources/Delta Habitat Conservation and Conveyance Program (DWR/DHCCP) for the Bay Delta Conservation Plan (BDCP) in 2009. Land uses that are incompatible with the species' habitat requirements, for example potential habitat polygons falling on leveled or developed lands, were removed from the model.

Assumptions. Historical and current records of this species in the Plan Area indicate that its current distribution is limited to alkaline soil areas with vernal pool and swale microtopography along the western border (Figure A-46b) (CNDDB 2010). The vegetation cover of the alkaline soils is typically a combination of vernal pool adapted species, alkaline soil adapted species, and annual ryegrass (CNDDB 2010).

A46.8 RECOVERY GOALS

A United States Fish and Wildlife (USFWS) recovery plan has not been prepared for this species and no recovery goals have been established.

A46.9 References

A46.9.1 Literature Cited

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APPENDIX A47. SLOUGH THISTLE (*CIRSIUM CRASSICAULE*)

A47.1 LEGAL STATUS

Slough thistle (*Cirsium crassicaule*) is not listed under either federal or California endangered species acts. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G2/S2.2 which means that globally (G) and within the state (S) there are either between six to 20 viable element occurrences of this species, 1,000 to 3,000 individuals of this species, or 2,000 to 10,000 acres (809 to 4,047 hectares) where this species occurs; and the state threat level rank is "threatened."

The California Native Plant Society (CNPS) List ranking of 1B.1 for slough thistle indicates that it is rare, threatened, or endangered. It is endemic to California and is considered by CNPS to be seriously endangered with more than 80 percent of occurrences threatened. Plants with a CNPS List rank of 1B are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

A47.2 SPECIES DISTRIBUTION AND STATUS

A47.2.1 Range and Status

Slough thistle is endemic to the San Joaquin Valley and has been reported from San Joaquin County in the north and in Kings and Kern counties in the south (CNPS 2009) (Figure A-47a). The few individuals who have direct experience with this species believe that its populations are declining throughout the San Joaquin Valley (T. Griggs pers. comm. 2009, R. Hansen pers. comm. 2009). A cluster of occurrences (CNDDB 2009) have been reported from the Hacienda Spillway which is a former flood channel of the Kern River at the southern end of Tulare Lake that is maintained as a flood conveyance and floodwater storage area (Hacienda Reservoir). Long term casual monitoring indicates that this species has declined to zero plants at one Hacienda Spillway occurrence (R. Hansen pers. comm. 2009) while the CNDDB record indicates that another occurrence was extirpated by the construction of storage ponds.

A47.2.2 Distribution and Status in the Plan Area

Slough thistle occurs in the southern end of the Plan Area in the San Joaquin River (Figure A-47b). There are seven records from near Lathrop and Vernalis; all but two of which have been extirpated by agriculture or urbanization (CNDDB 2009).

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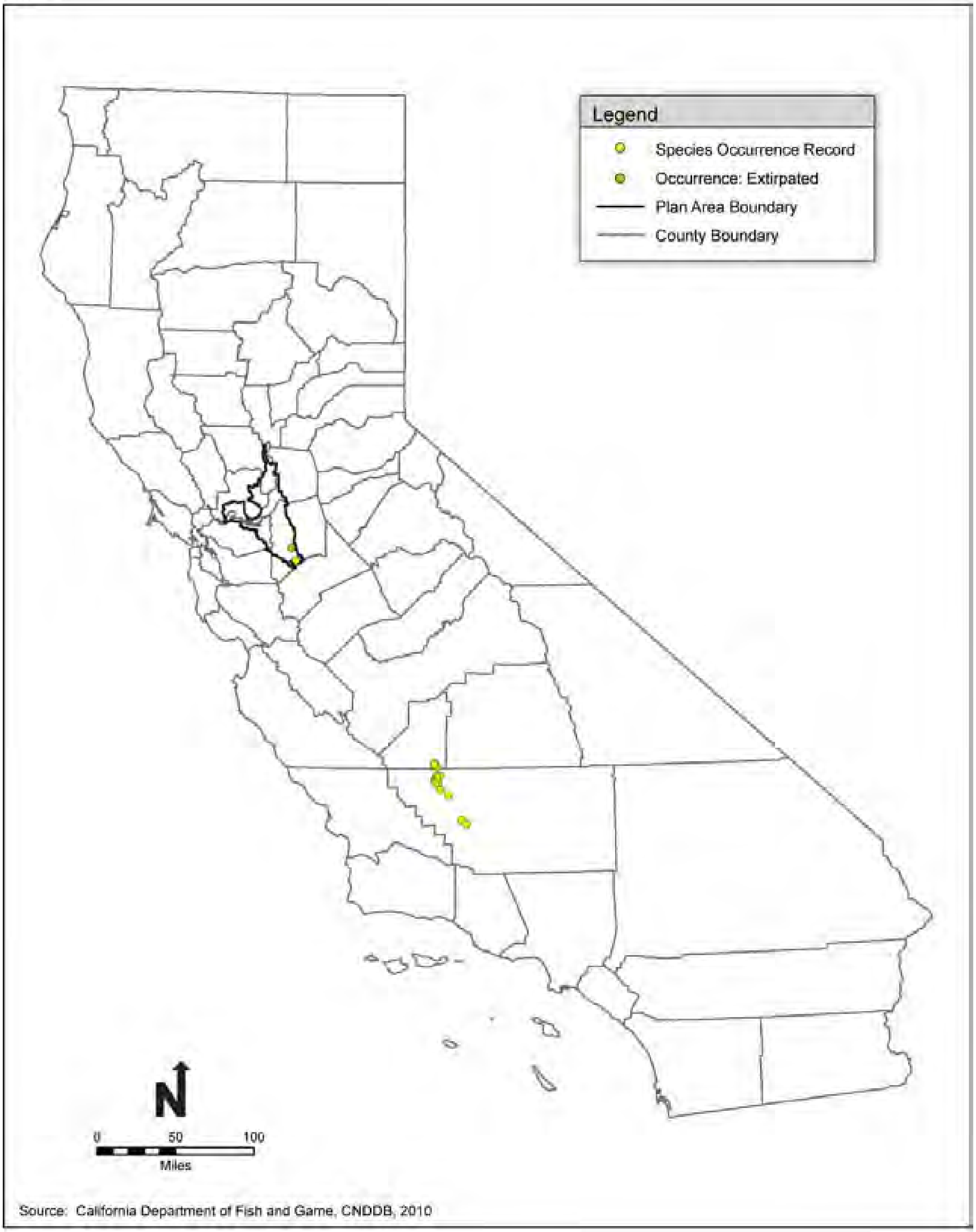

Figure A-47a. Slough Thistle Statewide Recorded Occurrences

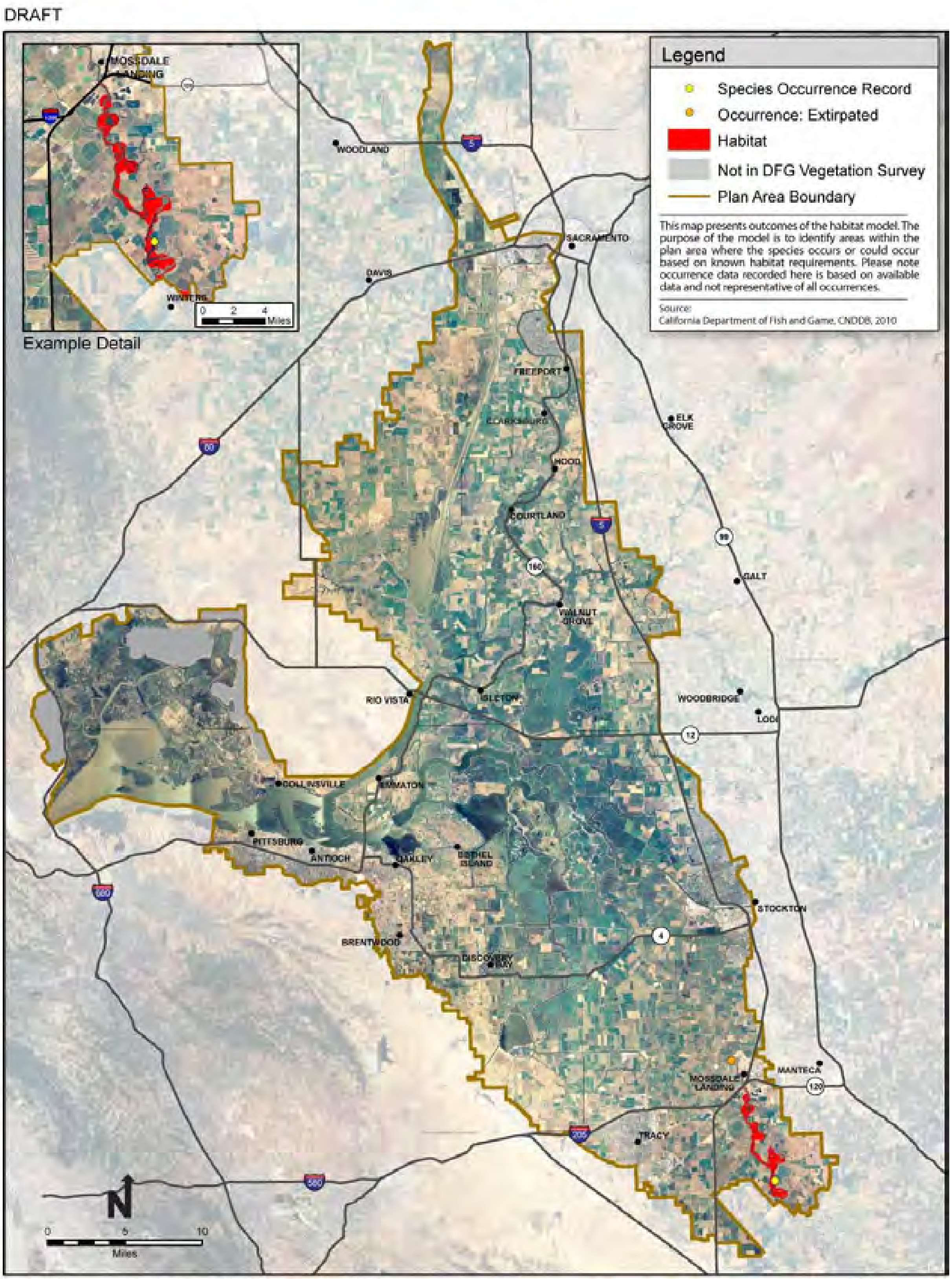

Figure A-47b. Slough Thistle Habitat Model and Recorded Occurrences

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A47.3 HABITAT REQUIREMENTS AND SPECIAL CONSIDERATIONS

Slough thistle has been reported from freshwater marshes and swamps, and in chenopod scrub and riparian scrub habitats (CNPS 2009). Under natural conditions, it almost always occurs in wetlands (Calflora 2009). Population sizes widely fluctuate (CNPS 2009). The locations reported in the southern San Joaquin Valley are all along or adjacent to high flood flow areas (CNDDB 2009) such as the Hacienda Spillway where high flows from the Kern River broke through the Sand Ridge and flowed into Tulare Lake (R. Hansen pers. comm. 2009). Because these high flow areas have been preserved, albeit in a modified condition, for floodwater conveyance, some habitat has been preserved in what is now an area of intensive agricultural production. Historically slough thistle was likely present throughout the Tulare Basin in lesser flow channels as well. It is generally found within the portions of channels that flood at high water and on the banks of flood water conveyance canals and drains (T. Griggs pers. comm. 2009, R. Hansen pers. comm. 2009).

A47.4 LIFE HISTORY

Slough thistle is a large (3.3- to 9.8-feet [1- to 3-meter]) tall annual to biennial herb of the sunflower family (Asteraceae) that blooms from May to August (Hickman 1993, CNPS 2009). It is found at elevations of 9.8 to 328 feet (3 to 100 meters) above sea level (CNPS 2009). Unless grazed, it generally has one stem that is hollow and openly branched near the top of the plant (Hickman 1993, T. Griggs pers. comm. 2009). Its leaves are thinly covered with cobwebby-tomentose hairs on top and gray-tomentose hairs below. Lower leaf lengths range from 6 to 27 inches (15.2 to 69 centimeters [cm]); middle and upper leaves are smaller, narrower, and sessile (Hickman 1993). Slough thistle flowers are pale rose-purple or sometimes white in color, 0.75 to 1.0 inch (1.0 to 5.1 cm) long, and are grouped into spiny heads one half to one inch wide which are in turn grouped into loose to crowded clusters called cymes in which the central flowers open before the surrounding flowers (Hickman 1993).

A47.5 THREATS AND STRESSORS

Conversions of suitable habitat to agricultural land uses and competition from nonnative plants have been reported as the primary threats to slough thistle (CNPS 2009). In the southern San Joaquin Valley, other threats include vegetation clearing on the banks of drains and canals, and weed control efforts (T. Griggs pers. comm. 2009, R. Hansen pers. comm. 2009).

A47.6 RELEVANT CONSERVATION EFFORTS

Slough thistle is a covered species in the San Joaquin County Multi-species Habitat Conservation and Open Space Plan, the Metro Bakersfield Habitat Conservation Plan, and the Kern Valley Floor Habitat Conservation Plan. It is also covered under the Kern and Pixley National Wildlife Refuges Comprehensive Conservation Plan (USFWS 2005).

A47.7 Species Habitat Suitability Model

Habitat. Slough thistle habitat was identified as all areas between the levees from the Mossdale Bridge to Vernalis. A historical occurrence from 1933 was located just north of the Mossdale Bridge but aerial imagery indicates that the occurrence has likely been extirpated due to intensive agriculture.

Assumptions. Historical and current records of this species indicate that its distribution within the Plan Area is limited to the flood plain of the San Joaquin River (Figure A-47b). Based on its distribution in the southern San Joaquin Valley, its habitat is likely to be areas along the river that have been disturbed by flood events and are being colonized by willow scrub vegetation.

A47.8 Recovery Goals

A USFWS recovery plan has not been prepared for this species and no recovery goals have been established.

A47.9 References

A47.9.1 Literature Cited

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A47.9.2 Personal Communications

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APPENDIX A48. SUISUN THISTLE (*CIRSIUM HYDROPHILUM* VAR. *HYDROPHILUM*)

A48.1 LEGAL STATUS

Suisun thistle (*Cirsium hydrophilum* var. *hydrophilum*) is listed as endangered under the federal Endangered Species Act (November 1997) (62 FR 61916). It is not listed under the California Endangered Species Act. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G1T1/S1.1 which means that globally (G) and within the state (S) both the species and variety have either less than 6 viable element occurrences, less than 1,000 individuals, or less than 2,000 acres (809 hectares) of occupied habitat; and the state threat level rank is "very threatened."

The California Native Plant Society (CNPS) List ranking of 1B.1 for Suisun thistle indicates that it is rare, threatened, or endangered. It is endemic to California and is considered by CNPS to be seriously endangered with more than 80 percent of occurrences threatened. Plants with a CNPS List rank of 1B are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

The United States Fish and Wildlife Service (USFWS) recently designated critical habitat that specifies the protection of Suisun thistle habitat in three areas of Suisun Marsh (72 FR 18517). Unit One contains no Suisun thistle (Hill Slough Marsh), but it has all the necessary habitat features. Units Two and Three contain or did contain Suisun thistle populations at the time of the listing (Peytonia Slough Ecological Reserve and Rush Ranch/Grizzly Island Wildlife Area).

A48.2 SPECIES DISTRIBUTION AND STATUS

A48.2.1 Range and Status

Suisun thistle has a very small range as it is endemic to a few areas in the northern portion of the Suisun Marsh in Solano County, California (62 FR 61916, USFWS 2009) (Figure A-48a). It is protected on public lands, and on non-governmental organization conservation lands in the Suisun Marsh, but its current primary habitat is along mosquito control ditches that may degrade through time (USFWS 2009). The Peytonia Slough Ecological Reserve population may have been extirpated through arson (USFWS 2009).

A48.2.2 Distribution and Status in the Plan Area

In 1975, Suisun thistle was presumed to be extinct because it had not been observed for 15 years (62 FR 61916, USFWS 2003, 2009); however, extensive surveys conducted at Suisun Marsh in 1989 rediscovered this species at two locations (62 FR 61916, USFWS 2003, 2009) (Figure A-48b).

Figure A-48a. Suisun Thistle Statewide Recorded Occurrences

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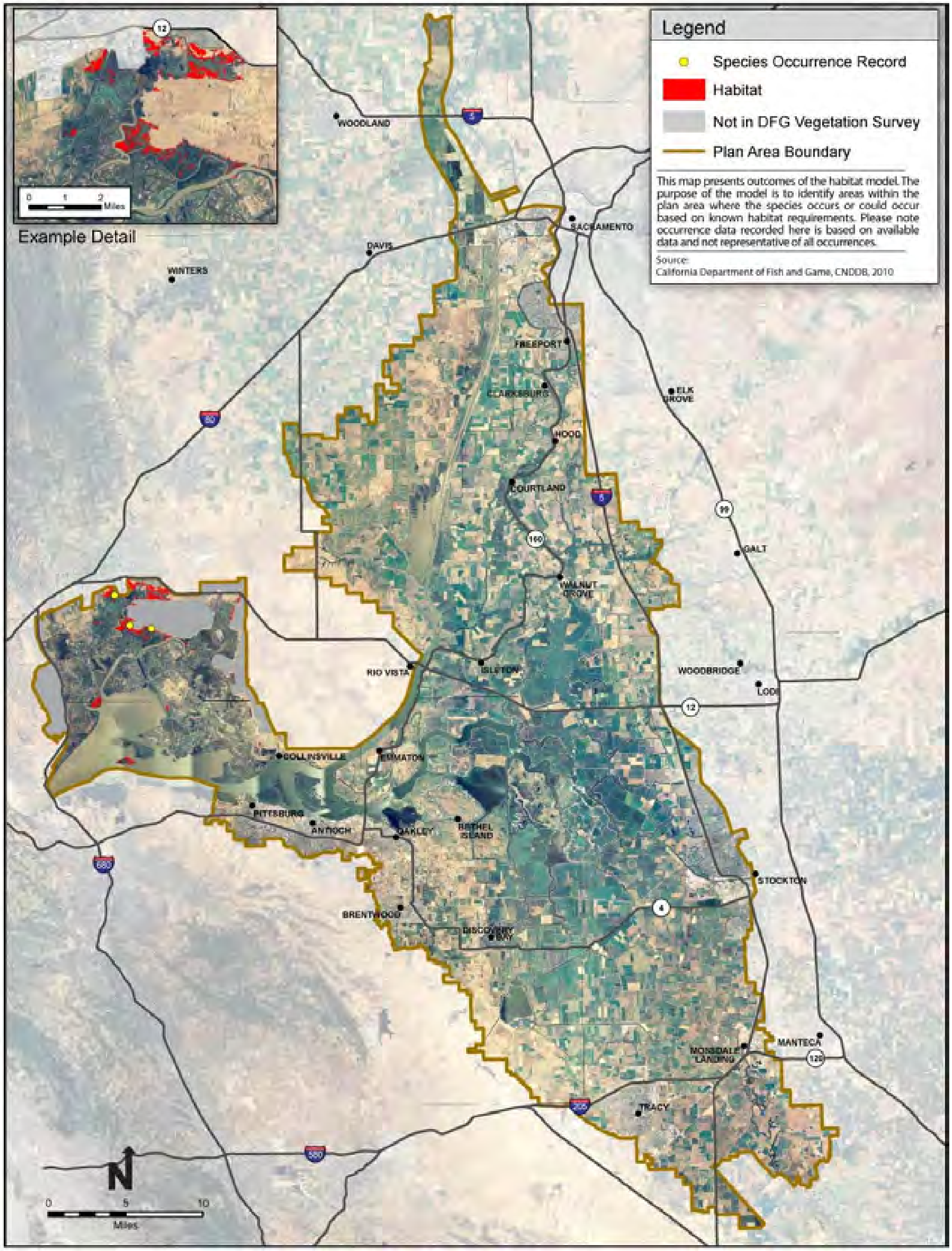

Figure A-48b. Suisun Thistle Habitat Model and Recorded Occurrences

1

Recent surveys have found Suisun thistle within relict undiked high tidal marshes at Rush Ranch, the Joice Island portion of the Grizzly Island Wildlife Area, and the Peytonia Slough Ecological Reserve (USFWS 2003, Fiedler et al. 2007). Thousands of plants were observed at Rush Ranch, much smaller numbers were observed at Grizzly Island Wildlife Area, and the population at the Peytonia Slough Ecological Reserve had declined to a single plant in 1996 (USFWS 2003, 2009).

A48.3 Habitat Requirements and Special Considerations

Suisun thistle is restricted to the brackish tidal marshes of Suisun Marsh (62 FR 61916, USFWS 2009) and is almost always found adjacent to first-order channels or mosquito control ditches that link to first-order channels (Fiedler et al. 2007, USFWS 2009). This habitat restriction is likely due to its low tolerance to soil salinity and possibly a preference for soils with less organic matter content. The Rush Ranch area of Suisun Marsh has been studied recently to determine how biological and physical factors interact in marshes around the Mean High Water (MHW) elevation (Culberson 2001, Culberson et al. 2004). A pattern emerged in this study such that the marsh could be analyzed spatially as channel (within 3.28 feet [1 meter] of a first-order channel), transitional (out to 82 feet [25 meters] from the channel), or marsh plain (beyond 82 feet [25 meters] from the channel). The study found that proximity to a channel, and not marsh elevation, was strongly correlated with the plant species composition and cover of the vegetation. The primary factor driving this correlation was found to be soil pore water salinity. The salinity of the water in the channel water and streamside soil pore water was generally 2-5 parts per thousand (ppt) with a non-linear increase with distance from the channel to approximately 15 ppt in the plain 131 feet (40 meters) from the channel. The study also found that below ground accumulation of organic carbon was the likely cause of the gradual increase in elevation (30 centimeters [cm]) from streamside to 230 feet (70 meters) out in the plain. Two other factors relevant to the ecology of Suisun thistle are the invasion of the streamside and transition zone by perennial pepperweed (*Lepidium latifolium*) which as of 2003 had invaded 85 percent of the Suisun thistle populations (Fiedler et al. 2007), and the extensive soil disturbance and plant damage caused by feral pigs (Culberson 2001, Fiedler et al. 2007, USFWS 2009).

A48.4 Life History

Suisun thistle is a large (3- to 4.5-feet [1- to 1.5-meter]) perennial herb of the sunflower family (Asteraceae) that blooms from June to September (62 FR 61916, CNPS 2009). It is found at sea level (< 3.28 feet [1 meter]) (Hickman 1993, Fiedler et al. 2007, USFWS 2009). Its stems are erect, slender, and branched above the middle (Hickman 1993, USFWS 2003). Suisun thistle leaves are spiny and deeply lobed; lower leaves have ear-like basal lobes, and upper leaves are reduced to narrow strips with strongly spine-toothed margins (62 FR 61916, USFWS 2003). The inflorescences are pale lavender-rose in color, about 1 inch (2.5-3 cm) in length, and grow singly or in loose groups (Hickman 1993, USFWS 2003). Flower head bracts have a distinct green, glutinous ridge on the back that distinguishes Suisun thistle from other *Cirsium* species in the area (62 FR 61916).

A48.5 Threats and Stressors

Historically, the marsh habitat suitable for Suisun thistle has been lost mostly through development, dredge disposal, agricultural conversion, and diking. Diked marshes generally lack rare tidal marsh species. It is believed that the conditions brought about by dikes favor robust generalist species that can better tolerate the long inundation periods in diked managed wetlands (Goals Project 2000).

Current threats to Suisun thistle include: the nonnative and highly invasive perennial pepperweed, feral pigs, and fire during sensitive periods of the species' lifecycle (Fiedler et al. 2007, USFWS 2009). Other potential but unquantified threats include hybridization with bull thistle (*Cirsium vulgare*) and seed predation by the introduced biocontrol thistle weevil (*Rhinocyllus conicus*) (Fiedler et al. 2007, USFWS 2009).

A48.6 Relevant Conservation Efforts

The California Department of Fish and Game provides some protection for Suisun thistle populations at Grizzly Island Wildlife Area and Peytonia Slough Ecological Reserve (CNPS 2009). The Suisun Marsh Habitat Management, Preservation and Restoration Plan is currently under development and should provide further conservation efforts for Suisun thistle.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for Suisun thistle is "Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP has established a goal to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

Suisun thistle is proposed for coverage under the Solano County Multispecies Habitat Conservation Plan.

A48.7 Species Habitat Suitability Model

Habitat. The modeled habitat for Suisun thistle in and near Suisun Marsh consists of all tidal brackish emergent wetland polygons with the appropriate vegetation (SFEI 2005, Boul and Keeler-Wolf 2008).

Vegetation Units. The following vegetation subunits were selected from the tidal brackish emergent wetland natural community:

- *Atriplex triangularis;*
- *Atriplex triangularis* (generic);
- *Atriplex*/annual grasses;
- *Atriplex*/*Distichlis;*
- *Distichlis* (generic);
- *Distichlis spicata;*
- *Distichlis spicata* - annual grasses;
- *Distichlis spicata - Salicornia virginica*[1]*;*
- *Distichlis-Juncus-Triglochin-Glaux;*
- *Distichlis*/annual grasses;
- *Distichlis*/*Cotula;*
- *Distichlis*/*Juncus;*
- *Distichlis*/*Lotus;*
- *Distichlis*/*S. americanus;*
- *Distichlis*/*S. maritimus;*
- *Distichlis*/*Salicornia*[2]*;*
- *Lepidium* (generic);
- *Lepidium*/*Distichlis;*
- Pickleweed (*Salicornia virginica*);
- *Salicornia* (generic);
- *Salicornia virginica;*
- *Salicornia virginica* - *Cotula coronopifolia;*
- *Salicornia virginica* - *Distichlis spicata;*
- *Salicornia*/annual grasses; and
- *Salicornia*/*Atriplex.*

Assumptions. Suisun thistle is endemic to Suisun Marsh and is found primarily away

[1] Currently known as *Sarcocornia pacifica.*
[2] Currently known as *Sarcocornia.*

from the main channels that are dominated by large emergent wetland species.

A48.8 Recovery Goals

A United States Fish and Wildlife Service (USFWS) approved Recovery Plan has not been prepared for this species but the recent 5-year species review (USFWS 2009) recommended that a recovery plan be prepared. However, this species is included in the Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California which specifies the preservation of individuals and habitat, the control of invasive species, and the restoration of tidal flows as recovery criteria goals (USFWS 2010). Additionally, the CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for Suisun thistle is "Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP has established a goal to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

A48.9 References

A48.9.1 Literature Cited

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A48.9.2 Federal Record Notices Cited

62 FR 61916. 1997. Final Rule: Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for Two Tidal Marsh Plants--*Cirsium hydrophilum* var. *hydrophilum* (Suisun Thistle) and *Cordylanthus mollis* ssp. *mollis* (Soft Bird's-Beak) From the San Francisco Bay Area of California. Federal Register 62: 61916.

72 FR 18517. 2007. Final Rule: Endangered and Threatened Wildlife and Plants; Designation of Critical habitat for *Cirsium hydrophilum* var. *hydrophilum* (Suisun thistle) and *Cordylanthus mollis* ssp. *mollis* (soft bird’s-beak). Federal Register 72: 18517.

APPENDIX A49. SOFT BIRD'S-BEAK (*CORDYLANTHUS MOLLIS* SSP. *MOLLIS*)

A49.1 LEGAL STATUS

Soft bird's-beak (*Cordylanthus mollis* ssp. *mollis*) is listed as endangered under the federal Endangered Species Act (November 1997) and listed as rare under the California Native Plant Protection Act (July 1979). Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G2T1/S1.1, which means that globally (G) this species has either between six to 20 viable element occurrences, 1,000 to 3,000 individuals, or 2,000 to 10,000 acres (809 to 4,047 hectares) of occupied habitat. In contrast, this particular subspecies has been ranked as threatened globally and within the state (S) as it has either less than six viable element occurrences, less than 1,000 individuals, or less than 2,000 acres (809 hectares) of occupied habitat. Its state threat level rank is "threatened."

The California Native Plant Society (CNPS) List ranking of 1B.2 for soft bird's-beak indicates that it is rare, threatened, or endangered in California and elsewhere, and is considered by CNPS to be fairly endangered in California with between 20 to 80 percent of occurrences threatened. Plants with a CNPS List rank of 1B are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

USFWS recently designated critical habitat that specifies the protection of soft bird's-beak populations in the four areas that contain the largest and most intact populations and habitat (72 FR 18517). Additionally, in its 5-year review of this species the United States Fish and Wildlife (USFWS) recommended the continuation of its endangered status and the development of a recovery plan (USFWS 2009).

A49.2 SPECIES DISTRIBUTION AND STATUS

A49.2.1 Range and Status

Historically, the range of soft bird's-beak extended from tidal marshes of Napa and Solano counties in the north, Contra Costa County in the south, Sonoma and Marin counties in the west, and Sacramento and San Joaquin counties in the east (Figure A-49a). It is now believed to be extirpated from Marin, San Joaquin, and Sonoma counties, and extant in Napa, Solano, Contra Costa, and Sacramento counties (CNDDB 2008). The largest extant occurrences are on California Department of Fish and Game (DFG) reserves and wildlife areas, a California Department of Parks and Recreation park, a county park, and a property held for conservation purposes by a land trust.

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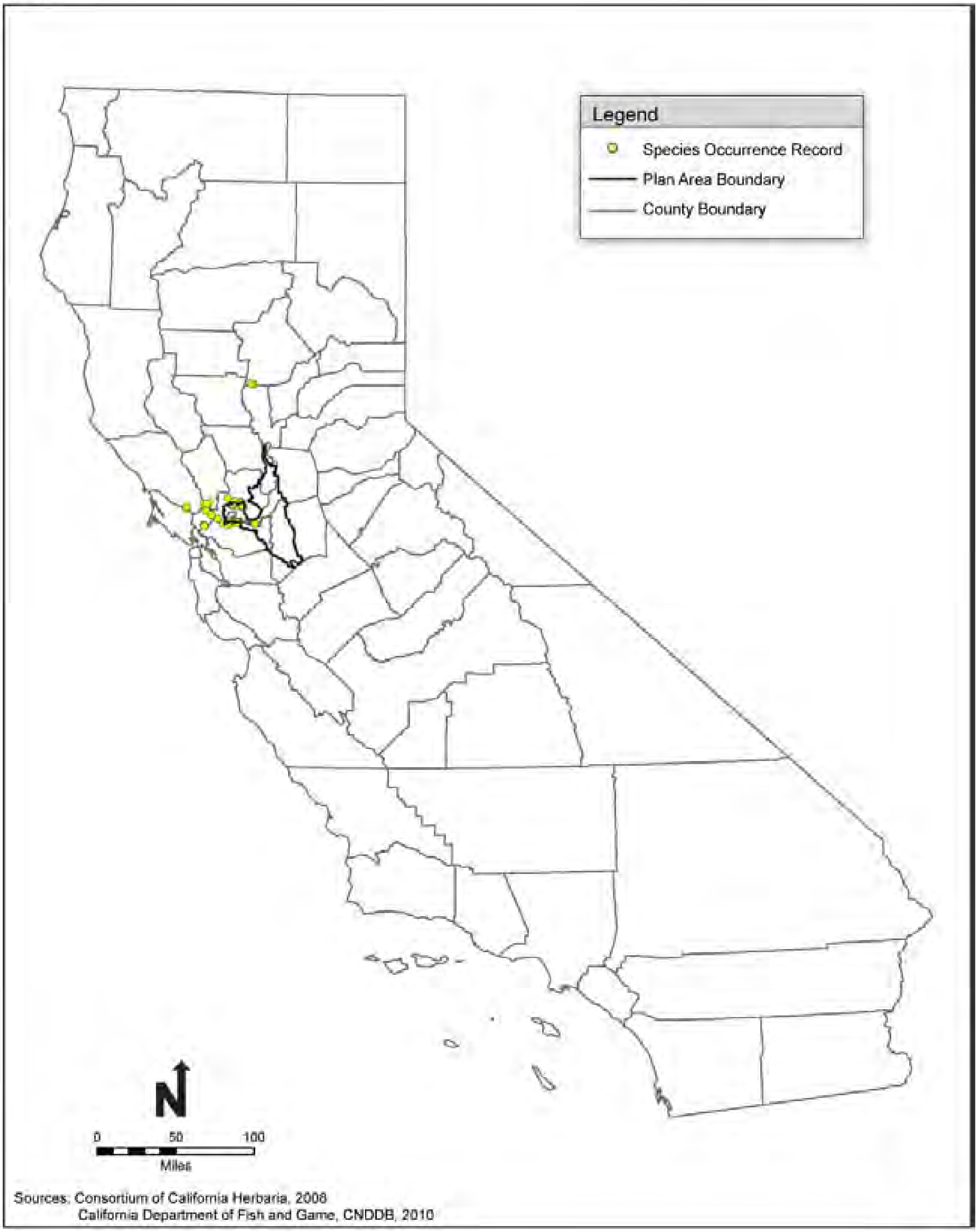

Figure A-49a. Soft Bird's-Beak Statewide Recorded Occurrences

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A49.2.2 Distribution and Status in the Plan Area

The majority of the occurrences in the Plan Area are in and around Suisun Marsh and Suisun Bay (USFWS 2009). A single occurrence has been reported in in Sacramento County along the north bank of the San Joaquin River immediately west of the Antioch Bridge (CNDDB 2008) (Figure A-49b). This occurrence was last observed in 1972 and may have been extirpated, but there are no additional data describing the site which aerial photographs now show to be a rip-rapped shoreline. No voucher specimen for this occurrence is on record at any California herbarium (Consortium of California Herbaria 2008).

A49.3 Habitat Requirements and Special Considerations

Soft bird's-beak grows at the lower margin of tidal brackish high marshes in the San Francisco Estuary (Baye et al. 2000, Grewell 2005, Grewell et al. 2007). Where the topography is relatively uniform, soft bird's-beak is distributed in bands at the lower margin of the brackish high marsh. In Suisun Marsh these bands are not correlated with elevation, but with soil pore water salinity during the dry season which is determined by distance to channel and varies from season to season depending on freshwater flows from creeks draining into the marsh (Culberson 2001). Where the topography is more complex, such as areas with ridges or mounds and on levee banks, soft bird's-beak can be found in a variety of patch shapes (Baye et al. 2000, Grewell 2005, Grewell et al. 2007). The distribution of these patches and the distribution of individual plants within the patches is controlled by a number of factors including the existence of a persistent seed bank, the dispersal and germination dynamics of its floating seed, the extent of bare soil where seedlings can establish, the presence of appropriate long-lived annual or perennial host species, and the absence of dense populations of large, perennial, nonnative plant species (Baye et al. 2000, Grewell et al. 2003, Grewell 2005, Grewell et al. 2007). The presence of a natural tidal inundation pattern is important and the more muted the tidal influence is, such as tidal creeks with salt water exclusion gates or marshes with extensive levee systems, the less valuable the habitat is for soft bird's-beak (Grewell et al. 2003, Grewell 2005, Grewell et al. 2007). A number of hypotheses have been suggested to explain the effects of the muted tidal influence including increased rates of seed predation and herbivory by native insects, high densities of inappropriate host species such as nonnative annual plants, and invasion and space preemption by large nonnative plant species such as perennial pepperweed (*Lepidium latifolium*) (Grewell 2005).

Dominant plant associates include pickleweed (*Sarcocornia pacifica*[1]), saltgrass (*Distichlis spicata*), salt marsh dodder (*Cuscuta salina*), and spearscale (*Atriplex triangularis*) (Baye et al. 2000, Grewell 2005, Grewell et al. 2007).

[1] Formerly known as *Salicornia virginica.*

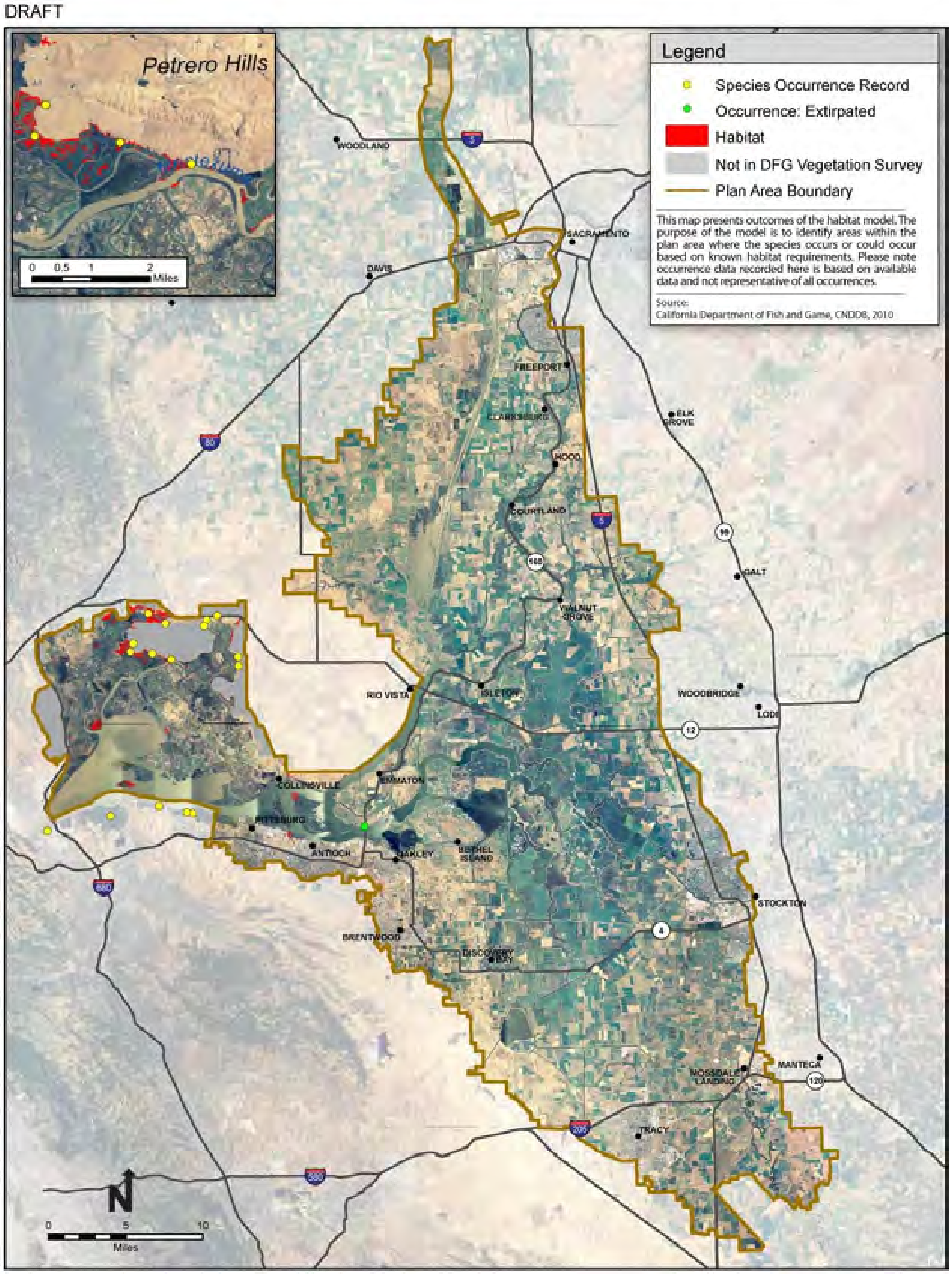

Figure A-49b. Soft Bird's-Beak Habitat Model and Recorded Occurrences

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Recent research in an analogous plant community has documented complex positive and negative ecological relationships between the related Point Reyes bird's-beak (*Cordylanthus maritimus* ssp. *palustris*), salt marsh dodder, and other species including pickleweed (Grewell 2008), but these findings have not been extended to soft bird's-beak.

A49.4 Life History

Soft bird's-beak is a 4- to 12-inch (10- to 30-centimeter) tall annual herb that parasitizes and draws nutrients from other plants through their roots systems (Hickman 1993, Grewell 2005). It may require pollinators such as bumblebees (*Bombus* spp.) or other insects to pollinate its flowers and produce viable seed but is apparently capable of producing seed without the movement of pollen by insects (Grewell et al. 2003, Grewell 2005). It appears to have a persistent seed bank and specific seed germination cues. Complex interactions between its seed germination characteristics, which respond to variable environmental factors, the lack or presence of bare soil for seedling establishment, and the presence or absence of appropriate host species can result in large annual changes in population sizes (Grewell 2005). Its seeds float and are dispersed by water, which is likely to aid its spread and reestablishment (Grewell 2005).

A49.5 Threats and Stressors

Threats to the species include the destruction of habitat, the elimination or muting of tidal regimes, overgrazing and trampling by livestock, rooting by feral pigs, invasion of habitat by nonnative annual plants that are inappropriate hosts, and invasion of its habitat by perennial pepperweed (Grewell et al. 2003, Grewell 2005, Fiedler et al 2007, CNDDB 2008, USFWS 2009).

A49.6 Relevant Conservation Efforts

Soft bird's-beak occurs on a number of government lands where is it protected from development, but sometimes impacted by lawful site use and management activities (Grewell 2005, 72 FR 18517, USFWS 2009). At the Rush Ranch site in Suisun Marsh, which is owned by the Solano Land Trust and protected by a conservation easement, marsh restoration was coupled with the reintroduction of soft bird's-beak through a high density seeding in 2000 (Grewell et al. 2003, Grewell 2005). It is unclear if this reintroduction has been successful as the 2004 census reported a substantial increase in the number of plants in the population but each plant was significantly smaller than a nearby natural population and the number of seeds produced by each plant had declined from 2000 per plant to near zero (Grewell 2005).

A United States Fish and Wildlife Service (USFWS) approved Recovery Plan has not been prepared for this species but the very recent 5-year species review (USFWS 2009) recommended that a recovery plan be prepared. However, this species is included in the Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California which specifies the preservation of individuals and habitat, the control of invasive species, and the restoration of tidal flows as recovery criteria goals (USFWS 2010). Additionally, the CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for soft bird's-beak is "Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP has established a goal to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

Soft bird's-beak is proposed for coverage under the Solano County Multispecies Habitat Conservation Plan.

A49.7 SPECIES HABITAT SUITABILITY MODEL

Habitat. The modeled habitat for soft bird's-beak consisted of pickleweed and saltgrass dominated vegetation located west of the Antioch Bridge. To isolate habitat in and near Suisun Marsh the model used all Tidal Brackish Emergent Wetland polygons from the San Francisco Estuary Institute (SFEI) (2005) that was limited by specific DFG vegetation units of Boul and Keeler-Wolf (2008) that are known to be closely associated with soft bird's-beak habitat.

Vegetation Units. The following vegetation subunits were selected from the BDCP vegetation dataset:

- *Atriplex triangularis;*
- *Atriplex triangularis* (generic);
- *Atriplex*/annual grasses;
- *Atriplex*/*Distichlis;*
- *Distichlis* (generic);
- *Distichlis spicata;*
- *Distichlis spicata* - Annual grasses;
- *Distichlis spicata - Salicornia virginica*[2]*;*
- *Distichlis-Juncus-Triglochin-Glaux;*
- *Distichlis*/annual grasses;
- *Distichlis*/*Cotula;*
- *Distichlis*/*Juncus;*
- *Distichlis*/*Lotus;*

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[2] Currently known as *Sarcocornia pacifica*.

- *Distichlis/S. americanus;*
- *Distichlis/S. maritimus;*
- *Distichlis/Salicornia*[3]*;*
- *Lepidium* (generic);
- *Lepidium/Distichlis;*
- Pickleweed (*Salicornia virginica*);
- *Salicornia* (generic);
- *Salicornia virginica;*
- *Salicornia virginica - Cotula coronopifolia;*
- *Salicornia virginica - Distichlis spicata;*
- *Salicornia*/annual grasses; and
- *Salicornia/Atriplex.*

Assumptions. Historical and current records of this species indicate that its distribution is limited to parts of the Plan Area and other conservation areas that are west of the Antioch Bridge (Figure A-49b) (CNDDB 2008). Soft bird's-beak grows at the lower margin of tidal brackish high marshes in the San Francisco Estuary (Baye et al. 2000, Grewell 2005, Grewell et al. 2007). Where the topography is relatively uniform, soft bird's-beak is generally distributed in bands in the Transition zone into the Marsh Plain zone. Where the topography is more complex, such as along tidal creeks, areas with some relief such as ridges or mounds, and on levees, soft bird's-beak can be found in a variety of patch shapes (Baye et al. 2000, Grewell 2005, Grewell et al. 2007). Dominant plant associates include pickleweed, saltgrass, salt marsh dodder (*Cuscuta salina*), and spearscale (Baye et al. 2000, Grewell 2005, Grewell et al. 2007).

A49.8 RECOVERY GOALS

Soft bird's-beak is federally listed as endangered, but a USFWS recovery plan has not yet been developed; however, the CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for soft bird's-beak is "Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP has established a goal to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

[3] Currently known as *Sarcocornia.*

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APPENDIX A50. DWARF DOWNINGIA (*DOWNINGIA PUSILLA*)

A50.1 LEGAL STATUS

Dwarf downingia (*Downingia pusilla*) is not listed under either the federal or California Endangered Species Act. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G3/S2.2 which means that globally (G) and within the state (S) there are either between 21 to 100 viable element occurrences of this species, 3,000 to 10,000 individuals of this species, or 10,000 to 50,000 acres (4,047 to 20,234 hectares) where this species occurs. Its state threat level rank is "threatened."

The California Native Plant Society (CNPS) List ranking of 2.2 for dwarf downingia indicates that it is rare, threatened, or endangered in California but more common elsewhere. Plants with a CNPS List rank of 2 are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

A50.2 SPECIES DISTRIBUTION AND STATUS

A50.2.1 Range and Status

In California, dwarf downingia's range extends from southern Tehama County to Fresno County and from Sonoma County to Placer County (Figure A-50a); and it is also found in Chile. It is found on alluvial terraces and floodplains in the Sacramento Valley, with its distribution at the south end of the Sacramento Valley bifurcated by the Delta (CNDDB 2010). It has been reported from the northeastern part of the San Joaquin Valley, but not near the border of the Plan Area and is also found on valley floors and margins in Sonoma and Napa counties (CNDDB 2010).

A50.2.2 Distribution and Status in the Plan Area

Dwarf downingia has been reported in the Plan Area from vernal pools, vernal swales, alkaline seasonal wetlands, tire ruts, and hydrologically altered sloughs in the greater Jepson Prairie area (Figure A-50b) (Witham 2006, Barbour et al. 2007, Lazar 2007, CNDDB 2010). During the spring 2009 California Department of Water Resources /Delta Habitat Conservation and Conveyance Program (DWR/DHCCP) field surveys conducted for the Bay Delta Conservation Plan (BDCP), dwarf downingia was found in vernal pools on the North Stone Lakes Unit of the Stone Lakes National Wildlife Refuge (NWR) area.

DRAFT

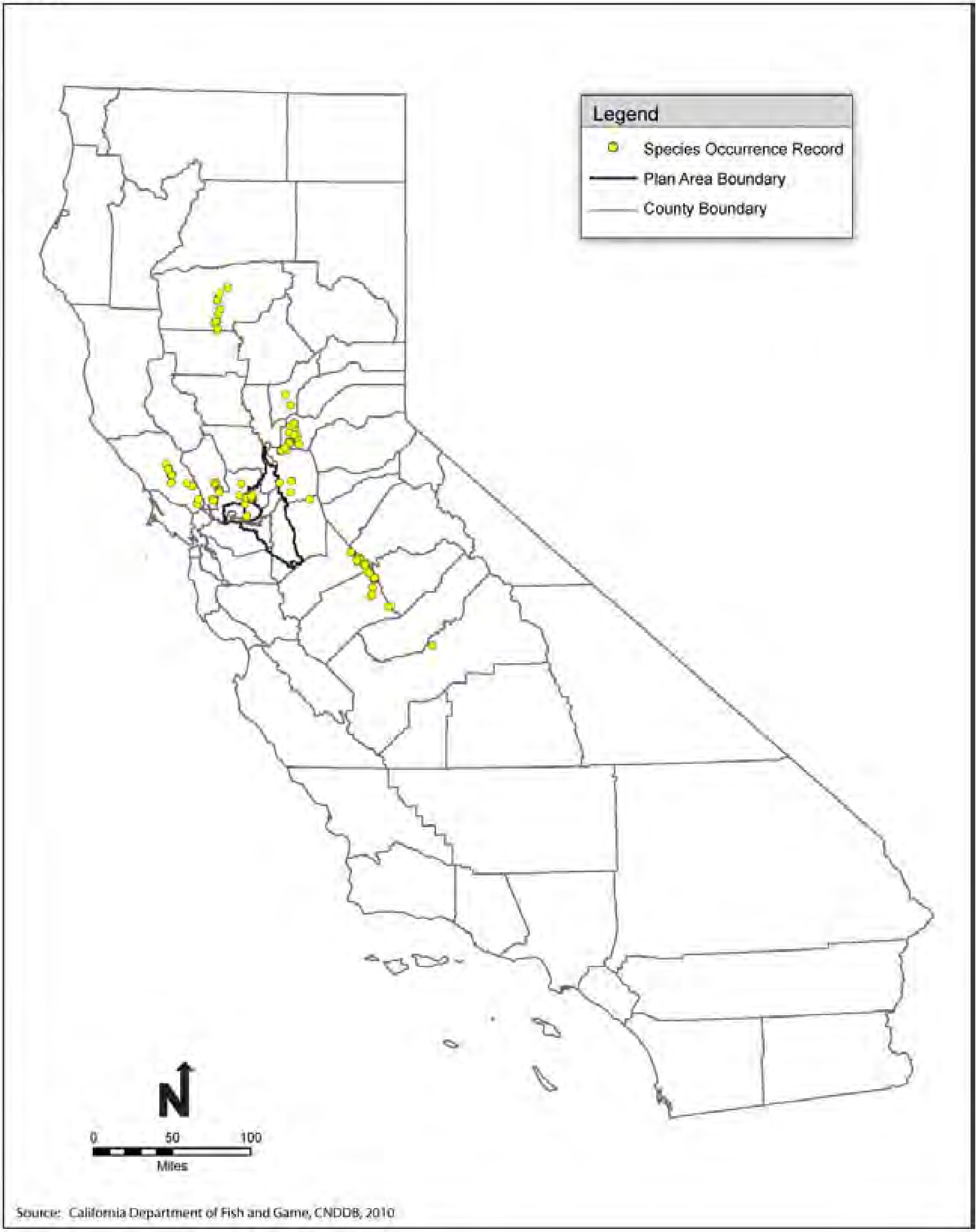

Figure A-50a. Dwarf Downingia Statewide Recorded Occurrences

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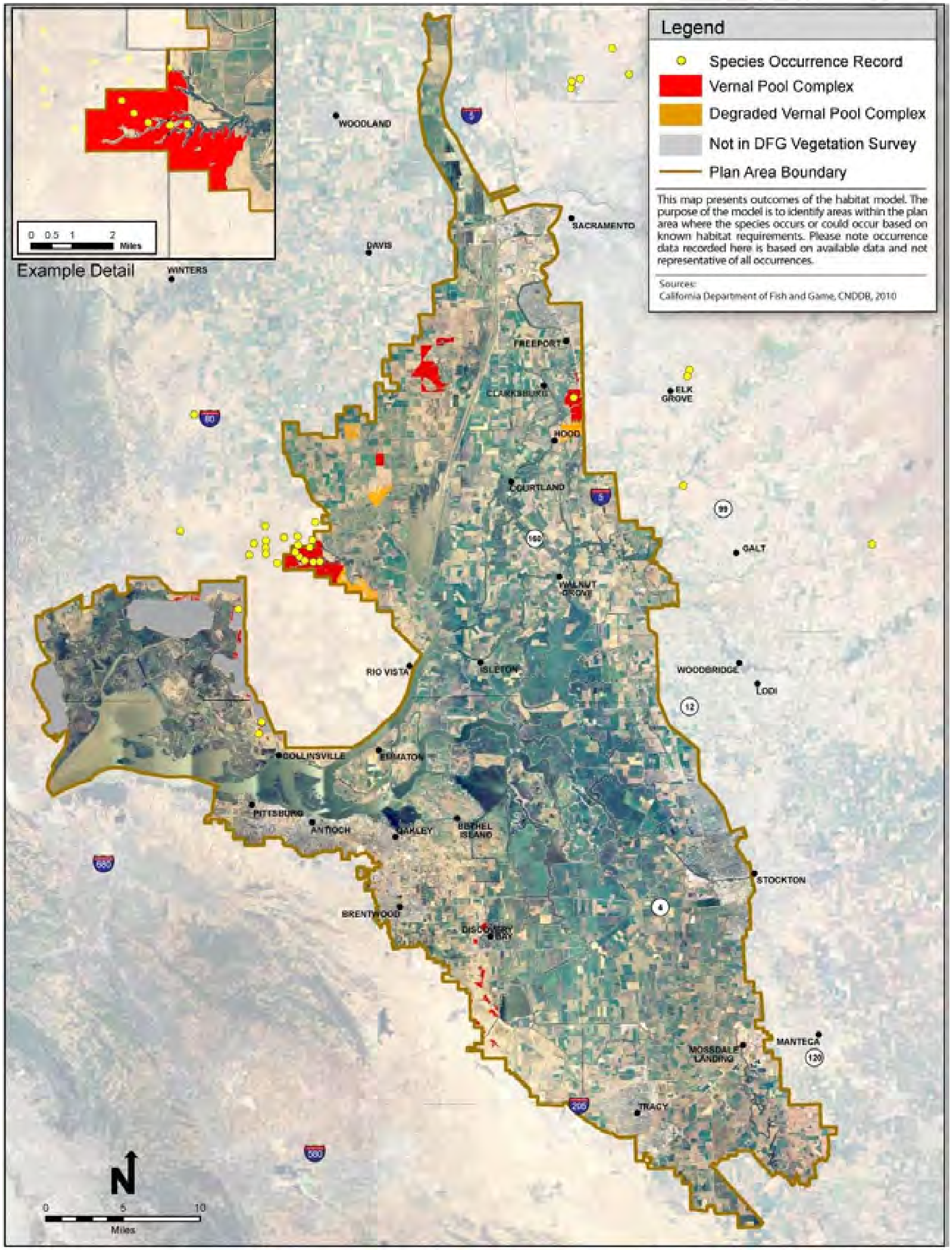

Figure A-50b. Dwarf Downingia Habitat Model and Recorded Occurrences

A50.3 Habitat Requirements and Special Considerations

Throughout its distribution, dwarf downingia occurs in vernal pools, vernal swales, pools in seasonal streambeds, vernal marshes, tire ruts, hydrologically altered sloughs, and irrigation ponds (CNDDB 2010). Some occurrence records state that it is found with long inundation indicator species such as pale spikerush (*Eleocharis macrostachya*), but on the clay soils of the greater Jepson Prairie area it is found in a range of microtopographic positions in vernal pools within grassland vegetation that typically has a high cover of the nonnative annual grass *Lolium multiflorum* (Witham 2006, Barbour et al. 2007, Lazar 2007). In the Stone Lakes areas, it is associated with vernal pools that form in the former headwaters of natural drainages propagating upslope from the Delta. When present in a vernal pool, its population persistence has been found to be relatively constant when compared to other rare vernal pool species (Buck 2004, Barbour et al. 2007).

A50.4 Life History

Dwarf downingia is a small submerged to emergent aquatic annual herbaceous plant during the wet season, when habitat is ponded, that becomes a small 4-12 inch (10-30 centimeter) terrestrial plant at the end of the wet season as the habitat dries. It has small, 0.02-0.25 inch (0.5-2 millimeters) wide, awl-like leaves and very small light blue flowers (Hickman 1993). Dwarf downingia seed dispersal is apparently aided by waterfowl, as it appeared spontaneously in vernal pools constructed as part of the Montezuma Wetlands Restoration Project (SFEI 2006). Nothing is known about its pollination biology, seed germination characteristics, or many other important biological and ecological characteristics.

A50.5 Threats and Stressors

Development, intensive agriculture, and exotic plant species (especially *Lolium multiflorum*) are considered to be the primary threats to alkaline vernal pools (Showers 1988, Showers 1996, Dawson et al. 2007) which are habitat for dwarf downingia. Additionally, waxy mannagrass (*Glyceria declinata*) may pose a threat to this species and many other vernal pool species (Gerlach et al. 2009).

A50.6 Relevant Conservation Efforts

The known occurrences in the Plan Area are protected from development or intensified agriculture under conservation easements or under ownership by a governmental agency (Witham 2006, Barbour et al. 2007, Lazar 2007, USFWS 2007, CNDDB 2010). Dwarf downingia is proposed for coverage under the Solano County Multi-species Habitat Conservation Plan and the South Sacramento County Habitat Conservation Plan.

A50.7 SPECIES HABITAT SUITABILITY MODEL

Model Approach. BDCP Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below and in Section 2.3.1, *Data Sources and Natural Community Classification*). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as vernal pools, individual trees, or small groups of trees. It is also possible, as with some vernal pool invertebrates that are restricted to seasonally ponded habitats, to underestimate potentially-occupied habitat due to the lack of information on small, degraded or artificially-created seasonal wetland habitats.

Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The dwarf downingia model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), DWR 2007 LiDAR elevation data, Google Earth 2009 aerial imagery and USDA 2005 aerial photography. Using these data sets, the model maps the distribution of suitable dwarf downingia habitat in the Plan Area according to the species' two habitat types, vernal pool complex and degraded vernal pool complex habitat. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Vernal Pool Complex Habitat: High quality permanent habitat that consists of vernal pools and uplands that display characteristic vernal pool and swale visual signatures that have not been significantly impacted by agricultural or development practices. Vernal pool complex habitat for dwarf downingia includes the following vegetation subunits that were selected from the BDCP vernal pool complex natural community:

- Vernal pool complex – All vegetation types

Degraded Vernal Pool Complex Habitat: Low quality ephemeral habitat that ranges from areas with vernal pool and swale visual signatures that display clear evidence of significant disturbance due to plowing, disking, or leveling to areas with clearly artificial basins such as shallow agricultural ditches, depressions in fallow fields, and areas of compacted soils in pastures. The aquatic features in this habitat are more clearly classified as temporary waters sensu lato (Williams 2006) than intact and fully functional vernal pools. Because these features are inundated during the wet season and may have historically been located in or near areas with natural vernal pool complex, they may support individuals or small populations of species that are found in vernal pools and swales. However, they do not possess the full complement of ecosystem and community characteristics of natural vernal pools, swales and their associated uplands and they are generally ephemeral features that are eliminated during the course of normal agricultural practices. Degraded vernal pool complex habitat for dwarf downingia includes the following vegetation subunits that were selected from the BDCP other natural seasonal wetlands and grasslands communities:

- Grasslands
    - Degraded vernal pool complex – California annual grasslands;
    - Degraded vernal pool complex – Ruderal herbaceous grasses and forbs;
    - Degraded vernal pool complex – Italian rye-grass (*Lolium multiflorum*); and
    - Degraded vernal pool complex – Rabbitsfoot grass (*Polygpogon maritimus*).
- Other natural seasonal wetlands
    - Degraded vernal pool complex-Vernal pools.

Potential habitat without concave surfaces (except for seeps along Suisun Marsh) was removed from the model. LiDAR elevation data was then visually inspected in four general areas to further assess specific locations that had been identified by the habitat selection process. These areas were selected based both on *a priori* knowledge of the region and because they were identified by the intersection of the selected vegetation types and soils. The analysis of the LiDAR data further refined the habitat model and provided a more accurate demarcation of suitable habitat. The GIS habitat model was then compared against field data from surveys conducted by DWR/DHCCP for the BDCP in 2009. Land uses that are incompatible with the species' habitat requirements, for example potential habitat polygons falling on leveled or developed lands, were removed from the model.

Assumptions. Historical and current records of this species in the Plan Area indicate that its current distribution is limited to alkaline soil areas with vernal pool and swale microtopography along the western border of the Plan Area (Figure A-50b) (Witham 2006, CNDDB 2010) and areas with swales and vernal pools along the eastern boundary of the Plan Area (CNDDB 2010). The vegetation cover is typically a combination of vernal pool adapted species and annual ryegrass (Witham 2006, CNDDB 2010).

A50.8 Recovery Goals

A USFWS recovery plan has not been prepared for this species and no recovery goals have been established.

A50.9 References

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APPENDIX A51. DELTA BUTTON-CELERY (*ERYNGIUM RACEMOSUM*)

A51.1 Legal Status

Delta button-celery (*Eryngium racemosum*) is listed as endangered under the California Endangered Species Act (August 1981). It is not listed under the federal Endangered Species Act. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G2Q/S2.1, which indicates that globally (G) and within the state (S) there are either between six to 20 viable element occurrences of this species, 1,000 to 3,000 individuals of this species, or 2,000 to 10,000 acres (809 to 4,047 hectares) where this species occurs. Its state threat level rank is "very threatened." The "Q" portion of the rank indicates that unresolved taxonomic questions remain for this rare species (NatureServe 2008).

The California Native Plant Society (CNPS) List ranking of 1B.1 for Delta button-celery indicates that it is rare, threatened, or endangered in California and elsewhere, and is considered by CNPS to be seriously endangered in California with more than 80 percent of occurrences threatened. Plants with a CNPS List rank of 1B are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

A51.2 Species Distribution and Status

A51.2.1 Range and Status

The range of Delta button-celery extends from San Joaquin County in the north, to Stanislaus and Merced counties in the south, to Contra Costa County in the west, and Calaveras County in the east (Figure A-51a).

Delta button-celery is endemic to the San Joaquin Valley, south of Brentwood, California (NatureServe 2008). All 26 reported occurrences are from Contra Costa, San Joaquin, Calaveras, Stanislaus, and Merced counties with the greatest number in Merced County. All reported localities are between 15 and 100 feet (4.6 and 30.5 meters) in elevation, except one location at 240 feet (73 meters) in Stanislaus County and one at 1,100 feet (335 meters) in Calaveras County. However, the herbarium voucher specimens for the two occurrences in the Sierra Nevada Foothills, Salt Spring Reservoir in Calaveras County and Turlock Lake in Stanislaus County have recently been examined and were determined to have been erroneously identified (R. Preston pers. comm.). Six of the recorded occurrences have been extirpated by agricultural expansion and disturbance (NatureServe 2008).

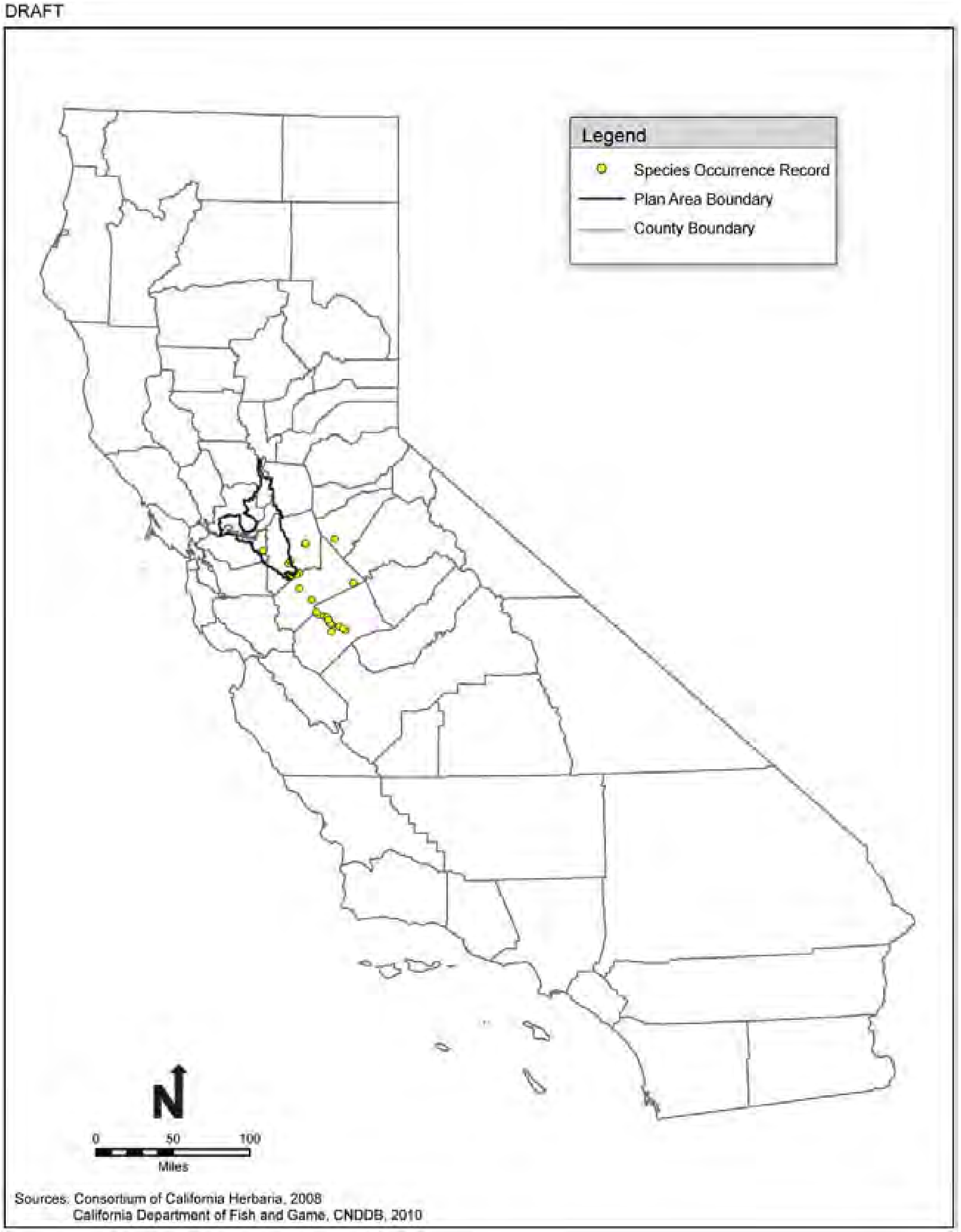

Figure A-51a. Delta Button-Celery Statewide Recorded Occurrences

Extant occurrences are on private land, and on land owned by California Department of Fish and Game (DFG), U.S. Fish and Wildlife Service (USFWS), and other public agencies. Occurrences on state and federally owned land are within designated wildlife areas and wildlife refuges.

A51.2.2 Distribution and Status in the Plan Area

Delta button-celery is known to occur in two locations in the Plan Area, one on the alluvial plain of Kellogg and Marsh creeks immediately west of Discovery Bay, and one along the San Joaquin River northeast of Tracy (Figure A-51b). The population near Discovery Bay was last observed in 1998 in a small area with about 1,500 individuals in alkali sink habitat with iodine bush (*Allenrolfea occidentalis*), alkali heath (*Frankenia salina*), and saltgrass (*Distichlis spicata*) (NatureServe 2008). The other occurrence in the Plan Area, located about 3 miles south of Lathrop, was first observed in 1984 and is believed to have been subsequently extirpated due to development of a walnut orchard.

Two occurrences have been recorded near the edge of the Plan Area. Both of these occurrences may have been extirpated. One was about 2.5 miles (4 kilometers) northeast of Vernalis, and the other was at the northeast end of Caswell Memorial State Park. Both sites were last visited in 1985, and the habitat was deemed unsuitable at that time.

A51.3 Habitat Requirements and Special Considerations

Based on its current and historical distributions, Delta button-celery occurs in two habitat types. One habitat type is seasonally scoured and inundated swales, depressions, and clay flats in the floodplain of the San Joaquin River (D. Woolington pers. comm.). The specific location of occurrences may shift depending on the disturbance and flooding regime. As a disturbance follower, there is no strong fidelity to a particular soil or vegetation type, but occurrences are primarily reported on alkaline clays deposited within bands of coarser textured soils and willow scrub vegetation. The associated species in this habitat type are characteristic of frequently disturbed riparian bottom lands and include turkey tangle fogfruit (*Phyla nodiflora*), spike rush (*Eleocharis* spp.), American bird’s foot trefoil (*Lotus purshianus*), Goodding’s black willow (*Salix gooddingii*), and common sunflower (*Helianthus annuus*).

The other habitat type is alkaline clay deltas of Coast Range tributaries that are deposited immediately above the flood basin of the San Joaquin River where plant cover is typical alkaline sink vegetation. The associated species in the alkaline sink vegetation include saltgrass, alkali heath, and iodine bush (NatureServe 2008).

A51.4 Life History

Delta button-celery is a prostrate biennial to short-lived perennial herb that germinates following flooding in areas adjacent to rivers and streams in the San Joaquin Valley (Hickman 1993). The sprawling stems are generally 4 to 20 inches (10 to 50 centimeters) in length (Hickman 1993). It is unique as it is California’s only native *Eryngium* species that produces roots and juvenile leaves at its stem nodes, and its spiny flower heads are arranged in an elongated raceme instead of a compact cyme (Hickman 1993).

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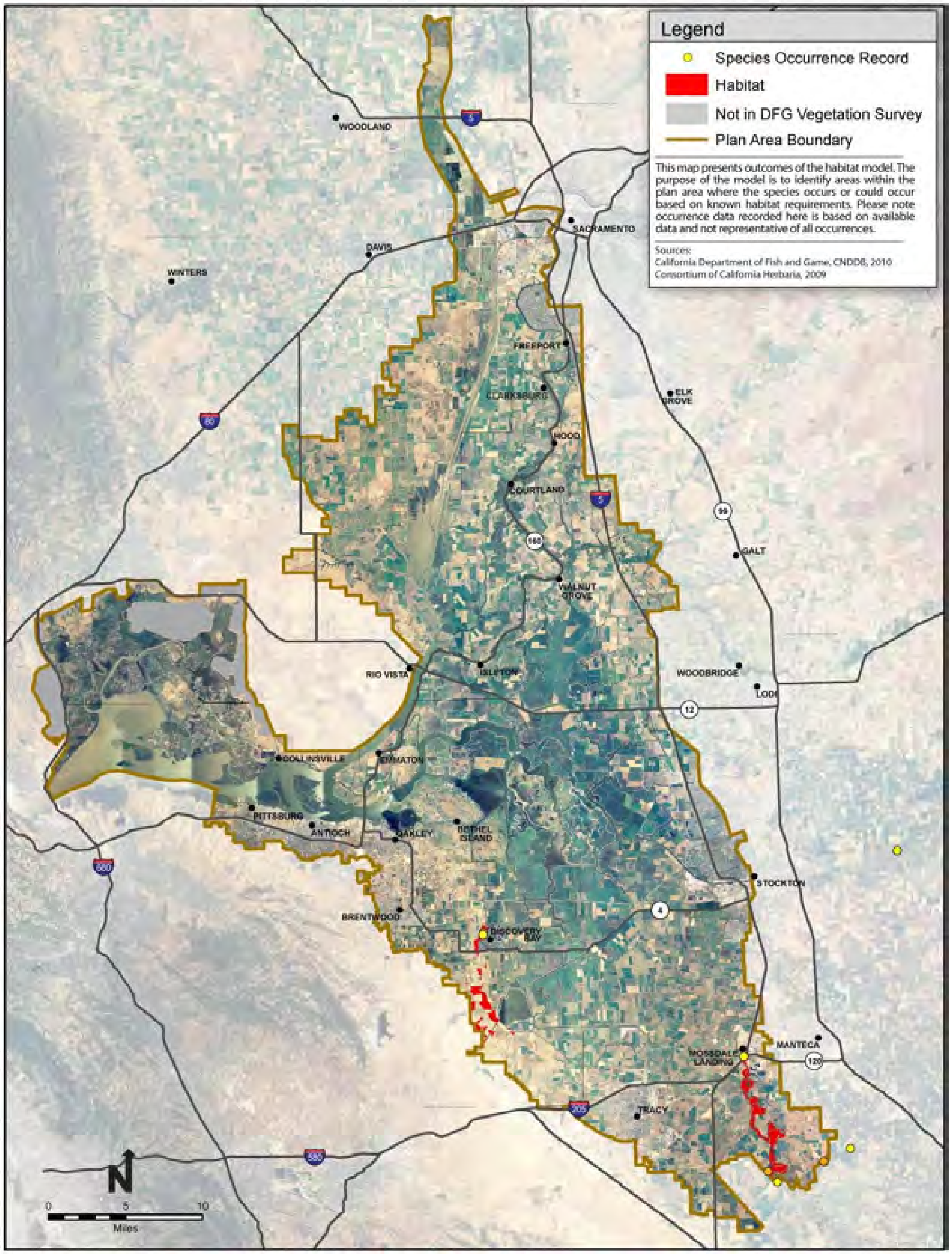

Figure A-51b. Delta Button-Celery Habitat Model and Recorded Occurrences

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California's *Eryngium* species can be difficult to differentiate based on morphological characteristics because individuals with characteristics that are intermediate between different species are common (Hickman 1993). It flowers from June to September (CNPS 2008).

A51.5 Threats and Stressors

Threats to the species include agricultural habitat conversion, channelization and channel maintenance activities, overgrazing, dredging, and invasion of habitat by nonnative plant species (DFG 2008, NatureServe 2008). Some occurrences have been eliminated by flood control activities and conversion of lowlands to agriculture including all of the occurrences in San Joaquin County and most in Stanislaus County (DFG 2008). Many occurrences along the San Joaquin River in Merced County are threatened due to reduced flooding because of controlled releases from Friant Dam and the construction of an extensive levee system (DFG 2008).

Agriculture. A substantial portion of the suitable habitat for the Delta button-celery is also prime agricultural land. Much of the suitable habitat for this species has been developed in various forms of agriculture, thus removing this species and severely altering that habitat. The known occurrences that have been extirpated have been converted to agriculture (NatureServe 2008).

Channel Maintenance Activities. Past channel maintenance has resulted in changes to the nature of the habitat and severe disturbance of adjacent areas (NatureServe 2008). More importantly, channel maintenance lessens the degree and frequency of flooding, reducing suitable habitat for this species.

Overgrazing. Overgrazing may adversely affect this species, but grazing may benefit the species by keeping the habitat open between floods and by controlling competing species such as Baltic rush (*Juncus balticus*). In addition, heavy grazing at one site did not appear to prevent occurrence of this species (DFG 1986). Additionally, the saltgrass covered bottom lands of the San Joaquin River basin have been heavily grazed by large cattle ranching operation since the 1820s.

Dredging. Dredging of waterways may reduce the extent of floodplain inundation, which appears to be necessary for seed germination, growth, and the maintenance of habitat openings that Delta button-celery may require (NatureServe 2008).

Invasion by Nonnative Plant Species. Nonnative invasive plant species compete with the Delta button-celery for habitat. Since the San Joaquin River floodplain habitat is subject to periodic natural disturbance (scouring), the habitat is ideal for many native and nonnative ruderal species as well. Some of these species include common sunflower (*Helianthus annus*) and cockle bur (*Xanthium* spp.), which may shade out Delta button-celery (NatureServe 2008) as has been noted at two protected sites in San Luis National Wildlife Refuge and Merced National Wildlife Refuge (NatureServe 2008).

A51.6 Relevant Conservation Efforts

The Delta button-celery occurs or formerly occurs at several publicly-owned properties including Caswell State Park, Merced National Wildlife Refuge, San Luis National Wildlife Refuge Complex, and the North Grasslands Wildlife Area. It is also a covered species in the San Joaquin County Multi-species Habitat Conservation and Open Space Plan.

A51.7 Species Habitat Suitability Model

Habitat. Delta button-celery habitat was identified as all areas between the levees from the Mossdale Bridge to Vernalis and as alkali seasonal wetland complex, vernal pool complex and Grassland on Brentwood (Bc), Grangerville (166), Marcuse (Mb), Solano (Sh, Sk), and Vernalis (269) soils within the San Joaquin Basin (i.e., south of the mainstem San Joaquin River). Vegetation types designated as species habitat in this model correspond to the mapped vegetation associations in the Bay Delta Conservation Plan (BDCP) geographic information system (GIS) vegetation data layer. For this species, a misclassification of land cover in the source data occurred north and south of the Discovery Bay area where intensive agriculture was classified as annual grassland, and those parcels were deleted from the area of predicted habitat. Additionally, other areas of potential habitat that have been developed were also deleted.

Assumptions. Historical and current records of this species indicate that its distribution is limited to the San Joaquin River Basin where it occurs in two discrete habitat types (Figure A-51b). In the floodplain of the San Joaquin River, it occurs on seasonally scoured and inundated swales, depressions, and clay flats (D. Woolington pers. comm.). The specific locations of the occurrences may shift depending on the disturbance and flooding regime. As a disturbance follower, there is no strong fidelity to a particular soil or vegetation type, but occurrences are primarily reported on alkaline clays deposited within bands of coarser textured soils and willow scrub vegetation. The other habitat type is alkaline clay deltas of Coast Range tributaries that are deposited immediately above the flood basin of the San Joaquin River where plant cover is typical alkaline sink vegetation or various types of grassland (CNDDB 2008, NatureServe 2008).

A51.8 Recovery Goals

A USFWS recovery plan has not been prepared for this species and no recovery goals have been established.

A51.9 References

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A51.9.2 Personal Communications

Preston, R. (Jepson Herbarium Volunteer and Jepson Manual 2nd ed. treatment of the Genus *Eryngium*). Email correspondence with John Gerlach on September 11, 2008.

Woolington, D. (USFWS Supervisory Wildlife Biologist, San Luis National Wildlife Refuge Complex). Email correspondence with Tamara Klug on September 18, 2008.

APPENDIX A52. CONTRA COSTA WALLFLOWER (*ERYSIMUM CAPITATUM* VAR. *ANGUSTATUM*)

A52.1 LEGAL STATUS

Contra Costa wallflower (*Erysimum capitatum* var. *angustatum*) is listed as endangered under both the Federal Endangered Species Act (April 1978) (43 FR 17910) and the California Endangered Species Act. It is endemic to a former dune near the city of Antioch, California. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G5T1/S1.1 which means that globally (G) the species is demonstrably secure to ineradicable due to being commonly found in the world, but the subspecies or variety (T) is has less than 6 viable element occurrences, less than 1,000 individuals, or less than 2,000 acres (809 hectares); and within the state (S) the threat level rank is “very threatened.”

The California Native Plant Society (CNPS) List ranking of 1B.1 for Contra Costa wallflower indicates that it is rare, threatened, or endangered in California (List 1B); the threat ranking (.1) indicates that it is considered by CNPS to be seriously threatened in California (high degree/immediacy of threat). Plants with a CNPS List rank of 1B are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

United States Fish and Wildlife Service (USFWS)-designated critical habitat that specifies the protection of Contra Costa wallflower habitat lies on and adjacent to the USFWS Antioch Dunes National Wildlife Refuge (43 FR 39042). This critical habitat was specifically established for this and two other endangered species. The designated critical habitat is entirely within the Plan Area.

A52.2 SPECIES DISTRIBUTION AND STATUS

A52.2.1 Range and Status

Contra Costa wallflower has an extremely restricted range. It is found only on a 20-acre (8-hectare) remnant of a former 190-acre (77-hectare) dune (plus an unknown amount of two Pacific Gas & Electric [PG&E] parcels that total 12 acres [5 hectares]) near the city of Antioch, California (USFWS 1984, 2001, 2008, 2010) (Figure A-52a). It is protected on the Antioch Dunes National Wildlife Refuge (NWR) and also occurs on two small adjacent parcels owned by PG&E, which manages the property in cooperation with USFWS. The second edition of the *Jepson Manual* treats this taxon as synonymous with the widespread variety *E. capitatum* var. *capitatum* which hybridizes with *E. ammophilum, E. franciscanum,* and *E. suffrutescens* (Rosatti ed. 2010).

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Figure A-52a. Contra Costa Wallflower Statewide Recorded Occurrences

A52.2.2 Distribution and Status in the Plan Area

The entire distribution of Contra Costa wallflower is within the Plan Area on the Antioch Dunes NWR and PG&E properties as described above (Figure A-52b).

A52.3 HABITAT REQUIREMENTS AND SPECIAL CONSIDERATIONS

Contra Costa wallflower is restricted to the remnant of former dune near the city of Antioch, California (USFWS 1984, 2001, 2008, 2010). This soil of the dune has been mapped as Oakley sand (Carpenter and Cosby 1939) and Delhi sand, 2 to 9 percent slopes (NRCS 2010) and is an infertile, very uniform textured, fine sand with very little clay content. While experiments at Antioch Dunes NWR found that Contra Costa wallflower will not grow and reproduce on soils with a relatively high clay content (Pavlik and Manning 1993), it does well and even becomes weedy, on gravelly or organic garden soils at the Tilden Regional Park Botanic Gardens in Berkeley, California (USFWS 1984). However, in its native habitat it appears to be restricted to sloping areas or banks with loose sand (USFWS 1984).

A52.4 LIFE HISTORY

Contra Costa wallflower is an erect, coarse-stemmed, biennial or short-lived perennial herb in the mustard family (Brassicaceae) (USFWS 1984, Hickman 1993, Rosatti ed. 2010, USFWS 2010). Plants are subshrubs that grow from a somewhat woody caudex (trunk-like base), which typically elongates into multiple branched stems 8 to 32 inches (20 to 81 centimeters [cm]) tall in mature plants. Lower leaves are lance-like to linear and tapering at the base, up to 6 inches (15 cm) long and about 0.5 inch (1.3 cm) wide, with minute teeth. It produces yellow four-petalled flowers, which bloom from March to July of the second year, laterally on unbranched stems at the top of the plant. The petals have claws (slender stalks) and are about 0.5 to 1 inch (1.3 to 2.5 cm) long. The slender pod-like fruit (silique) is dry when ripe and can be up to 4 inches (10 cm) long.

A52.5 THREATS AND STRESSORS

Invasive plants are one of the primary threats to Contra Costa wallflower because they cause habitat loss and may compete for soil moisture (USFWS 2008, 2010). The most common invasive nonnative grasses and forbs found at the refuge include ripgut brome (*Bromus diandrus*), winter vetch (*Vicia villosa*), and yellow star thistle (*Centaurea solstitialis*). Wildfires started by trespassers on the Antioch Dunes NWR are another serious threat.

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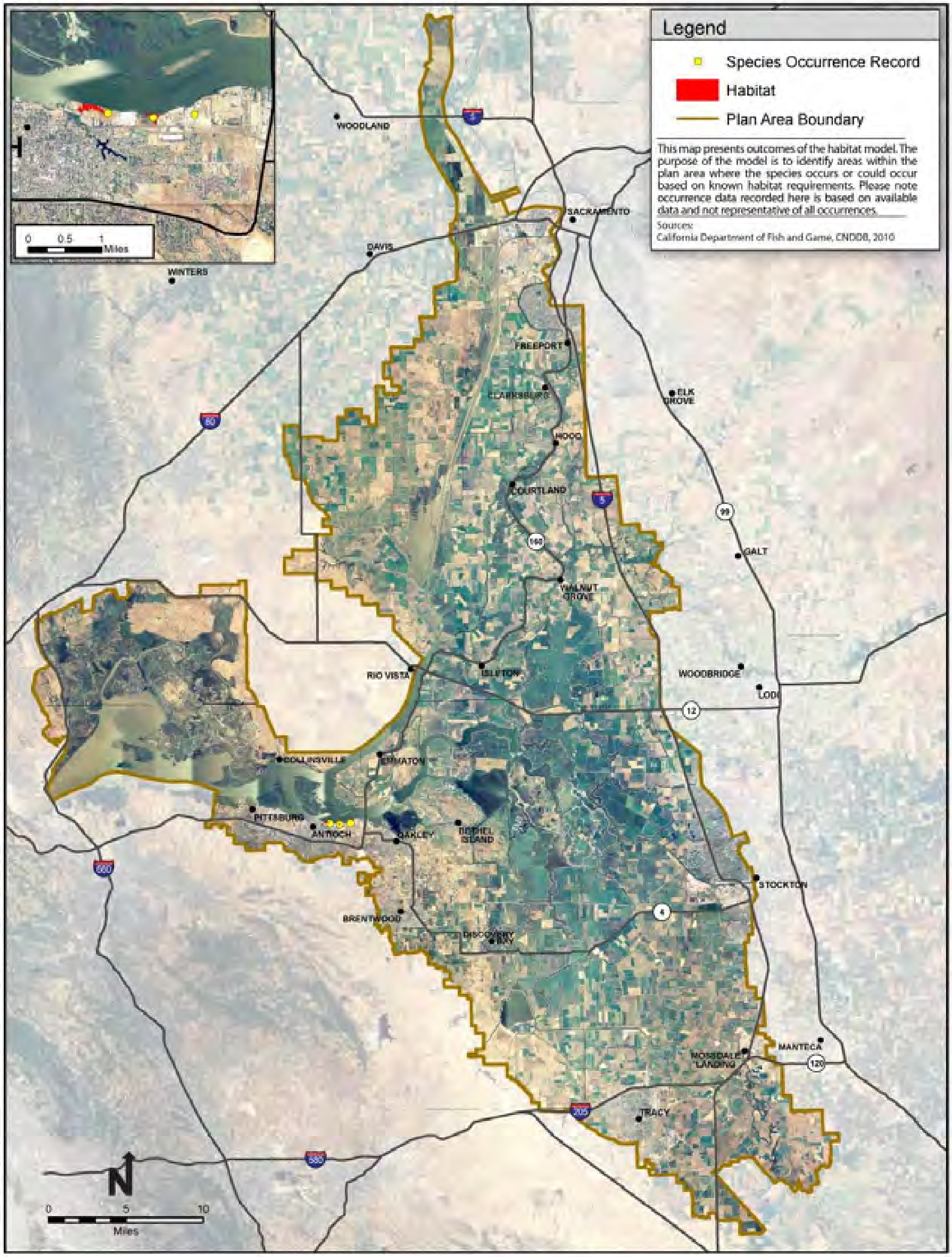

Figure A-52b. Contra Costa Wallflower Habitat Model and Recorded Occurrences

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A52.6 RELEVANT CONSERVATION EFFORTS

Contra Costa wallflower was declining significantly at Antioch Dunes NWR until an out-planting of nursery grown stock and direct seeding into restored sandy habitat in 2005 and 2006 appears to have stopped the decline. However, the population is not yet considered to be self-sustaining because of invasive species problems (USFWS 2008). The current management plan for the Antioch Dunes NWR provides for invasive nonnative plant species control efforts which are being implemented by hand pulling individual invasive plants through the efforts of volunteers, and targeted herbicide application (USFWS 2001, 2008). Controlled burns have been discontinued as a management tool (L.Terrazas *In Litteris*).

A52.7 SPECIES HABITAT SUITABILITY MODEL

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nevertheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lower probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf 2007. Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers, connectivity between habitat types, and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life history requirements. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The Contra Costa wallflower habitat suitability model is based on the California Department of Fish and Game (DFG) mapping of Delta vegetation (Hickson and Keeler-Wolf 2007).

Habitat. The modeled habitat for Contra Costa wallflower consists of two shrub dominated vegetation associations from the Antioch Dunes NWR (Hickson and Keeler-Wolf 2007).

Vegetation Units. The following vegetation subunits were selected from the DFG vegetation units (Hickson and Keeler-Wolf 2007):

- *Lupinus albifrons* Antioch Dunes Association
- *Lotus scoparius* Antioch Dunes Association

A52.8 Recovery Goals

A USFWS revised recovery plan for Contra Costa wallflower was approved in 1984 but the very recent 5-year species review (USFWS 2008) found that there are no recovery criteria listed in the Recovery Plan. The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for Contra Costa wallflower is "Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP has established a goal to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

A52.9 References

A52.9.1 Literature Cited

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A52.9.2 Federal Record Notices Cited

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43 FR 39042. 1978. Determination of Critical Habitat for Two California Plants. Federal Register. 43: 39042-39044.

APPENDIX A53. BOGGS LAKE HEDGE-HYSSOP (*GRATIOLA HETEROSEPALA*)

A53.1 LEGAL STATUS

Boggs Lake hedge-hyssop (*Gratiola heterosepala*) is listed as endangered under the California Endangered Species Act (November 1978). It is not listed under the federal Endangered Species Act. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G3/S3.1 which means that globally (G) and within the state (S) there are either between 21 to 80 viable element occurrences of this species, 3,000 to 10,000 individuals of this species, or 10,000 to 50,000 acres (4,047 to 20,234 hectares) where this species occurs; and the state threat level rank is "very threatened" (CNDDB Special Vascular Plants, Bryophytes, and Lichens List).

The California Native Plant Society (CNPS) List ranking of 1B.2 for Boggs Lake hedge-hyssop indicates that it is rare, threatened, or endangered in California and elsewhere, and is considered by CNPS to be fairly endangered in California with between 20 to 80 percent of occurrences threatened. Plants with a CNPS List rank of 1B are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

A53.2 SPECIES DISTRIBUTION AND STATUS

A53.2.1 Range and Status

Boggs Lake hedge-hyssop occurs in northeastern California on the Modoc Plateau in Siskiyou, Modoc, Lassen, Shasta, and Tehama counties and then southwards in the Central Valley to Fresno County. There are also records from Bogg's Lake in Lake County (Figure A-53a) (CNDDB 2009, CNPS 2009). It is widely distributed throughout the range of vernal pool habitat (Barbour et al. 2007); and there is one occurrence found in Oregon, where it is state listed as "threatened" (CNPS 2009). Population sizes range from small numbers to thousands of plants (CNDDB 2009, CNPS 2009).

A53.2.2 Distribution and Status in the Plan Area

Within the Plan Area, several populations have been reported to occur sporadically on and in the vicinity of Jepson Prairie Preserve and the Gridley Preserve (Witham 2006, Barbour et al. 2007, CNDDB 2009) (Figure A-53b). There are no reported occurrences in the southwestern portion of the Plan Area, but that area is within the species' range and suitable claypan vernal pool habitat occurs there.

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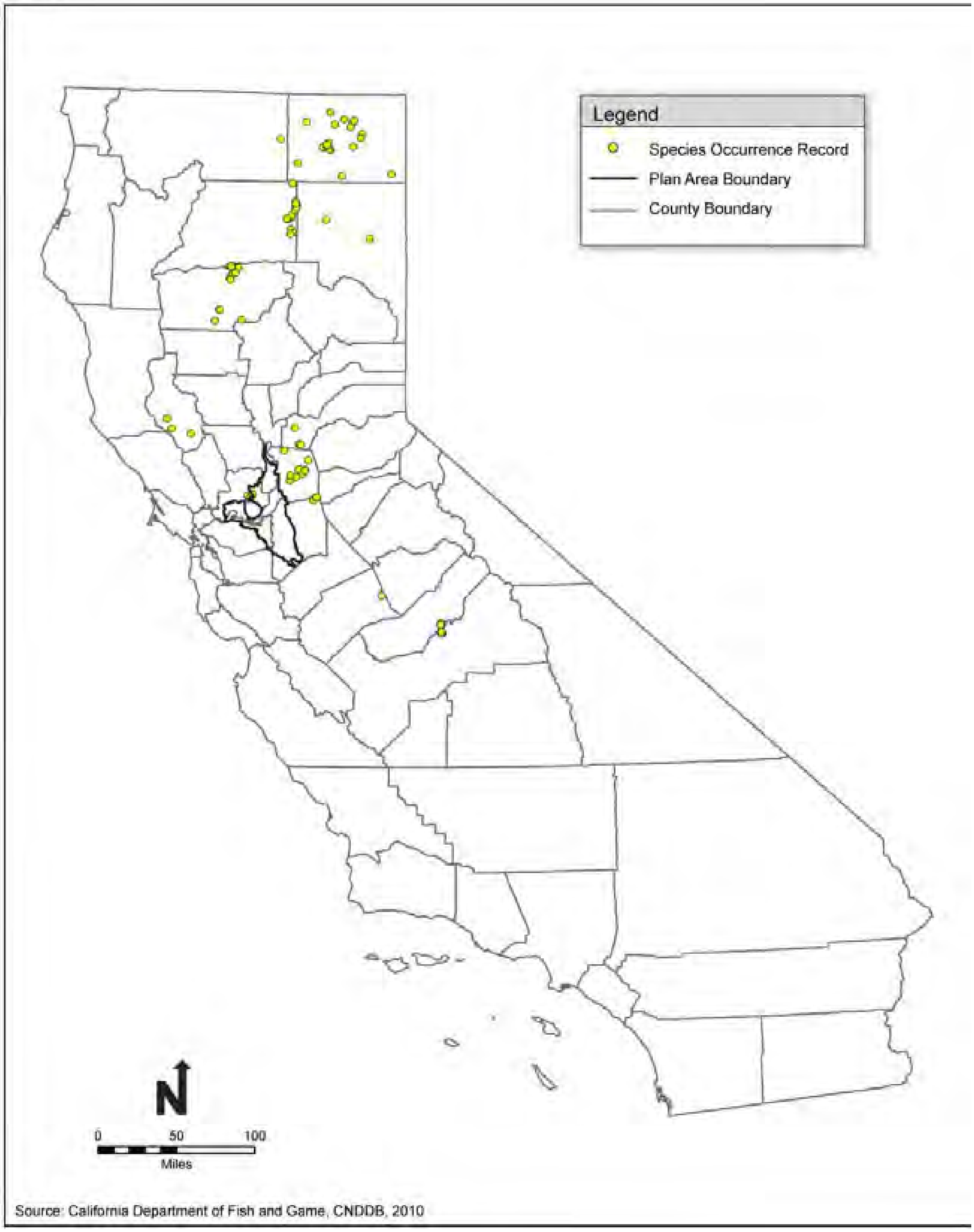

Figure A-53a. Boggs Lake Hedge-Hyssop Statewide Recorded Occurrences

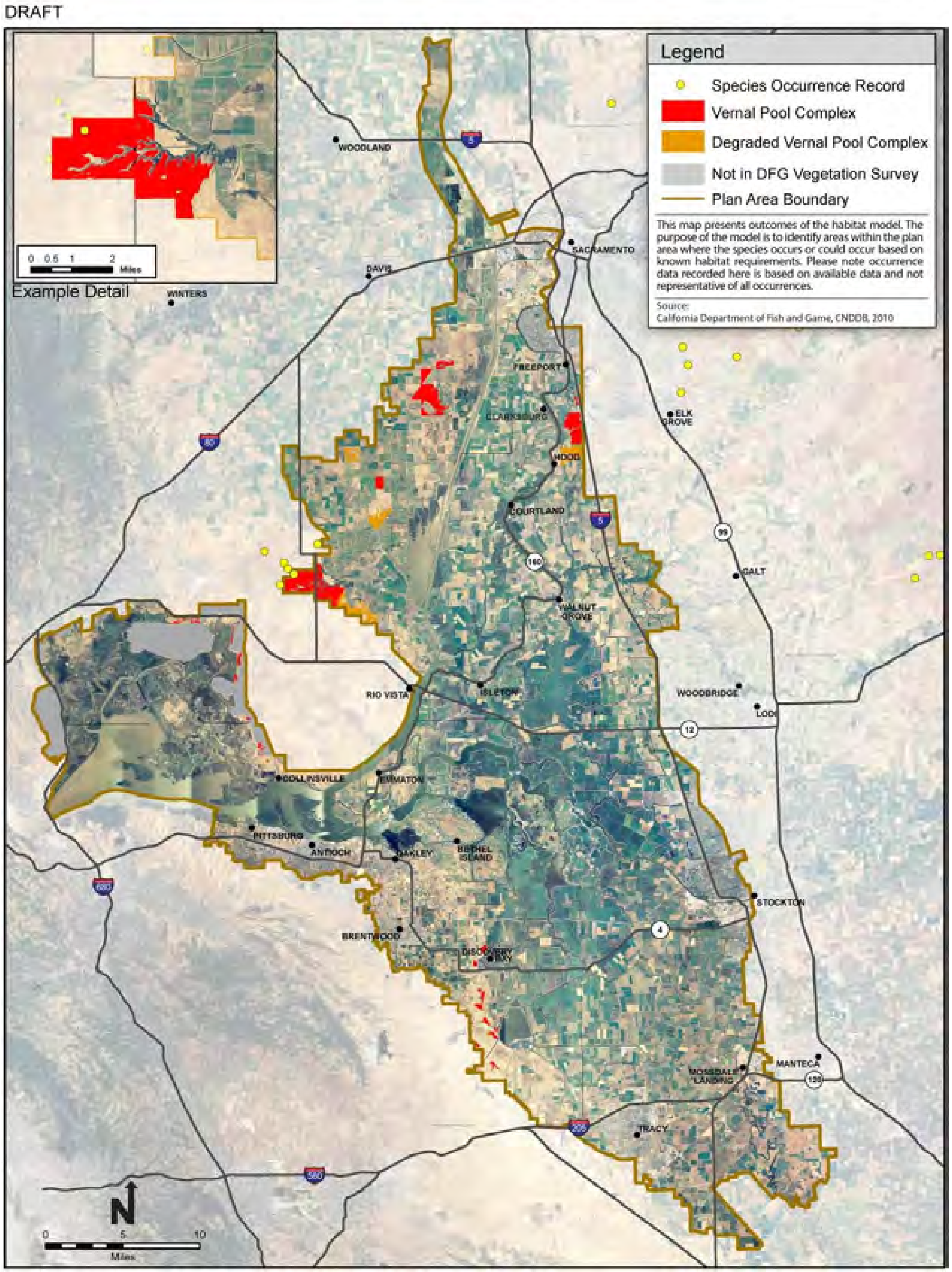

Figure A-53b. Boggs Lake Hedge-Hyssop Habitat Model and Recorded Occurrences

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A53.3 HABITAT REQUIREMENTS AND SPECIAL CONSIDERATIONS

Boggs Lake hedge-hyssop has been reported from a variety of habitats including the edges of marshes and natural lakes, stock ponds, swales, and vernal pools (Witham 2006, Barbour et al. 2007, CNDDB 2009). It has been observed in several types of vernal pools including basalt flow, hardpan, claypan, and alkaline playa pools. In the Plan Area, the species commonly associated with Boggs Lake hedge-hyssop include toothed downingia (*Downingia cuspitata*), dwarf downingia (*Downingia pusilla*), Fremont's goldfields (*Lasthenia fremontii*), and white-headed navarretia (*Navarretia leucocephala* ssp. *bakeri*) (Barbour et al. 2007, CNDDB 2009).

Grazing has been reported as both a positive and negative factor for this species (CNDDB 2009). A general finding of recent grazing research in the Jepson Prairie area is that the timing and intensity of grazing are important for maintaining native plant diversity and cover in the vernal pools and that seasonal changes in precipitation generally have a larger effect than grazing intensity but less of an effect that the cessation of grazing (Swiecki and Bernhardt 2008). This study found that light and/or sporadic grazing during the period of time when the vernal pools are inundated is the best management option and that the positive effect was largely due to impacts on nonnative annual ryegrass (*Lolium multiflorum*) growing around the margins of the inundated vernal pools. In the 2007 season, the pattern of precipitation was such that the vernal pools were not inundated during the grazing season and grazing had a significant negative effect on native plant species.

A53.4 LIFE HISTORY

Boggs Lake hedge-hyssop is a very small (less than 10-centimeter [cm] [less than 4-inch]), semi-aquatic annual herb of the snapdragon family (Scrophulariaceae) that blooms from April to August (Hickman 1993, CNPS 2009). The lower portions of the brownish-red fleshy stems are glabrous, and the upper portions are glandular-sticky with puberulent hairs (Hickman 1993). Leaves are small less than 2 cm less than 0.8 inch]) and rounded at the tips. The predominantly yellow corolla has five lobes: two are yellow and fused; three are white and separate (Hickman 1993). A related species that is much more common – bractless hedge-hyssop (*Gratiola ebracteata*) – can be distinguished from Boggs Lake hedge-hyssop by its more elongate and pointed sepals and mostly white flowers. Boggs Lake hedge-hyssop seeds can lie dormant in the soil for years, and the number of vegetative plants in a population can vary greatly from year to year (USFWS 2005).

A53.5 THREATS AND STRESSORS

Vernal pool loss through development, damage by intensive grazing, trampling, off-road vehicles, and invasive nonnative species are generally cited as threats (CNDDB 2009, CNPS 2009). As noted above, grazing can have both positive and negative effects on this species.

A53.6 Relevant Conservation Efforts

Boggs Lake hedge-hyssop is protected on a number of government, non-governmental organization, and mitigation bank sites throughout California (USFWS 2005). In the Plan Area, it is generally protected on Solano Land Trust properties in the Jepson Prairie area (Witham 2006). It is a covered species under the Natomas Basin Habitat Conservation Plan and the San Joaquin County Multi-species Habitat Conservation and Open Space Plan; and it is proposed for coverage under the Solano County Multispecies Habitat Conservation Plan and the South Sacramento Habitat Conservation Plan.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for the Boggs Lake hedge-hyssop is "Maintain" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions to maintain the species by avoiding, minimizing, and compensating for any adverse effects to the species created by ERP restoration actions. To the extent practicable, the ERP will improve species habitat conditions.

A53.7 Species Habitat Suitability Model

Model Approach. The Bay Delta Conservation Plan (BDCP) Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below and in Section 2.3.1, *Data Sources and Natural Community Classification*). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as vernal pools, individual trees, or small groups of trees. It is also possible, as with some vernal pool invertebrates that are restricted to seasonally ponded habitats, to underestimate potentially-occupied habitat due to the lack of information on small, degraded or artificially-created seasonal wetland habitats.

Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The Boggs Lake hedge-hyssop model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), DWR 2007 LiDAR elevation data, Google Earth 2009 aerial imagery and USDA 2005 aerial photography. Using these data sets, the model maps the distribution of suitable Boggs Lake hedge-hyssop habitat in the Plan Area according to the species' two habitat types, vernal pool complex and degraded vernal pool complex habitat. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Vernal Pool Complex Habitat: High quality permanent habitat that consists of vernal pools and uplands that display characteristic vernal pool and swale visual signatures that have not been significantly impacted by agricultural or development practices. Vernal pool complex habitat for Boggs Lake hedge-hyssop includes the following vegetation subunits that were selected from the BDCP vernal pool complex natural community:

- Vernal pool complex – All vegetation types

Degraded Vernal Pool Complex Habitat: Low quality ephemeral habitat that ranges from areas with vernal pool and swale visual signatures that display clear evidence of significant disturbance due to plowing, disking, or leveling to areas with clearly artificial basins such as shallow agricultural ditches, depressions in fallow fields, and areas of compacted soils in pastures. The aquatic features in this habitat are more clearly classified as temporary waters sensu lato (Williams 2006) than intact and fully functional vernal pools. Because these features are inundated during the wet season and may have historically been located in or near areas with natural vernal pool complex, they may support individuals or small populations of species that are found in vernal pools and swales. However, they do not possess the full complement of ecosystem and community characteristics of natural vernal pools, swales and their associated uplands and they are generally ephemeral features that are eliminated during the course of normal agricultural practices. Degraded vernal pool complex habitat for Boggs Lake hedge-hyssop includes the following vegetation subunits that were selected from the BDCP other natural seasonal wetlands and grasslands communities:

- Grasslands
  - Degraded vernal pool complex – California annual grasslands;
  - Degraded vernal pool complex – Ruderal herbaceous grasses and forbs;
  - Degraded vernal pool complex – Italian rye-grass (*Lolium multiflorum*); and
  - Degraded vernal pool complex – Rabbitsfoot grass (*Polygpogon maritimus*).
- Other natural seasonal wetlands
  - Degraded vernal pool complex-Vernal pools.

Potential habitat without concave surfaces (except for seeps along Suisun Marsh) was removed from the model. LiDAR elevation data was then visually inspected in four general areas to further assess specific locations that had been identified by the habitat selection process. These areas were selected based both on *a priori* knowledge of the region and because they were identified by the intersection of the selected vegetation types and soils. The analysis of the LiDAR data further refined the habitat model and provided a more accurate demarcation of suitable habitat. The GIS habitat model was then compared against field data from surveys conducted by the California Department of Water Resources/Delta Habitat Conservation and Conveyance Program (DWR/DHCCP) for the Bay Delta Conservation Plan (BDCP) in 2009. Land uses that are incompatible with the species' habitat requirements, for example potential habitat polygons falling on leveled or developed lands, were removed from the model.

Assumptions. Historical and current records of this species in the Plan Area indicate that its current distribution is limited to alkaline soil areas with vernal pool and swale microtopography along the northwestern border of the Plan Area (Figure A-53b) (Witham 2006, CNDDB 2010). The vegetation cover of the alkaline soils is typically a combination of vernal pool adapted species and annual ryegrass (Witham 2006, CNDDB 2010). Similar habitat exists in the central-western and southwestern portions of the Plan Area, and its habitat was extended into those alkaline soil areas as well. Also, because this species occurs in similar habitats with Heckard's peppergrass which was recently discovered in the Stone Lakes area by DWR/DHCCP field survey teams, the habitat range of Boggs Lake hedge-hyssop was extended into areas with vernal pool and swale microtopography along the eastern border of the Plan Area. The vegetation cover of the alkaline soils is typically a combination of vernal pool adapted species and annual ryegrass (Witham 2002, 2003, 2006, CNDDB 2010).

A53.8 Recovery Goals

Although Boggs Lake hedge-hyssop is not a federally listed taxon, it is included in the Draft Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (USFWS 2005). The Recovery Plan explicitly states that its goal is to ensure the long-term conservation of this species and 32 other taxa by using an ecosystem level strategy that is based on: current knowledge of the existing conditions of vernal pool communities, the distribution and status of the populations of each of the species, and current and anticipated process that impact vernal pool ecosystems. Because the goal of the Recovery Plan is primarily directed at habitat preservation, its implementation program specifically addresses factors that relate to habitat acquisition and management: (1) habitat protection, (2) adaptive habitat management and monitoring, (3) status surveys, (4) research, and (5) public participation.

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APPENDIX A54. CARQUINEZ GOLDENBUSH (*ISOCOMA ARGUTA*)

A54.1 Legal Status

Carquinez Goldenbush (*Isocoma arguta*) is not listed under either federal or California endangered species acts. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G1/S1.1 which means that globally (G) and within the state (S) there are less than six viable element occurrences, less than 1,000 individuals, or less than 2,000 acres (809 hectares) of occupied habitat; and the state threat level rank is "very threatened."

The California Native Plant Society (CNPS) List ranking of 1B.1 for Carquinez goldenbush indicates that it is rare, threatened, or endangered. It is endemic to California and is considered by CNPS to be seriously endangered with more than 80 percent of occurrences threatened. Plants with a CNPS List rank of 1B are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

A54.2 Species Distribution and Status

A54.2.1 Range and Status

Carquinez goldenbush is known only from a very limited geographic range in Solano County, California (Nesom 1991, Hickman 1993, CNDDB 2009, CNPS 2009) (Figure A-54a). All of the 13 reported occurrences are on the Montezuma Block geological formation or its western fault line with small populations of plants restricted to ephemeral drainages, within a very narrow elevation band between uplands and Suisun Marsh, or adjacent to a large alkaline playa (Band 1998, Graymer et al. 2002, DWR 2007, CNDDB 2009). Based on the reported occurrences, it appears to be restricted to alluvial soils associated with the Tehama geological formation and the Montezuma Block north and west of the Montezuma Hills in Solano County (Hickman 1993, Graymer et al. 2002, CNPS 2009, NRCS 2009).

A54.2.2 Distribution and Status in the Plan Area

The 13 reported occurrences are scattered in a small populations that are within the potential Impacts Area and in adjacent area immediately outside of the Planning and Impacts Areas. It occurs near Bird's Landing, Denverton, the Montezuma Hills, the Hay Road Landfill, Jepson Prairie, and historically in the Vanden area. Aerial imagery shows that the Vanden occurrence has likely been extirpated by development. Each occurrence generally consists of a few plants and by far the largest number of plants was reported in 1992 from near Bird's Landing and consisted of 760 plants. Two populations in the Jepson Prairie area had 35 and 85 plants in the late 1990's (CNDDB 2009). Nine reported occurrences of Carquinez goldenbush are potentially within the Plan Area (Figure A-54b).

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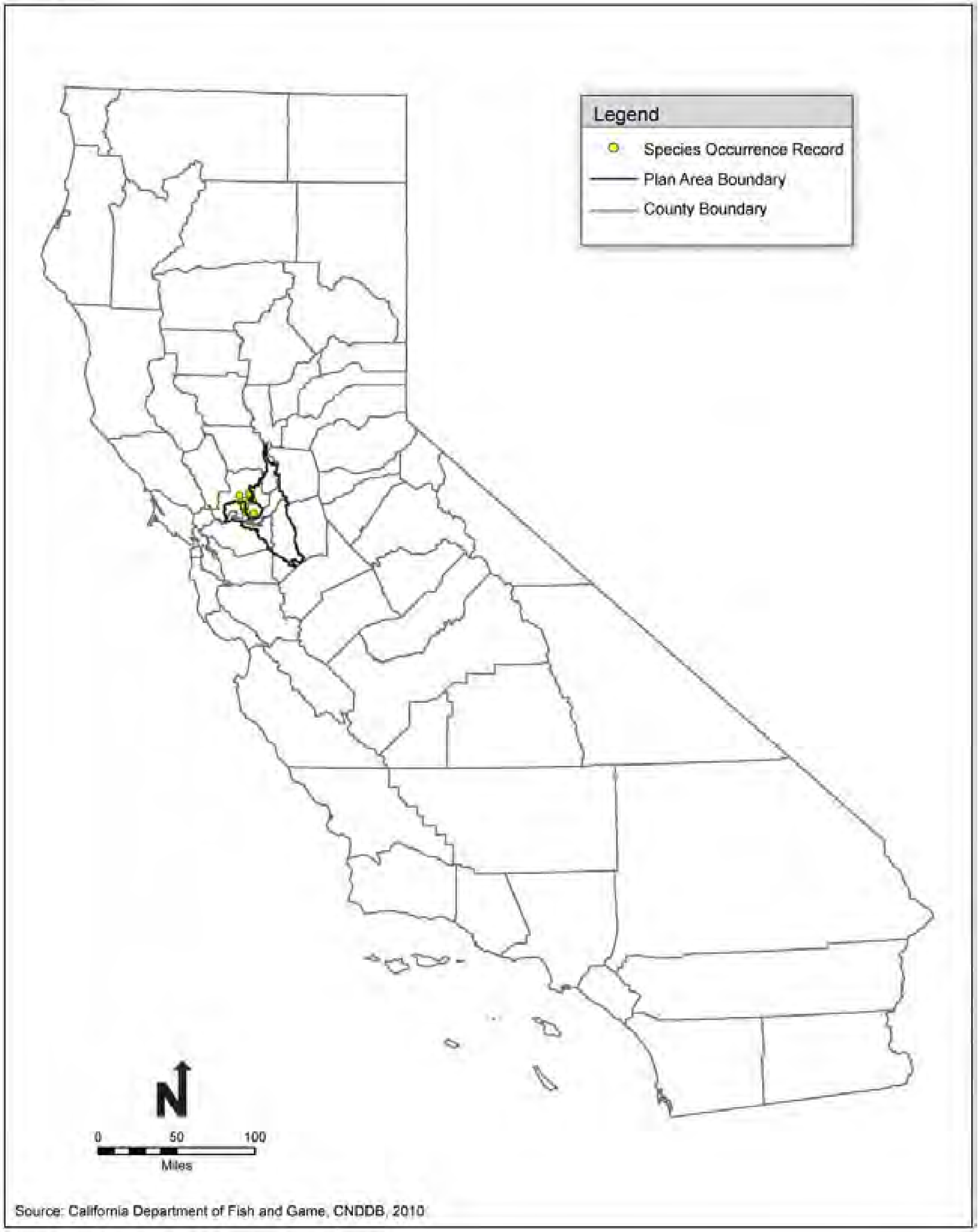

Figure A-54a. Carquinez Goldenbush Statewide Recorded Occurrences

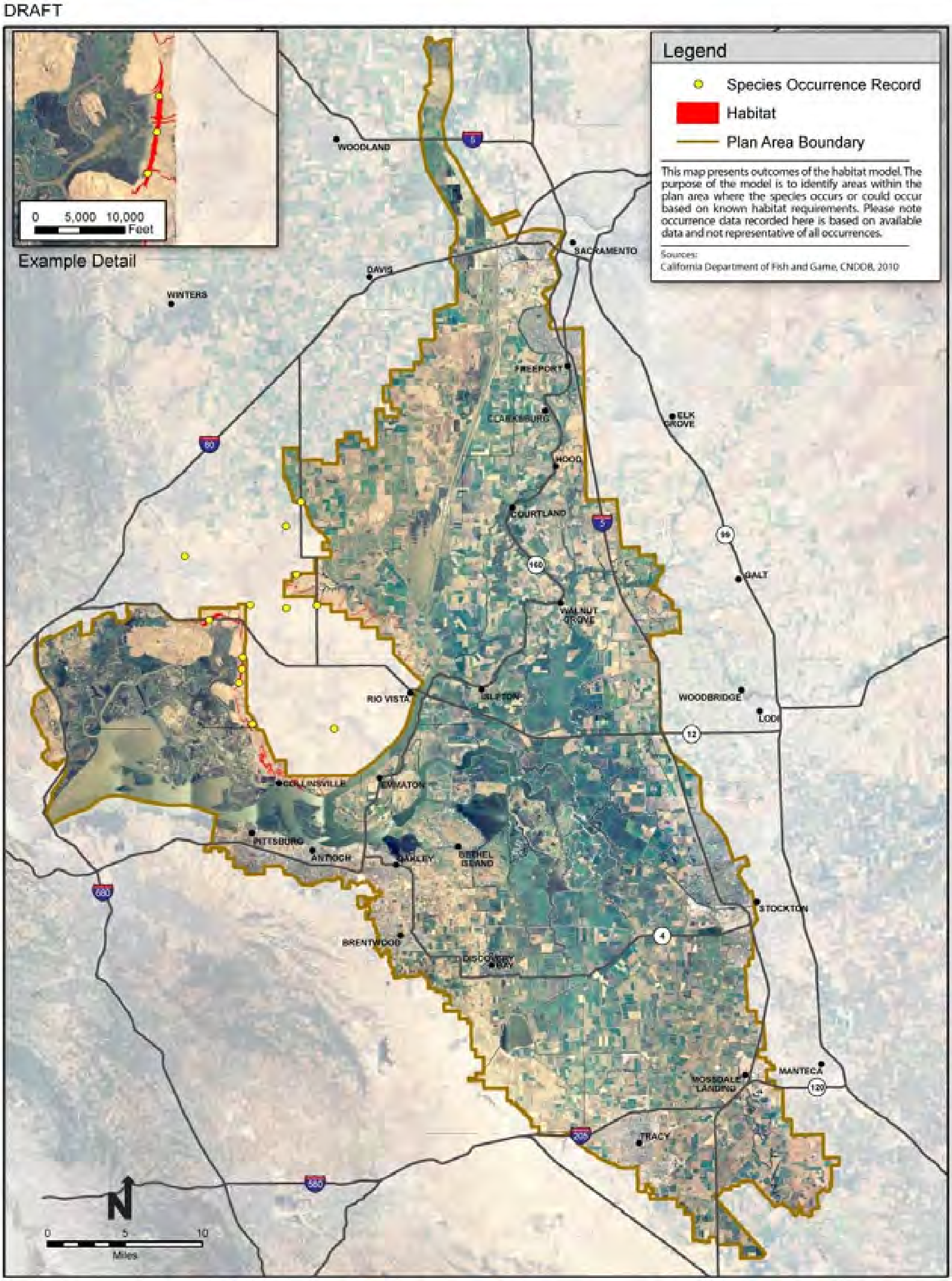

Figure A-54b. Carquinez Goldenbush Habitat Model and Recorded Occurrences

A54.3 Habitat Requirements and Special Considerations

Very little is known about the habitat requirements of Carquinez goldenbush. Based on its reported distribution and collection notes, it is restricted to recent alluvial soils that are derived from the Tehama geological formation and which are located on the Montezuma Block or along the fault that runs along its western margin (Hickman 1993, Band 1998, Graymer et al. 2002, Calflora 2009, CNDDB 2009, CNPS 2009). It grows along seasonal drainages, adjacent to the margins of alkaline playas, and in association with vegetation that is transitional between the brackish marsh and the grasslands within the 3.4-4.3 meter NAVD88 elevation band along the eastern border of Suisun Marsh (Hickman 1993, Band 1998, Graymer et al. 2002, DWR 2007, CNDDB 2009, CNPS 2009, NRCS 2009).

A54.4 Life History

Carquinez goldenbush is a very small shrub in the sunflower family (Asteraceae) with flowering heads that bloom from August to December and contain 10-13 yellow flowers (Hickman 1993, CNPS 2009). Its maximum reported height is 30 centimeters (cm) (< 1 foot) and the woody stems which branch from the base of the plants can be either erect or lie mostly flat on the ground with the branch tips curving upward (Nesom 1991). The leaves are hairless, light gray-green in color, dotted with glands, and less than 2 cm (0.8 inch) long. Unlike the highly variable and closely related species that occur immediately to the south, Carquinez goldenbush has consistent morphological characteristics across its distribution (Nesom 1991).

A54.5 Threats and Stressors

Activities that have been reported to have impacted Carquinez goldenbush include agricultural land conversion, grazing, road widening, and development (CNPS 2009).

A54.6 Relevant Conservation Efforts

Carquinez goldenbush is a covered species under the Solano County Multispecies Habitat Conservation Plan. Some of the reported extant occurrences are generally within protected areas such as the Greater Jepson Prairie Ecosystem Regional Management Plan area (Witham 2006) or within the Suisun Marsh Management Area.

A54.7 Species Habitat Suitability Model

Carquinez goldenbush occurrences in the Plan Area are all in close proximity to hydrological features such as alluvium in stream corridors on the Montezuma Block and along the upper margin of Suisun Marsh. The United States Geological Survey (USGS) geological data (Graymer et al. 2002) was used to select the following alluvium units that were related to the Montezuma Block and along the Suisun Marsh: Qa, Qhb, Qhbm, Qhc, Qhbm, Qhc, Qhdm, Qhf, Qmz Qoa, and Qpf. Stream corridors (intermittent and perennial) that intersected these geologic units were selected and truncated at the point at which they encountered the upper elevation of intertidal marsh (Siegel 2007). The corridors were buffered 50 feet (15 meters) on either side in an effort to capture the estimated maximum extend of alluvium deposits in close proximity to the actual rivers/streams. Field reconnaissance on the Montezuma Block area in May 2009 indicates that this buffering width is liberal and tends to overpredict potential habitat (J. Gerlach, personal observation).

Physical factors such as the tidal waters and high groundwater elevations in the Suisun Marsh may cause a backwater effect on the down gradient moving groundwater of the uplands resulting in localized shallow upland groundwater and resulting changes in vegetation (Rains et al. 2004), or the change in slope combined with finer textured soils at the transition from upland to marsh may cause temporary shallow water tables in the same area (Loheide II et al. 2009). Alternatively, the association of this species with stream corridors and the narrow elevation band along Suisun Marsh may be an artifact of the area's extensive dry-farmed grain cropping where soil disking fallows and seeding commonly occur through smaller drainages and to the wetland borders of larger drainages and Suisun Marsh (J. Gerlach, personal observation). The upper margins of the marsh (11-15 feet LiDAR elevation re-sampled to 10 meters, NAVD88) were used to identify areas that may provide suitable combinations of soil properties and moisture.

A54.8 Recovery Goals

A United States Fish and Wildlife Service (USFWS) recovery plan has not been prepared for this species and no recovery goals have been established.

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APPENDIX A55. DELTA TULE PEA (*LATHYRUS JEPSONII* VAR. *JEPSONII*)

A55.1 LEGAL STATUS

Delta tule pea (*Lathyrus jepsonii* var. *jepsonii*) is not listed under either federal or California endangered species acts. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G5T2/S2.2, which means that this species has a population or stand demonstrably secure to ineradicable due to being commonly found in the world. In contrast, this particular variety of the species has been ranked as globally (G) and within the state (S) rarer with either between six to 20 viable element occurrences, 1,000 to 3,000 individuals, or 2,000 to 10,000 acres (809 to 4,047 hectares) of occupied habitat; and the state threat level rank is "threatened."

The California Native Plant Society (CNPS) List ranking of 1B.2 for Delta tule pea indicates that it is rare, threatened, or endangered in California and elsewhere, and is considered by CNPS to be fairly endangered in California with between 20 to 80 percent of occurrences threatened. Plants with a CNPS List rank of 1B are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

A55.2 SPECIES DISTRIBUTION AND STATUS

A55.2.1 Range and Status

The range of Delta tule pea extends from Sacramento and Solano counties in the north, Napa and Sonoma counties in the west, and Contra Costa and San Joaquin counties in the south (Figure A-55a). Delta tule pea is endemic to California, and its distribution is based on 207 observations (Calflora 2007). Historically, it was reported as common in Suisun Marsh in 1894 and 1911, but today it is occasional to rare in Suisun Marsh. It occurs throughout the legal Delta (CNDDB 2008) and along the Napa River (Dutchman Slough) (Goals Project 2000).

A55.2.2 Distribution and Status in the Plan Area

Within the Plan Area, there are occurrences of Delta tule pea at and immediately above the tidal zone in marshes and along rivers and streams (Figure A-55b). It has been observed near Hass Slough, Snodgrass Slough, Lost Slough, on Ryer Island, Staten Island, Andrus Island, Bouldin Island, Rough and Ready Island, Browns Island, Winter Island, on the banks of the Middle River by the Upper and Lower Jones tracts, and near Collinsville and Pittsburgh among other locations throughout the Delta (CNDDB 2008). It also occurs within the tidal zone along Calhoun Cut and Barker Slough (Witham and Kareofelas 1994).

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Figure A-55a. Delta Tule Pea Statewide Recorded Occurrences

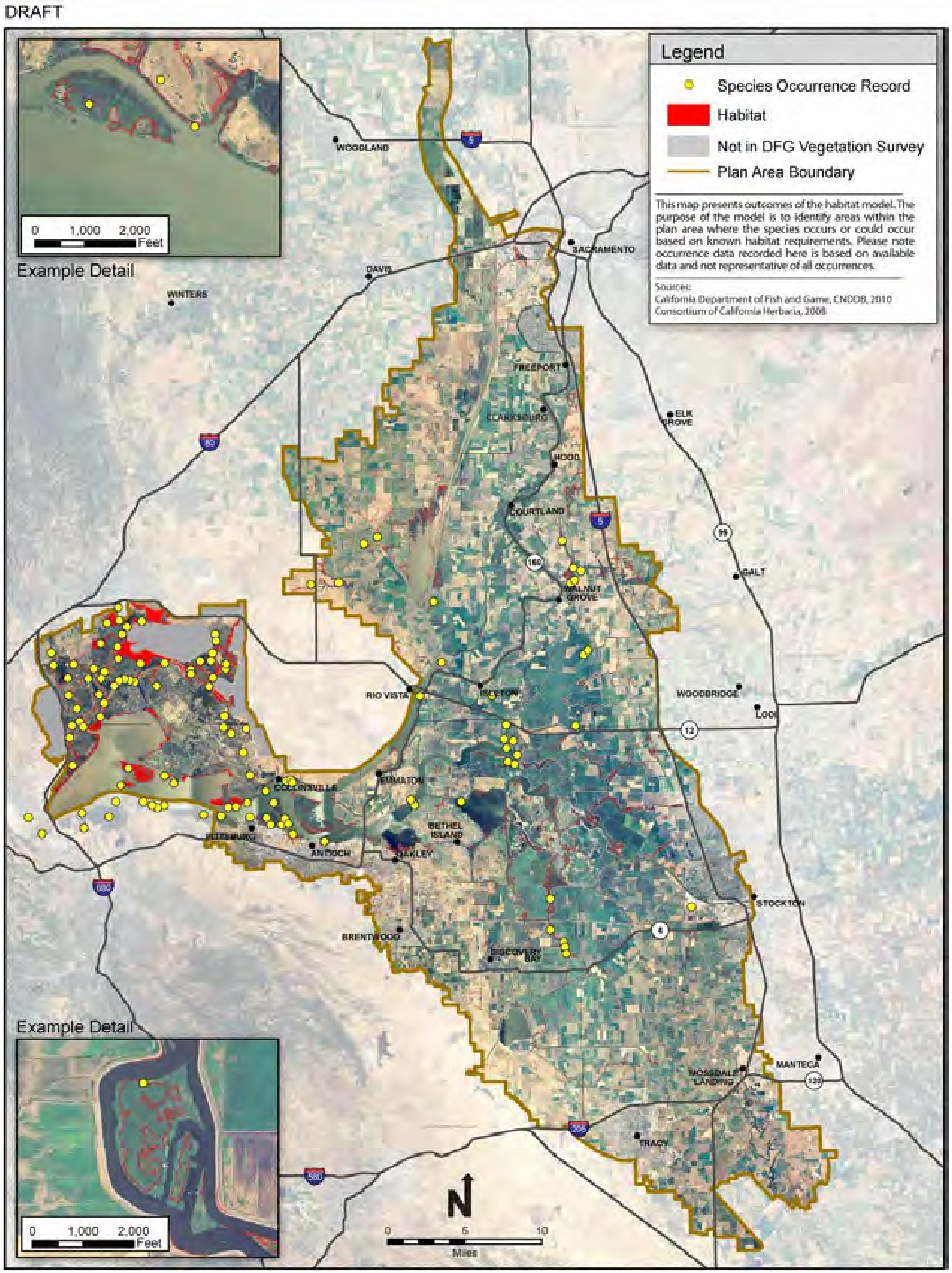

Figure A-55b. Delta Tule Pea Habitat Model and Recorded Occurrences

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Population trends of Delta tule pea have not been documented. It is unclear whether this species is in decline. According to the CNPS (2008), occurrences of Delta tule pea in California are highly limited, most known occurrences are small, and the species is at risk throughout its range.

A55.3 Habitat Requirements and Special Considerations

Delta tule pea occurs on the borders of fresh and brackish marshes from zero to 13 feet in elevation (Grewell et al. 2007, CNPS 2008). It has been observed to co-occur with or near other BDCP covered plant species, such as soft bird's-beak (*Cordylanthus mollis* ssp. *mollis*), Mason's lilaeopsis (*Lilaeopsis masonii*), Suisun Marsh aster (*Symphyotrichum lentum*), and Delta mudwort (*Limosella subulata*) (CNDDB 2008).

A55.4 Life History

Delta tule pea is a glabrous climbing perennial herb with winged stems and is a member of the pea family (Fabaceae) (Hickman 1993). It is identified by the number of leaflets, its glabrous winged stem, blue-grey leaf color, and pink to pink-purple flowers. Because of its climbing habit, Delta tule pea tends to grow over other vegetation and can have stems up to 2.5 meters (8.2 feet) tall. The leaves have small narrow stipules, 10 to 16 leaflets, and coiled branched tendrils (Hickman 1993). It bears six to 15 pink-purple flowers, 0.6 to 0.8 inches (1.5 to 2 centimeters [cm]) long, in an unbranched inflorescence (raceme) at the end of the stems. The fruits (legumes) are glabrous (without hairs) (Hickman 1993, CNPS 2008). This species blooms from May to September (CNPS 2008).

A55.5 Threats and Stressors

The primary threat to Delta tule pea is the loss of marsh and floodplain habitat within the range of the species. Potential ways this habitat could be eliminated or degraded include agriculture, water diversions, and erosion (CNPS 2008). Fishing and hunting access also pose a threat to this species through trampling impacts (Witham and Kareofelas 1994).

A55.6 Relevant Conservation Efforts

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designates the Delta tule pea as "Contribute to Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its control and within its scope that are necessary to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

Delta tule pea is a covered species under the approved San Joaquin County Multi-species Habitat Conservation and Open Space Plan and the Natomas Basin Habitat Conservation Plan. Delta tule pea is proposed for coverage under the Solano County Multi-species Habitat Conservation Plan and the Yolo County Natural Heritage Program Plan.

A55.7 Species Habitat Suitability Model

Habitat. Habitat was modeled separately based upon the salinity of the water. For freshwater areas, essentially the area within the legal delta, Suisun Marsh aster habitat was identified as the area within 10 feet (3 meters) of the landward side of the landward boundary of tidal freshwater emergent wetland BDCP land cover type exclusively where this land cover type is adjacent to grassland, vernal pool complex, valley/foothill riparian, or agricultural habitats cover types. For brackish water areas in and near Suisun Marsh, the model used all tidal brackish emergent wetland polygons (SFEI 2005, Boul and Keeler-Wolf 2008) which, using the California Department of Water Resources (DWR) LiDAR data set as resampled at 10 meters (DWR 2007), were then intersected with an elevation range of 7 to 10 feet (2 to 3 meters) to capture elevations 1 foot (30 cm) below intertidal to 2 feet (60 cm) above intertidal (i.e. the upper limit of the intertidal range was estimated at 8 feet, NAVD88; Siegel estimated the intertidal range in Suisun to occur between 1 to 8 feet (30 cm to 2.4 meters), NAVD88 (Siegel 2007).

Assumptions. Historical and current records of this species indicate that its distribution extends throughout most of the Plan Area having been observed in tidally influenced waters from Calhoun Cut and in the Sacramento River near Walnut Grove southward and from Tom Pain Slough near the southern boundary of the Plan Area northward (Figure A-55b) (Witham and Kareofelas 1994, CNDDB 2008). While there are no occurrences within the Plan Area north of Calhoun Cut and Walnut Grove, patches of suitable habitat extend into those areas. For purposes of this model, a 10 foot-wide (3 meter) buffer on the landward side of the landward boundaries of the tidal freshwater emergent wetland land and tidal brackish emergent wetland contained within the 7-10 foot (2-3 meter) elevation within Suisun Marsh have been included as the potential extent of habitat that supports Suisun Marsh aster.

A55.8 Recovery Goals

A United States Fish and Wildlife Service (USFWS) approved Recovery Plan has not been prepared for this species; however, this species is included in the Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California which specifies the preservation of individuals and habitat, the control of invasive species, and the restoration of tidal flows as recovery criteria goals (USFWS 2010). Additionally, the CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan’s Multi-Species Conservation Strategy designates the Delta tule pea as “Contribute to Recovery” (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its control and within its scope that are necessary to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

A55.9 REFERENCES

A55.9.1 Literature Cited

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APPENDIX A56. LEGENERE (*LEGENERE LIMOSA*)

A56.1 Legal Status

Legenere (*Legenere limosa*) is not listed under either federal or California endangered species acts. Legenere has been designated as sensitive by the Bureau of Land Management (BLM), which means that the BLM State Director calls for special management consideration of this species on BLM-administered lands. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G2/S2.2 which means that globally (G) and within the state (S) there are either between six to 20 viable element occurrences of this species, 1,000 to 3,000 individuals of this species, or 2,000 to 10,000 acres (809 to 4,047 hectares) where this species occurs. Its state threat level rank is “threatened.”

The California Native Plant Society (CNPS) List ranking of 1B.1 for legenere indicates that it is rare, threatened, or endangered in California and elsewhere, and is considered by CNPS to be seriously endangered in California with more than 80 percent of occurrences threatened. Plants with a CNPS List rank of 1B are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

A56.2 Species Distribution and Status

A56.2.1 Range and Status

Legenere’s range extends from southern Shasta County to southern Santa Clara County (Figure A-56a). It is found on bottom lands and alluvial terraces in the Sacramento Valley with its distribution at the south end of the Sacramento Valley bifurcated by the Delta (CNDDB 2008). It occurs in the extreme northeastern part of the San Joaquin Valley and is also found on valley floors and margins in both the northern end of Southern Coast Range in San Mateo, Alameda, and Santa Clara counties and the southern end of the Northern Coast Range in Sonoma and Napa counties (CNDDB 2008).

A56.2.2 Distribution and Status in the Plan Area

Legenere has been reported in the Plan Area from vernal pools, vernal swales, and alkaline flats in vernal pool grasslands in the greater Jepson Prairie area (Figure A-56b) (Witham 2003, Buck 2004, Witham 2006, Barbour et al. 2007, Lazar 2007, CNDDB 2008). During spring 2009 California Department of Water Resources/Delta Habitat Conservation and Conveyance Program (DWR/DHCCP) field surveys conducted for the Bay Delta Conservation Plan (BDCP), legenere was discovered growing in a roadside ditch in the Stone Lakes area.

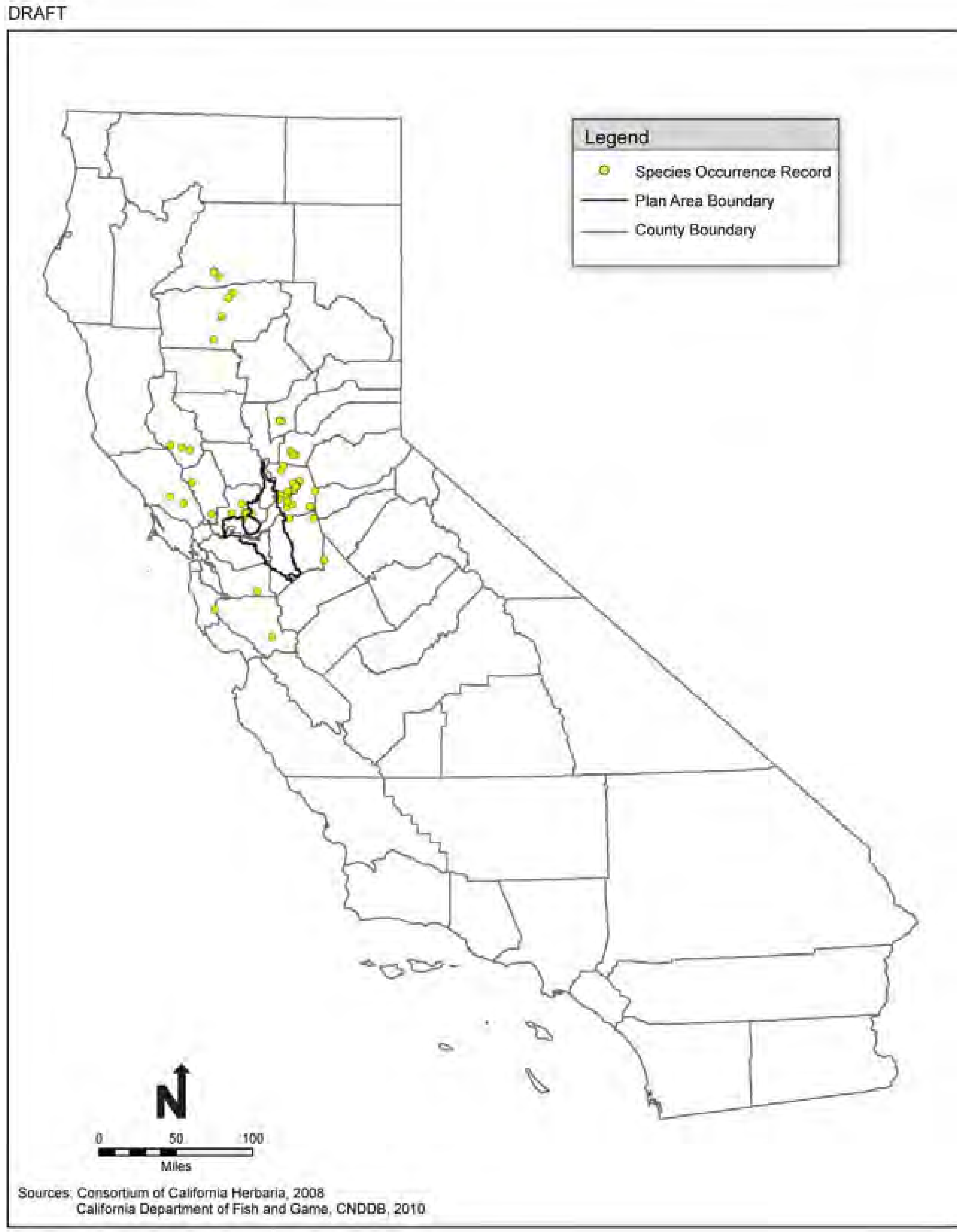

Figure A-56a. Legenere Statewide Recorded Occurrences

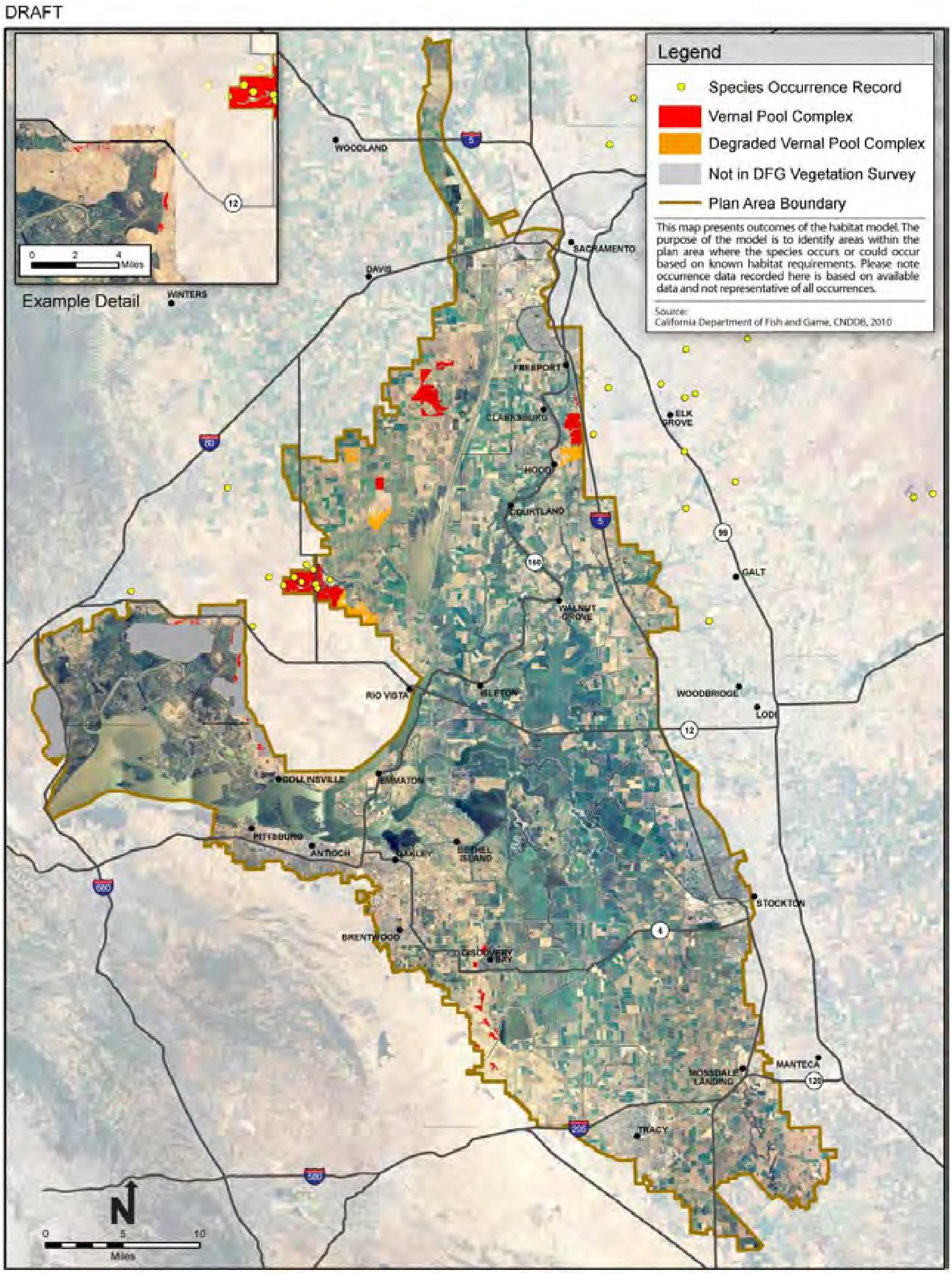

Figure A-56b. Legenere Habitat Model and Recorded Occurrences

Recorded occurrences in western Sacramento and San Joaquin counties are immediately east of the eastern boundary of the Plan Area.

A56.3 Habitat Requirements and Special Considerations

Throughout its distribution, legenere occurs in vernal pools, vernal swales, pools in seasonal streambeds, vernal marshes, and stock ponds (CNDDB 2008). Occurrence records often state that it is found with long inundation indicator species such as pale spikerush (*Eleocharis macrostachya*), but on the clay soils of the greater Jepson Prairie area it is found in a range of microtopographic positions in vernal pool grassland vegetation that typically have a high cover of the nonnative annual grass *Lolium multiflorum* (Witham 2006, Barbour et al. 2007, Lazar 2007, CNDDB 2008).

In a large multiple-year vernal pool study, the occurrence of vegetative plants in particular vernal pools was found to fluctuate dramatically with the species disappearing and reappearing in some years (Buck 2004, Barbour et al. 2007). These fluctuations can occur for decades as one occurrence observed in 1961 was not observed in 1971, 1980, or 1983 but was observed again in 1991 (CNDDB 2008). Legenere species may respond positively to dry season soil disturbances as one occurrence in Sacramento County was reported to support up to 1,000 to 10,000 plants in 1991 despite having been "…disked annually for firebreak," but no plants were observed during a 2007 survey (CNDDB 2008). Legenere is one of few vernal pool endemic species that can be considered an evolutionary relict (remnant of an otherwise extinct flora or fauna in an environment much changed from that in which it originated) (Stone 1990).

A56.4 Life History

Legenere is a small submerged to emergent aquatic annual herbaceous plant during the wet season when habitat is ponded that becomes a 4- to 12-inch (10- to 30-centimeter) long sprawling terrestrial plant at the end of the wet season as the habitat dries. The small, 0.1- to 0.5-inch (2- to 10-millimeter) long, narrow leaves support flowers in the upper axils of the characteristic zigzag appearing stems (Hickman 1993). Because of its small size and inconspicuous white flowers, it is difficult to detect during field surveys and may be frequently overlooked (Anonymous 2008). Nothing is known about its pollination biology, seed germination characteristics, or many other important biological and ecological characteristics.

A56.5 Threats and Stressors

Development, intensive agriculture, and exotic plant species (especially *Lolium multiflorum*) are considered to be the primary threats to legenere (Showers 1988, Showers 1996, Dawson et al. 2007, CNDDB 2008). Additionally, waxy mannagrass (*Glyceria declinata*) may pose a threat to legenere and many other vernal pool species (Gerlach et al. 2009).

A56.6 Relevant Conservation Efforts

The known occurrences in the Plan Area are protected from development or intensified agriculture under conservation easements (Witham 2006, Barbour et al. 2007, Lazar 2007, CNDDB 2008). Legenere is included in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (USFWS 2005). Legenere is a covered species under the permitted San Joaquin County Multi-species Habitat Conservation and Open Space Plan and the Natomas Basin Habitat Conservation Plan; and it is proposed for coverage under the Solano County Multispecies Habitat Conservation Plan and the South Sacramento County Habitat Conservation Plan.

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for legenere is "Maintain" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions to maintain the species by avoiding, minimizing, and compensating for any adverse effects to the species created by ERP restoration actions. To the extent practicable, the ERP will improve species habitat conditions.

A56.7 Species Habitat Suitability Model

Model Approach. Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below and in Section 2.3.1, *Data Sources and Natural Community Classification*). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as vernal pools, individual trees, or small groups of trees. It is also possible, as with some vernal pool invertebrates that are restricted to seasonally ponded habitats, to underestimate potentially-occupied habitat due to the lack of information on small, degraded or artificially-created seasonal wetland habitats.

Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The legenere model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), DWR 2007 LiDAR elevation data, Google Earth 2009 aerial imagery and USDA 2005 aerial photography. Using these data sets, the model maps the distribution of suitable legenere habitat in the Plan Area according to the species' two habitat types, vernal pool complex and degraded vernal pool complex habitat. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Vernal Pool Complex Habitat: High quality permanent habitat that consists of vernal pools and uplands that display characteristic vernal pool and swale visual signatures that have not been significantly impacted by agricultural or development practices. Vernal pool complex habitat for legenere includes the following vegetation subunits that were selected from the BDCP vernal pool complex natural community:

- Vernal pool complex – all vegetation types

Degraded Vernal Pool Complex Habitat: Low quality ephemeral habitat that ranges from areas with vernal pool and swale visual signatures that display clear evidence of significant disturbance due to plowing, disking, or leveling to areas with clearly artificial basins such as shallow agricultural ditches, depressions in fallow fields, and areas of compacted soils in pastures. The aquatic features in this habitat are more clearly classified as temporary waters sensu lato (Williams 2006) than intact and fully functional vernal pools. Because these features are inundated during the wet season and may have historically been located in or near areas with natural vernal pool complex, they may support individuals or small populations of species that are found in vernal pools and swales. However, they do not possess the full complement of ecosystem and community characteristics of natural vernal pools, swales and their associated uplands and they are generally ephemeral features that are eliminated during the course of normal agricultural practices. Degraded vernal pool complex habitat for legenere includes the following vegetation subunits that were selected from the BDCP other natural seasonal wetlands and grasslands communities:

- Grasslands
  - Degraded vernal pool complex – California annual grasslands;
  - Degraded vernal pool complex – Ruderal herbaceous grasses and forbs;
  - Degraded vernal pool complex – Italian rye-grass (*Lolium multiflorum*); and
  - Degraded vernal pool complex – Rabbitsfoot grass (*Polygpogon maritimus*).
- Other natural seasonal wetlands
  - Degraded vernal pool complex-Vernal pools.

Potential habitat without concave surfaces (except for seeps along Suisun Marsh) was removed from the model. LiDAR elevation data was then visually inspected in four general areas to further assess specific locations that had been identified by the habitat selection process. These areas were selected based both on *a priori* knowledge of the region and because they were identified by the intersection of the selected vegetation types and soils. The analysis of the LiDAR data further refined the habitat model and provided a more accurate demarcation of suitable habitat. The GIS habitat model was then compared against field data from DWR/DHCCP surveys conducted in 2009 for the BDCP. Land uses that are incompatible with the species' habitat requirements, for example potential habitat polygons falling on leveled or developed lands, were removed from the model.

Assumptions. Historical and current records of this species in the Plan Area indicate that its current distribution is limited to alkaline soil areas with vernal pool and swale microtopography along the western border of the Plan Area (Figure A-56b) (Witham 2006, CNDDB 2010) and areas with swales and vernal pools along the eastern boundary of the Plan Area (CNDDB 2010). The vegetation cover is typically a combination of vernal pool adapted species and annual ryegrass (Witham 2006, CNDDB 2010).

A56.8 Recovery Goals

Although legenere is not a federally listed species, it is included in the Draft Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (USFWS 2005). The Recovery Plan explicitly states that its goal is to ensure the long-term conservation of legenere and 32 other taxa by using an ecosystem level strategy that is based on: (1) current knowledge of the existing conditions of vernal pool communities, (2) the distribution and status of the populations of each of the species, and (3) current and anticipated processes that impact vernal pool ecosystems. Because the goal of the Recovery Plan is primarily directed at habitat preservation, its implementation program specifically addresses factors that relate to habitat acquisition and management: (1) habitat protection; (2) adaptive habitat management and monitoring; (3) status surveys; (4) research; and (5) public participation.

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APPENDIX A57. HECKARD'S PEPPER-GRASS (*LEPIDIUM LATIPES* VAR. *HECKARDII*)

A57.1 LEGAL STATUS

Heckard's pepper-grass (*Lepidium latipes* var. *heckardii*) is not listed under either federal or California endangered species acts. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G4T1/S1.2 which means that the species as a whole is apparently secure across its overall distribution, but some factors of concern, such as narrow habitat requirements or continuing threats, do exist. In contrast, this particular variety of the species has been ranked as threatened globally (G) and within the state (S) because it has either fewer than six viable occurrences, fewer than 1,000 individuals, or fewer than 2,000 acres (809 hectares) of occupied habitat. Its state threat level rank is "threatened."

The California Native Plant Society (CNPS) List ranking of 1B.2 for Heckard's pepper-grass indicates that it is rare, threatened, or endangered in California and elsewhere, and it is considered by CNPS to be fairly endangered in California with between 20 to 80 percent of occurrences threatened. Plants with a CNPS List rank of 1B are considered by CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

A57.2 SPECIES DISTRIBUTION AND STATUS

A57.2.1 Range and Status

The reported range of Heckard's pepper-grass extends from Glenn and Colusa counties to Merced County (Figure A-57a) (CNDDB 2008, Consortium of California Herbaria 2008, Burmester pers. comm. 2009). The distribution of this species includes the alkaline soil areas to the southeast and south of the City of Woodland and at the California Department of Fish and Game (DFG) Tule Ranch unit of the DFG Yolo Bypass Wildlife Area (Tule Ranch) in Yolo County (Showers 1996, Witham 2003, CNDDB 2008). Populations of Heckard's pepper-grass at the Tule Ranch site are sparse but dispersed throughout the site (Witham 2003). In Solano County, Heckard's pepper-grass has been reported from the East Wilcox and Gridley ranches in the greater Jepson Prairie area (Witham 2006, CNDDB 2008) and along Haas Slough, but that occurrence was last observed by Jepson in 1891 (Consortium of California Herbaria 2008). Aerial imagery indicates that Haas Slough occurrence is likely to have been extirpated by the spread of intensive agriculture along both sides of the slough. Although occurrences have been recently discovered, Heckard's pepper-grass is extremely rare in California (CalFlora 2000, CNPS 2008) and is expected to continue to decline, although data on population trends are lacking.

DRAFT

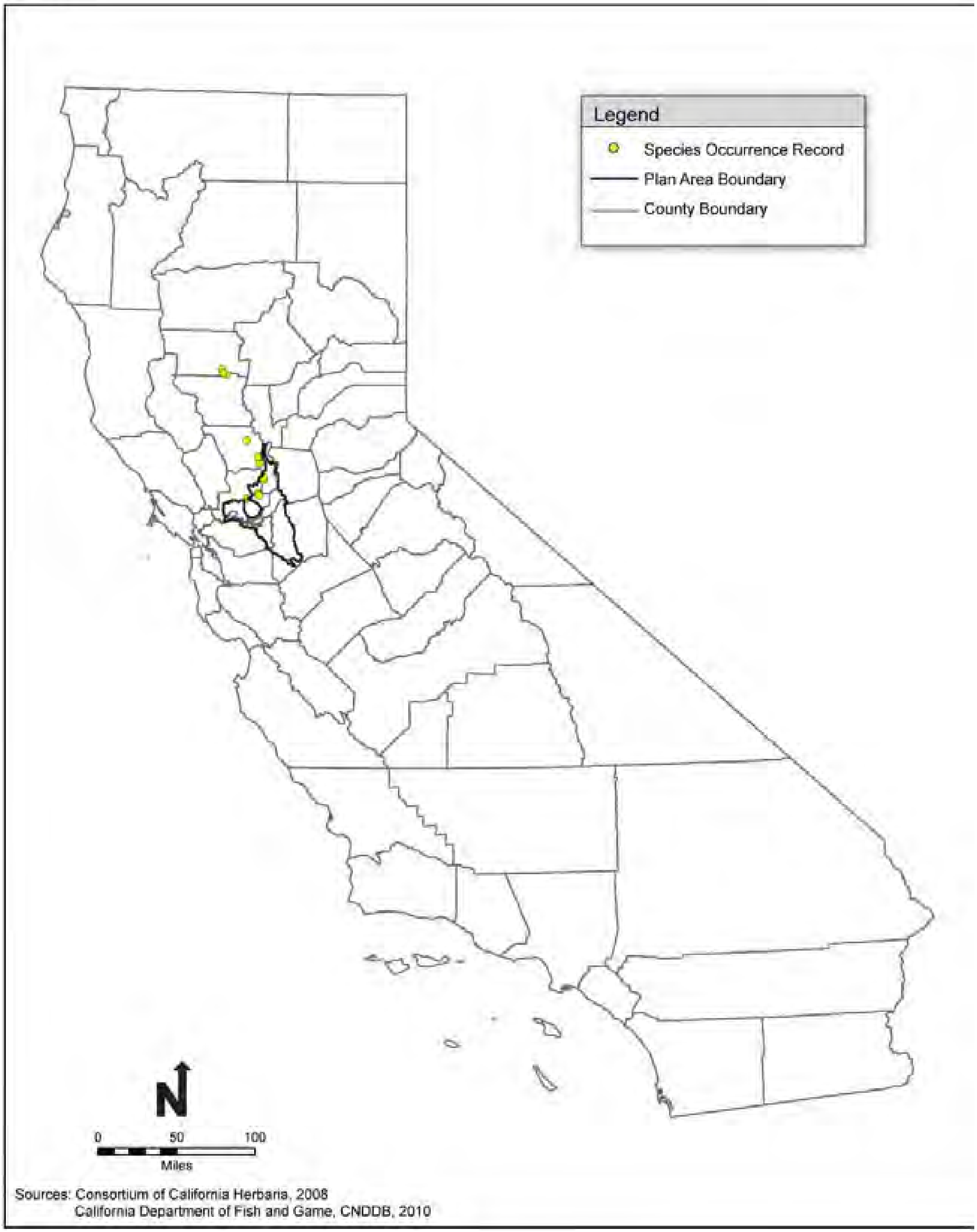

Figure A-57a. Heckard's Pepper-Grass Statewide Recorded Occurrences

A57.2.2 Distribution and Status in the Plan Area

Heckard's pepper-grass has been observed in the Plan Area west of Yolo Bypass in Yolo County in the area of the Tule Ranch (Witham 2003, CNDDB 2008, Consortium of California Herbaria. 2008), and in Solano County on the Wilcox and Gridley ranches of the greater Jepson Prairie area (Figure A-57b) (Witham 2006). The hydrology and vegetation of the Gridley Ranch site is described in Williamson et al. (2005). It has also been detected along agricultural ditches in the Stone Lakes area during 2009 California Department of Water Resources/Delta Habitat Conservation and Conveyance Program (DWR/DHCCP) field surveys conducted for the Bay Delta Conservation Plan (BDCP). The occurrences in natural communities in the Plan Area are within vernal pool complexes on clay-rich alkaline soils that have not been intensively farmed.

A57.3 Habitat Requirements and Special Considerations

Very little is known regarding the ecology of Heckard's pepper-grass. Populations near the city of Woodland occur on alkaline flats and mesic alkaline grasslands that were once contour rice fields on Pescadero silty clay, saline-alkali, Marvin soils, and Willows clay soil types. On the Tule Ranch site in the Yolo Bypass, and on the East Wilcox and Gridley ranches in Solano County it occurs in grazed, slightly alkaline vernal pool grassland in areas that are dominated by annual ryegrass (*Lolium multiflorum*) (Witham 2006, CNDDB 2008), a nonnative that is tolerant of alkaline soils (Dawson et al. 2007). Occurrence records and survey reports suggest that Heckard's pepper-grass is closely associated with Sacramento Valley populations of alkali milk-vetch (*Astragalus tener* var. *tener*) (another BDCP covered species) (CNDDB 2008).

A57.4 Life History

Heckard's pepper-grass is a 1- to 10-inch (3- to 25-centimeter [cm]) tall herbaceous annual plant in the mustard family (Brassicaceae). It is differentiated from dwarf pepper-grass (*L. latipes* var. *latipes*) based on its height, the distance between its leaf nodes, and its lack of a basal rosette (Hickman 1993, Rollins 1993). Heckard's pepper-grass has dense foliage with 2- to 4-inch (5- to 10-cm) long linear leaves. Small, greenish flowers occur in a raceme in fruit that is greater than basal leaves and the flat, oval fruits are deeply notched at their tops (Hickman 1993, Rollins 1993). Heckard's pepper-grass flowers March through May (CNPS 2008). Studies are needed to shed light on basic biological and ecological requirements such as pollination systems, seed dormancy and germination cues, dispersal vectors, and seed predation.

A57.5 Threats and Stressors

Development, waterfowl management, agricultural conversion, urban development, and exotic plant species are considered the primary threats to Heckard's pepper-grass (Showers 1988, Showers 1996, Dawson et al. 2007, CNDDB 2008). All of these threats lead to the loss of habitat or the degradation of conditions the plant requires to survive.

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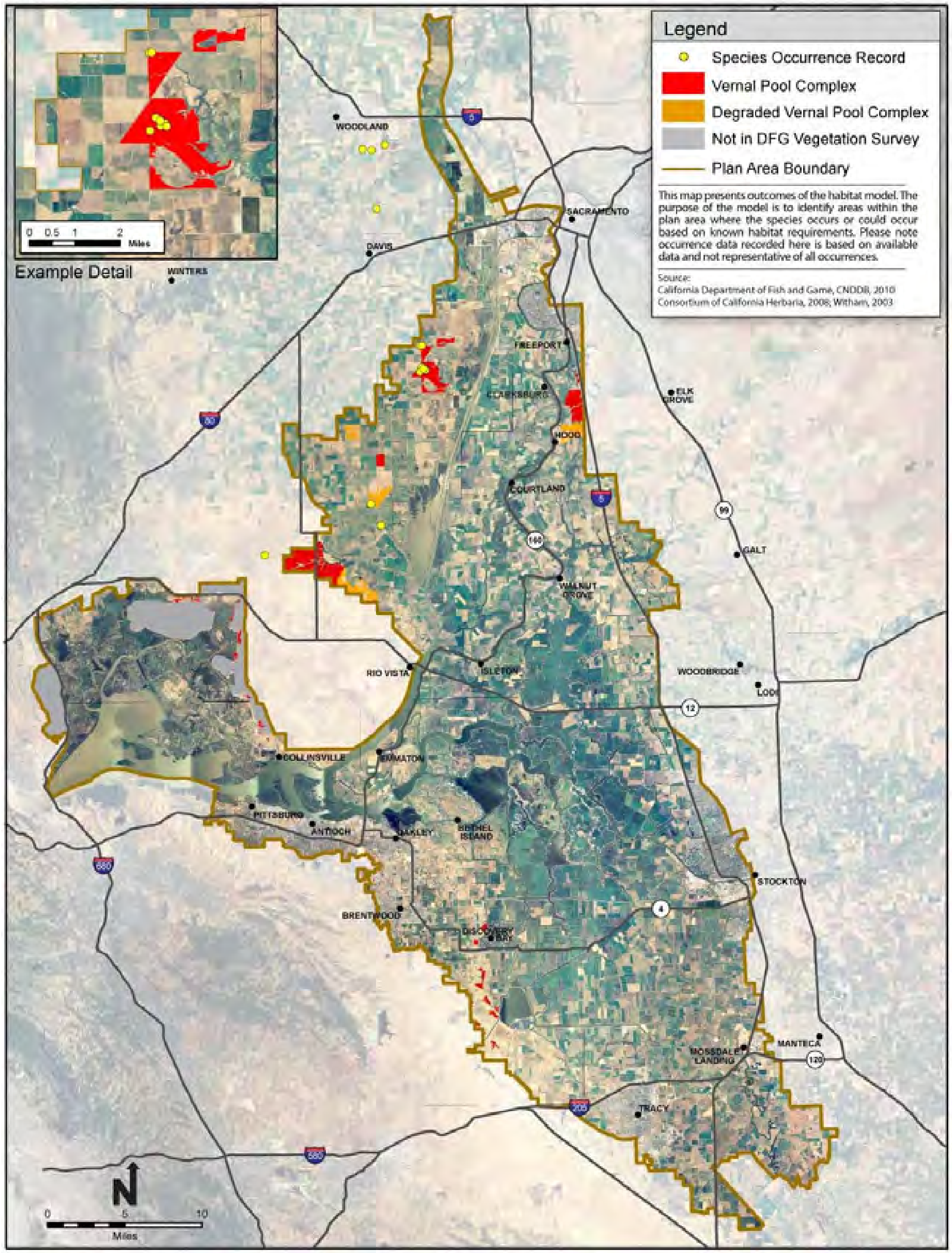

Figure A-57b. Heckard's Pepper-Grass Habitat Model and Recorded Occurrences

A57.6 Relevant Conservation Efforts

The known populations of Heckard's pepper-grass in Solano County are under conservation easements and those in Yolo County are protected on the DFG Tule Ranch Reserve or by a conservation easement in the Spring Lakes area near the city of Woodland. The Tule Ranch and greater Jepson Prairie area populations are currently grazed.

Heckard's pepper-grass is proposed for coverage under the Solano County Multispecies Habitat Conservation Plan and the Yolo County Natural Heritage Program Plan.

A57.7 Species Habitat Suitability Model

Model Approach. BDCP Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below and in Section 2.3.1, *Data Sources and Natural Community Classification*). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as vernal pools, individual trees, or small groups of trees. It is also possible, as with some vernal pool invertebrates that are restricted to seasonally ponded habitats, to underestimate potentially-occupied habitat due to the lack of information on small, degraded or artificially-created seasonal wetland habitats.

Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The Heckard's pepper-grass model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), DWR 2007 LiDAR elevation data, Google Earth 2009 aerial imagery and USDA 2005 aerial photography. Using these data sets, the model maps the distribution of suitable Heckard's pepper-grass habitat in the Plan Area according to the species' two habitat types, vernal pool complex and degraded vernal pool complex habitat. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

Vernal Pool Complex Habitat: High quality permanent habitat that consists of vernal pools and uplands that display characteristic vernal pool and swale visual signatures that have not been significantly impacted by agricultural or development practices. Vernal pool complex habitat for Heckard's pepper-grass includes the following vegetation subunits that were selected from the BDCP vernal pool complex natural community:

- Vernal pool complex – All vegetation types

Degraded Vernal Pool Complex Habitat: Low quality ephemeral habitat that ranges from areas with vernal pool and swale visual signatures that display clear evidence of significant disturbance due to plowing, disking, or leveling to areas with clearly artificial basins such as shallow agricultural ditches, depressions in fallow fields, and areas of compacted soils in pastures. The aquatic features in this habitat are more clearly classified as temporary waters sensu lato (Williams 2006) than intact and fully functional vernal pools. Because these features are inundated during the wet season and may have historically been located in or near areas with natural vernal pool complex, they may support individuals or small populations of species that are found in vernal pools and swales. However, they do not possess the full complement of ecosystem and community characteristics of natural vernal pools, swales and their associated uplands and they are generally ephemeral features that are eliminated during the course of normal agricultural practices. Degraded vernal pool complex habitat for Heckard's pepper-grass includes the following vegetation subunits that were selected from the BDCP other natural seasonal wetlands and grasslands communities:

- Grasslands
    - Degraded vernal pool complex – California annual grasslands;
    - Degraded vernal pool complex – Ruderal herbaceous grasses and forbs;
    - Degraded vernal pool complex – Italian rye-grass (*Lolium multiflorum*); and
    - Degraded vernal pool complex – Rabbitsfoot grass (*Polygpogon maritimus*).

- Other natural seasonal wetlands
  - Degraded vernal pool complex-Vernal pools.

Potential habitat without concave surfaces (except for seeps along Suisun Marsh) was removed from the model. LiDAR elevation data was then visually inspected in four general areas to further assess specific locations that had been identified by the habitat selection process. These areas were selected based both on *a priori* knowledge of the region and because they were identified by the intersection of the selected vegetation types and soils. The analysis of the LiDAR data further refined the habitat model and provided a more accurate demarcation of suitable habitat. The GIS habitat model was then compared against DWR/DHCCP field data from surveys conducted for the BDCP in 2009. Land uses that are incompatible with the species' habitat requirements, for example potential habitat polygons falling on leveled or developed lands, were removed from the model.

Assumptions. Historical and current records of this species in the Plan Area indicate that its current distribution is limited to alkaline soil areas with vernal pool and swale microtopography along the northwestern border of the Plan Area (Figure A-57b) (Witham 2002, 2003, 2006, ESA 2005, Barona et al. 2007, Consortium of California Herbaria 2008, CNDDB 2010). The vegetation cover of the alkaline soils is typically a combination of vernal pool adapted species and annual ryegrass (Witham 2002, 2003, 2006, CNDDB 2010). Heckard's pepper-grass was discovered in the Stone Lakes area by DWR/DHCCP field survey teams, and its habitat range was extended into areas with vernal pool and swale microtopography along the northeastern border of the Plan Area. Because Heckard's pepper-grass also frequently occurs in the same habitats as alkali milk-vetch (Witham 2002, 2003, 2006, CNDDB 2010), its habitat range was extended in the central-western and southwestern portions of the Plan Area to match that of alkali milk-vetch. The vegetation cover of the alkaline soils is typically a combination of vernal pool adapted species and annual ryegrass (Witham 2002, 2003, 2006, CNDDB 2010).

A57.8 Recovery Goals

A United States Fish and Wildlife Service (USFWS) recovery plan has not been prepared for this species and no recovery goals have been established.

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A57.9.2 Personal Communications

Burmester, D. (California Department of Fish and Game Botanist). Comment submitted on draft BDCP Heckard's Pepper-grass Species Account on June 15, 2009.

APPENDIX A58. MASON'S LILAEOPSIS (*LILAEOPSIS MASONII*)

A58.1 Legal Status

Mason's lilaeopsis (*Lilaeopsis masonii*) is state-listed as rare under the California Native Plant Protection Act (November 1979). It is not listed under the federal or California endangered species acts. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G3/S3.1 which means that globally (G) and within the state (S) there are either between 21 to 80 viable element occurrences of this species, 3,000 to 10,000 individuals of this species, or 10,000 to 50,000 acres (4,047 to 20,234 hectares) where this species occurs. Its state threat level rank is "very threatened."

The California Native Plant Society (CNPS) List ranking of 1B.1 for Mason's lilaeopsis indicates that it is rare, threatened, or endangered in California and elsewhere, and is considered by CNPS to be seriously endangered in California with more than 80 percent of occurrences threatened. Plants with a CNPS List rank of 1B are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

A58.2 Species Distribution and Status

A58.2.1 Range and Status

Mason's lilaeopsis is endemic to California and its distribution is based on 298 observations (Figure A-58a) (Calflora 2007). The range of Mason's lilaeopsis extends from Napa and Solano counties in the north, to Contra Costa and Alameda counties in the south, to Marin County in the west, and Sacramento and San Joaquin counties in the east (CNDDB 2008). Contemporary distribution includes occurrences at Napa Marsh, Suisun Marsh area, Tolay Creek, and San Pablo Bay (Goals Project 2000). Currently it is less common in the western Sacramento River area (Goals Project 2000).

Although population trends of Mason's lilaeopsis have not been documented, this species has been determined to be stable to declining (CNDDB 2008). According to the CNPS (2008), occurrences of Mason's lilaeopsis in California are highly limited and the species is at serious risk throughout its range. Surveys in Solano County found that it had declined because its habitat along the margins of small islands within the sloughs had decreased as the islands shrunk in size (Meisler 2002).

There are some data that indicate that Mason's lilaeopsis is indistinguishable from western lilaeopsis (*Lilaeopsis occidentalis*) based on morphological characteristics and a preliminary molecular genetic analysis (Fiedler and Zebell 1993).

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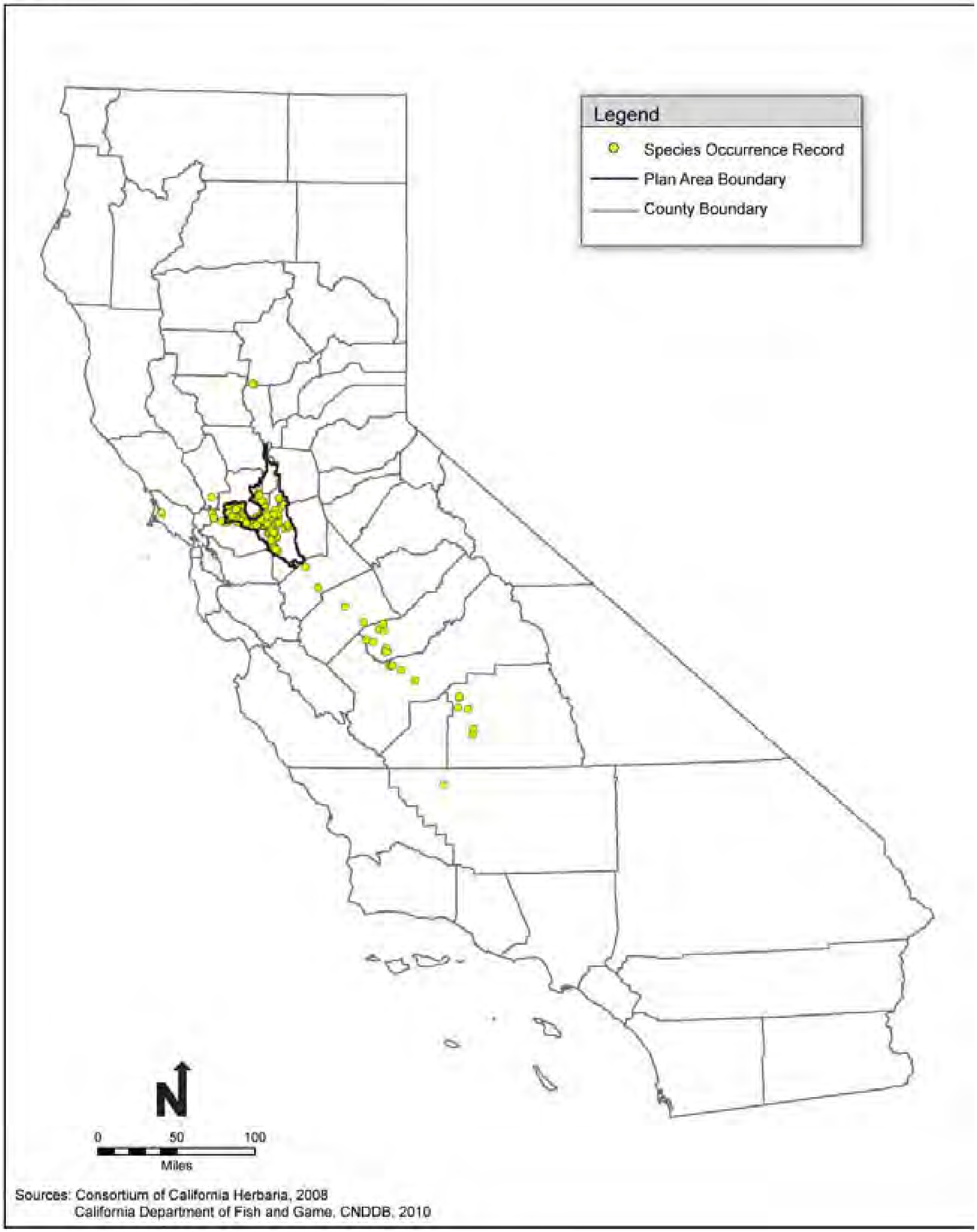

Figure A-58a. Mason's Lilaeopsis Statewide Recorded Occurrences

A58.2.2 Distribution and Status in the Plan Area

Mason's lilaeopsis is found throughout the Delta along rivers and sloughs (Figure A-58b) (CNDDB 2008, Consortium of California Herbaria 2008). Most occurrences are known from the central and west Delta. In the south Delta, occurrences are predominately along Old River and Middle River. In the north Delta, it occurs in the Cache Slough Complex and near Delta Meadows.

A58.3 HABITAT REQUIREMENTS AND SPECIAL CONSIDERATIONS

Mason's lilaeopsis is found in relatively unvegetated areas within brackish or fresh water habitats that are inundated by waves or tides such as estuarine wetlands and immediately below the banks of tidal sloughs, rivers, and creeks (Golden and Fiedler 1991, Fiedler and Zebell 1993, DFG 2000, CNPS 2008). It is a colonizing species that establishes on newly deposited or exposed sediments (CNPS 2008) and has a preference for low tidal flats on clayey or silty soils (Witham and Kareofelas 1994). It is occasionally found distributed among rip-rap lining levees (Golden and Fiedler 1991) and along the edges of tule marshes (Witham and Kareofelas 1994, May & Associates 2005). It has been found in areas with high soil salinity, but those sites might not be optimum habitat (Fiedler and Zebell 1993). Within the Delta, Mason's lilaeopsis is not found upstream of the extent of active tidal fluctuation (B. Grewell, personal observation as cited in Suisun Ecological Workgroup 1997).

Some of the species commonly associated with Mason's lilaeopsis in the Sacramento Delta include California tule (*Scirpus californicus*[1]), whorled marsh pennywort (*Hydrocotyle verticillata*), and annual tule (*Scirpus cernuus*[2]) (Golden and Fiedler 1991). In the sloughs that radiate westward into Solano County at the southern end of the Sacramento River Deep Ship Channel, it grows in a narrow band between the mudflats and mesic terrestrial vegetation (Meisler 2002). In Suisun Marsh and other places, California tule (*Scirpus californicus*), annual tule (*Scirpus cernuus*), and three-ribbed arrowgrass (*Triglochin striata*) are predominantly associated with Mason's lilaeopsis (B. Grewell per. comm. as cited in Suisun Ecological Workgroup 1997, May & Associates 2005, CNDDB 2008). Mason's lilaeopsis does not appear to be substrate-specific as it is found in organic mucks, silty clays, and even pure sand throughout its range (Golden and Fiedler 1991).

[1] Currently known as *Schoenoplectus californicus*.
[2] Currently known as *Isolepis cernua*.

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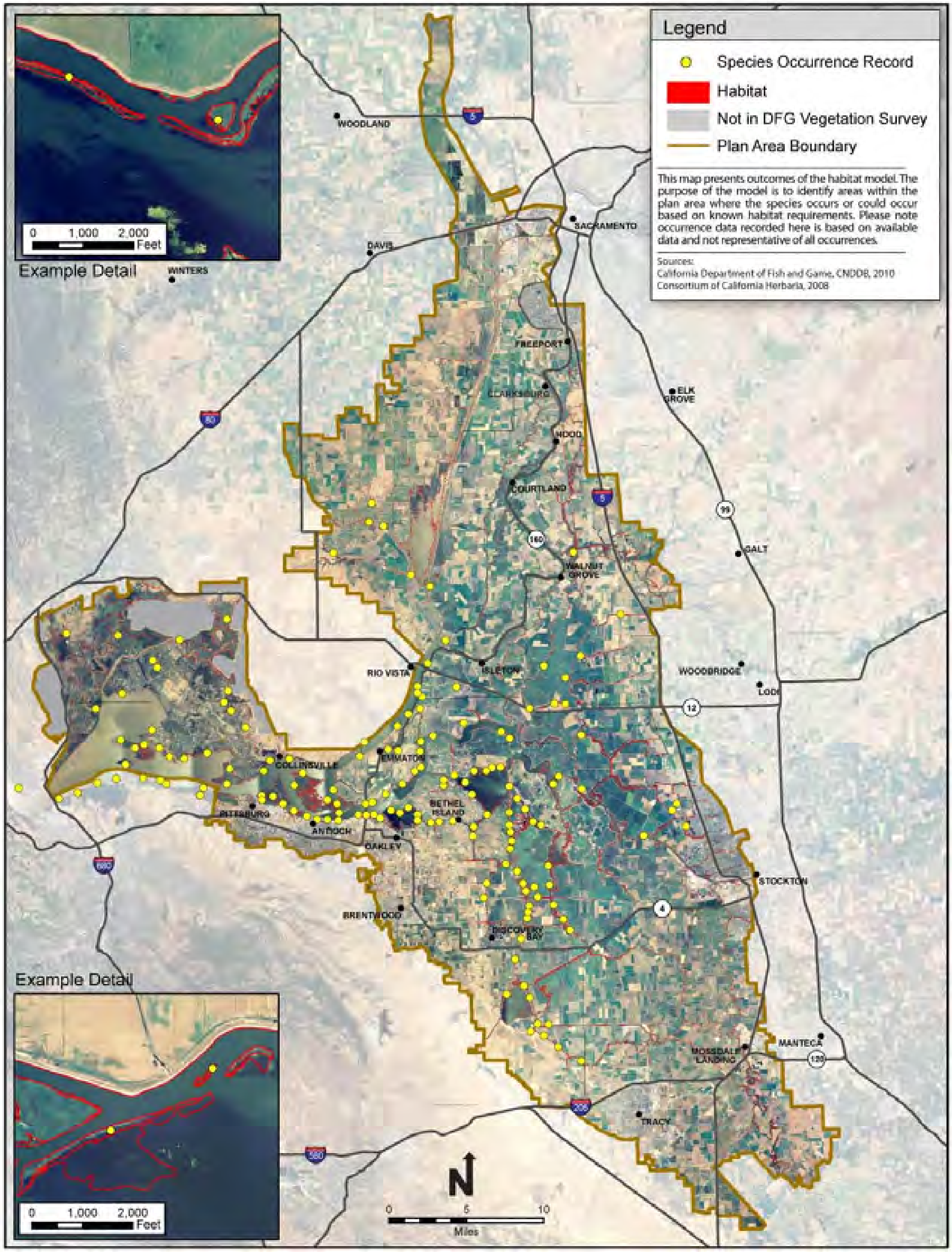

Figure A-58b. Mason's Lilaeopsis Habitat Model and Recorded Occurrences

A58.4 Life History

Mason's lilaeopsis is a small 1.5- to 7.5-centimeter (0.6- to 3-inch) perennial, rhizomatous herb with tufted linear or thread-like jointed leaves and is a member of the carrot family (Apiaceae) (Hickman 1993, DFG 2000). The inflorescences consist of few to several-flowered umbels of tiny white or maroon flowers (Hickman 1993, CNPS 2008), and they bloom from April to November (CNPS 2008). Mason's lilaeopsis primarily reproduces vegetatively by creeping rhizomes or by being dislodged and floating to new sites. Because it is a rhizomatous plant, the number of individuals in a population is difficult to determine. Population size is therefore often expressed as "several colonies" or as an "area." Reported colony sizes range from 16 to 3,000 ft^2 (5 to 700 m^2) (CNDDB 2008).

A58.5 Threats and Stressors

Fishing and hunting access pose a threat to this species due to trampling effects (Witham and Kareofelas 1994).

Reduced habitat. The primary threat to Mason's lilaeopsis is the loss of marsh and floodplain habitat. There are numerous processes and activities that threaten this habitat including erosion, channel stabilization, levee maintenance and construction, flood-control improvements, dredging, dumping spoils, agriculture, recreation, and water quality changes (CNPS 2008, CNDDB 2008). A long-term threat is the stabilization of banks and mudflats due to highly regulated water flow regimes, which can cause floodplain habitat to be less dynamic (Fiedler and Zebell 1993).

Nonnative species. Successional changes in marsh vegetation to denser vegetation types or to types that could grow in the intertidal area could pose an additional threat (CNPS 2008). One example of this type of threat is the invasion of some areas by nonnative water hyacinth (*Eichhornia crassipes*) (Zebell and Fiedler 1996, CNDDB 2008, CNPS 2008). Additionally, diked salt marshes generally lack rare tidal marsh species. It is believed that the conditions brought about by dikes favor robust generalist species that can better tolerate the extremes of inundation and dryness in diked wetlands (Goals Project 2000).

Exposure to toxics. Petroleum product spills could have a significant impact on tidal flat biota, and non-biodegradable litter such as plastics could collect near the tidal drift line, inhibiting plant establishment and growth (Witham and Kareofelas 1994).

A58.6 Relevant Conservation Efforts

Mason's lilaeopsis is found in a range of protected and unprotected sites (Fiedler and Zebell 1993, Witham and Kareofelas 1994, Zebell and Fiedler 1996, CNDDB 2008).

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for Mason's lilaeopsis is "Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP has established a goal to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

Mason's lilaeopsis is a covered species under the approved San Joaquin County Multi-species Habitat Conservation and Open Space Plan. It is also proposed for coverage under the Solano County Multi-species Habitat Conservation Plan and the Yolo County Natural Heritage Program Plan.

A58.7 Species Habitat Suitability Model

Habitat. Mason's lilaeopsis habitat is identified as areas within 10 feet (3 meters) on either side of the landward boundary of tidal perennial aquatic land cover type. Vegetation types designated as species habitat in this model correspond to the mapped vegetation associations in the Bay Delta Conservation Plan (BDCP) geographic information system (GIS) vegetation data layer. Tidal perennial aquatic vegetation type from the Suisun Marsh and Yolo Natural Heritage Program (Boul and Keeler-Wolf 2008, TAIC 2008) classifications was converted to a line shapefile and then buffered 10 ft on either side of each line. For this species, the golf course, artificial lake, and boat docks of Discovery Bay represented a misclassification of land cover in the source data and they were deleted from the GIS vegetation data layer.

Assumptions. Historical and current records of this species indicate that its distribution extends almost throughout the Plan Area, having been observed in tidally influenced waters from Liberty Island southward and from the area of the Clifton Court Forebay northwards (Figure A-58b) (Golden and Fiedler 1991, Fiedler and Zebell 1993, Witham and Kareofelas 1994, Zebell and Fiedler 1996, Suisun Ecological Workgroup 1997, Goals Project 2000, Meisler 2002, May & Associates 2005, CNDDB 2008). While there are no occurrences within the Plan Area north of Liberty Island or significantly south of the Old River channel near the Clifton Court Forebay, patches of suitable habitat extend beyond those areas. For purposes of this model, a 10 foot-wide (3 meter) buffer on each side of the landward edge of the tidal perennial aquatic land cover type (20 foot combined width [6 meter]) is included as the potential extent of tidal mudflat habitat that supports the Mason's lilaeopsis. Within the Plan Area this species' primary habitat is tidally-inundated bare areas of clay or clay loam substrate that is located on the outer margin of wave-cut beaches, or eroding earthen levees, or on the flats immediately below wave-cut beaches and eroding levees (Witham and Kareofelas 1994, Zebell and Fiedler 1996). This substrate-defined habitat has not been mapped separately, but it generally occurs in close association with the tidal perennial aquatic land cover type. Therefore, the habitat model uses the buffered landward boundary of tidal perennial aquatic land cover type as a surrogate for identifying tidal mudflats that support this species' habitat. Mason's lilaeopsis is also found in a range of less suitable habitats that include the spaces between riprap on armored banks and levees which also occur in close association with the tidal perennial aquatic land cover type (Zebell and Fiedler 1996).

A58.8 Recovery Goals

A United States Fish and Wildlife (USFWS) recovery plan has not been prepared for this species and no recovery goals have been established; however, the CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for Mason's lilaeopsis is "Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP has established a goal to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

A58.9 References

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APPENDIX A59. DELTA MUDWORT *(LIMOSELLA SUBULATA)*

A59.1 LEGAL STATUS

Delta mudwort (*Limosella subulata*) is not listed under either federal or California endangered species acts. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G4?Q/S2.1 which means that the species as a whole is apparently secure across its overall distribution, but some factors of concern, such as narrow habitat or continuing threats, do exist. The "?" portion of the rank indicates that there is uncertainty about the rank. The "Q" portion of the rank indicates that unresolved taxonomic questions remain for this rare species. The state level rank of distribution indicates that in the State of California, there are either between six to 20 viable element occurrences of this species, 1,000 to 3,000 individuals, or 2,000 to 10,000 acres (809 to 4,047 hectares) where this species occurs. Its state threat level rank is "very threatened."

The California Native Plant Society (CNPS) List ranking of 2.1 for Delta mudwort indicates that it is rare, threatened, or endangered in California, but more common elsewhere. It is considered by CNPS to be seriously endangered in California with over 80 percent of occurrences threatened. Without the wider distribution outside of California, plants on CNPS List 2 would be placed on List 1B. Plants with a CNPS List rank of 1B are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

A59.2 SPECIES DISTRIBUTION AND STATUS

A59.2.1 Range and Status

In California, Delta mudwort is found only in the Sacramento-San Joaquin Delta region (Figure A-59a). Its range extends from Solano County in the north, San Joaquin County in the south, Contra Costa County in the west, and Sacramento County in the east. Outside of California, it can be found in British Columbia, on the east coast of North America, and in Europe (Hickman 1993). On the east coast of the United States, it is threatened by habitat destruction (CNPS 2008).

A59.2.2 Distribution and Status in the Plan Area

Within the Plan Area, Delta mudwort occurs in the tidal zones of marshes, rivers, and creeks, predominantly in the central area of the legal Delta (Figure A-59b). It has been observed within the tidal zone along Calhoun Cut and Barker Slough (Witham and Kareofelas 1994), in the Miner Slough Wildlife Area, along Montezuma Slough, near Three Mile Slough, at Brown's Island, and near Collinsville among other locations throughout the Delta (CNDDB 2008).

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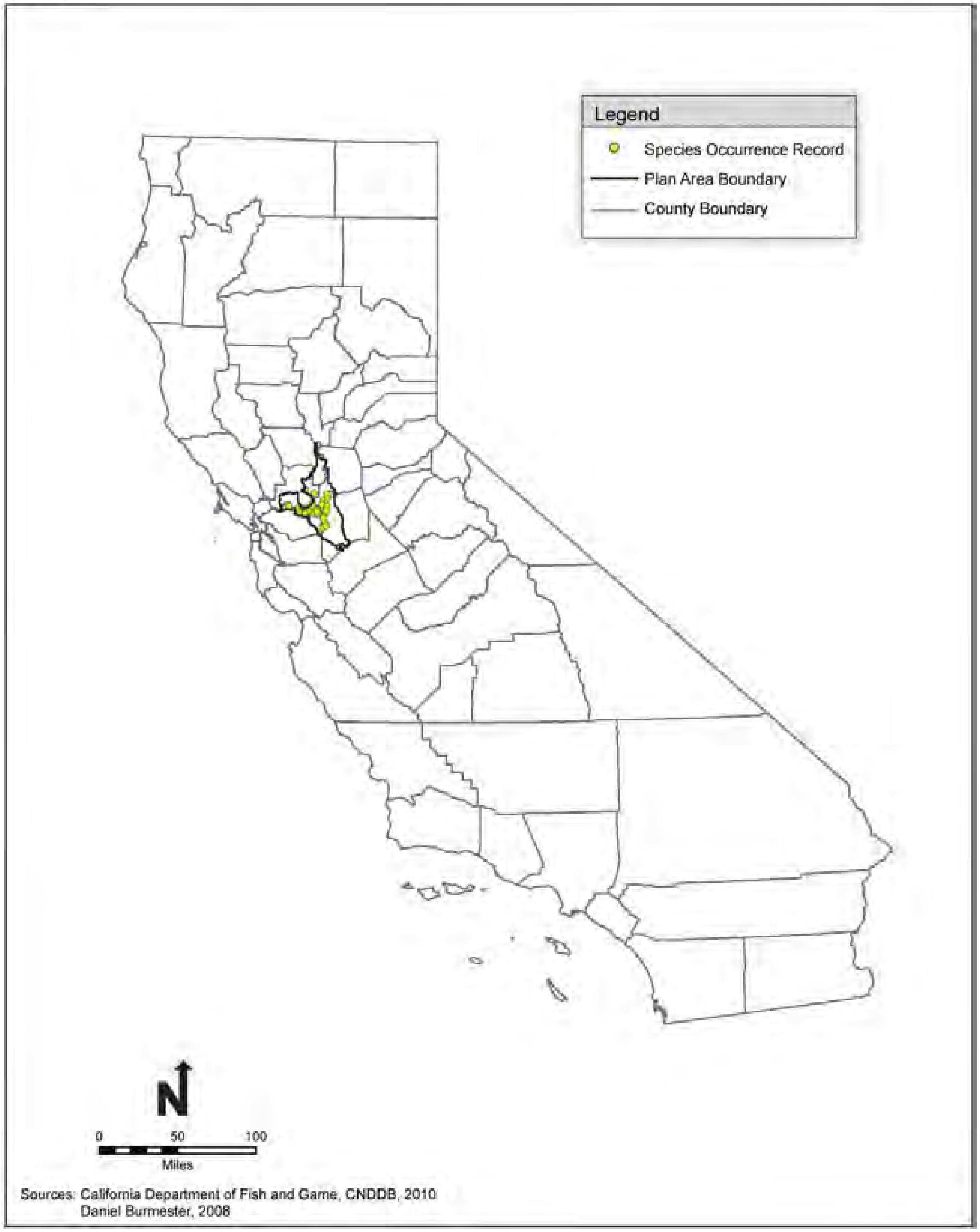

Figure A-59a. Delta Mudwort Statewide Recorded Occurrences

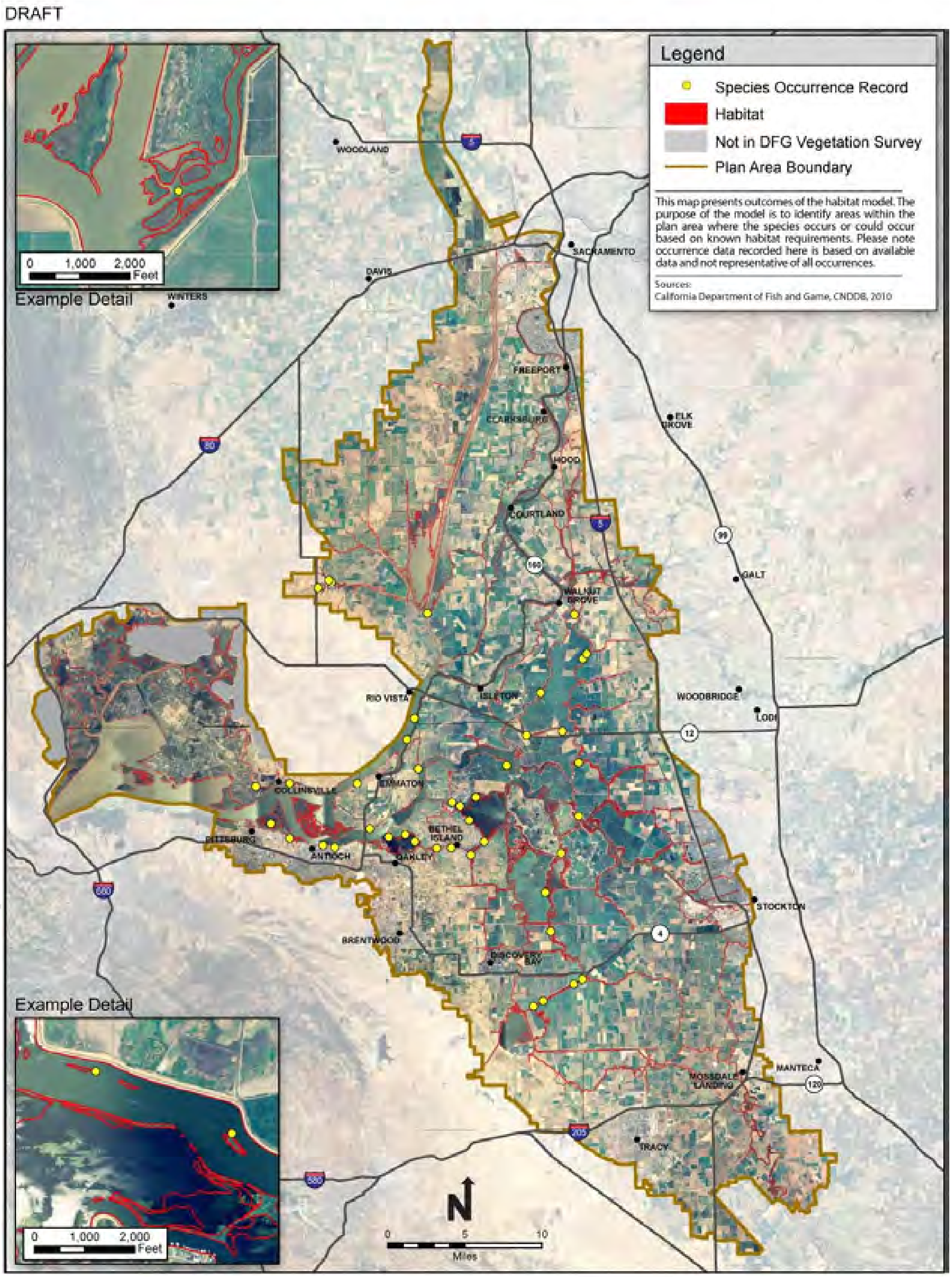

Figure A-59b. Delta Mudwort Habitat Model and Recorded Occurrences

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It is found in brackish and freshwater tidal marsh plant communities along with Mason's lilaeopsis (*Lilaeopsis masonii*) immediately below the tidal elevation where Delta tule pea (*Lathyrus jepsonii* var. *jepsonii*) and Suisun Marsh aster (*Symphyotrichum lentum*) are commonly found (Witham and Kareofelas 1994).

A59.3 Habitat Requirements and Special Considerations

Delta mudwort grows on intertidal flats and muddy banks of watercourses in estuarine areas, surrounded by brackish or freshwater marsh and riparian scrub vegetation. Occasionally it can be found along the edges of tule marshes (Witham and Kareofelas 1994). It blooms from May to August (Hickman 1993, CNPS 2008) and has been observed associated with or near other Bay Delta Conservation Plan (BDCP) covered species Mason's lilaeopsis, Delta tule pea, and Suisun Marsh aster (Witham and Kareofelas 1994, May & Associates 2005). Although the data are somewhat inconclusive, Delta mudwort appears to be more sensitive to salinity concentrations near or greater than 7 parts per thousand than is Mason's lilaeopsis, with substantially reduced flowering and seed germination rates (Golden and Fiedler 1991, Fiedler and Zebell 1993, Zebell and Fiedler 1996).

A59.4 Life History

Delta mudwort is a stoloniferous, aquatic, perennial herb in the snapdragon family (Scrophulariaceae). The leaves are 1 to 3 centimeters (0.4 to 1.2 inches) long and cylindrical, giving the plant a "grasslike" appearance. The stems bear solitary white to lavender-blue flowers approximately 3 millimeters (0.1 inch) in length (Hickman 1993). Delta mudwort strongly resembles Mason's lilaeopsis when vegetative (before flowering and fruiting). The bell-shaped flowers of Delta mudwort make it easy to distinguish when in bloom. When not blooming, Mason's lilaeopsis can be distinguished by partitions in its cylindrical leaves; while Delta mudwort lacks this feature (Witham and Kareofelas 1994). The California Department of Fish and Game (DFG) considers the Delta mudwort to be native to California (R. Bittman pers. comm.), while *The Jepson Manual* (Hickman 1993) identifies the species as not native to California.

A59.5 Threats and Stressors

Delta mudwort is threatened by habitat destruction, including alteration of hydrology and recreational activities such as boating, which creates wakes that erode banks and shorelines. Fishing and hunting access also pose a threat to this species (Witham and Kareofelas 1994). Petroleum product spills could have a significant impact on tidal flat biota, and non-biodegradable litter such as plastics could collect near the tidal drift line, inhibiting plant establishment and growth (Witham and Kareofelas 1994).

A59.6 RELEVANT CONSERVATION EFFORTS

Populations are preserved on the DFG Calhoun Cut Ecological Preserve and in the Miner Slough Wildlife Area (CNDDB 2008).

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designates the Delta mudwort as "Contribute to Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its control and within its scope that are necessary to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

Delta mudwort is a covered species under the approved San Joaquin County Multi-species Habitat Conservation and Open Space Plan. It is also proposed for coverage under the Solano County Multispecies Habitat Conservation Plan.

A59.7 SPECIES HABITAT SUITABILITY MODEL

Habitat. Vegetation types designated as species habitat in this model correspond to the mapped vegetation associations in the BDCP geographic information system (GIS) vegetation data layer. Tidal perennial aquatic vegetation type from the BDCP GIS vegetation dataset, Suisun Marsh, and Yolo Natural Heritage Program (Boul and Keeler-Wolf 2008, TAIC 2008) classifications was converted to a line shapefile and then buffered 10 feet (3 meters) on either side of each line. For this species, the golf course, artificial lake, and boat docks of Discovery Bay represented a misclassification of land cover in the source data and they were deleted from the GIS vegetation data layer. Delta mudwort habitat is identified as all areas within 10 feet on either side of the landward boundary of tidal perennial aquatic land cover type.

Assumptions. Historical and current records of this species indicate that its distribution extends almost throughout the Plan Area having been observed in tidally influenced waters from Liberty Island southward and from the area of the Clifton Court Forebay northwards (Figure A-59b) (Fiedler and Zebell 1993, Witham and Kareofelas 1994, Zebell and Fiedler 1996, CNDDB 2008). While there are no occurrences within the Plan Area north of Liberty Island or significantly south of the Old River channel near the Clifton Court Forebay, patches of suitable habitat extend beyond those areas. For purposes of this model, a 10-foot wide buffer on each side of the landward edge of the tidal perennial aquatic land cover type (20 foot combined width) is included as the potential extent of tidal mudflat habitat that supports this species. Within the Plan Area this species' primary habitat is tidally inundated bare areas of clay or clay loam substrate on the outer margin of wave-cut beaches, or eroding earthen levees, or on the flats immediately below wave-cut beaches and eroding levees (Witham and Kareofelas 1994, Zebell and Fiedler 1996). This substrate-defined habitat has not been separately mapped, but it generally occurs in close association with the tidal perennial aquatic land cover type. Therefore, the habitat model uses the buffered landward boundary of tidal perennial aquatic land cover type as a surrogate for identifying tidal mudflats that support habitat for Delta mudwort.

A59.8 RECOVERY GOALS

A United States Fish and Wildlife (USFWS) recovery plan has not been prepared for this species and no recovery goals have been established; however, the CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designates the Delta mudwort as "Contribute to Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP will undertake actions under its control and within its scope that are necessary to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

A59.9 REFERENCES

A59.9.1 Literature Cited

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A59.9.2 Personal Communications

Roxanne Bittman (Senior Biologist, California Department of Fish and Game, Sacramento, CA), email to John Gerlach regarding the native status of Delta mudwort (*Limosella subulata*). September 15, 2008.

APPENDIX A60. ANTIOCH DUNES EVENING PRIMROSE *(OENOTHERA DELTOIDES SSP. HOWELLII)*

A60.1 LEGAL STATUS

Antioch Dunes evening primrose (*Oenothera deltoides* ssp. *howellii*) is listed as endangered under both the Federal Endangered Species Act (April 1978) (43 FR 17910) and the California Endangered Species Act. It is endemic to a former dune near the city of Antioch, California. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G5T1/S1.1 which means that globally (G) the species is demonstrably secure to ineradicable due to being commonly found in the world, but the subspecies or variety (T) is has less than 6 viable element occurrences, less than 1,000 individuals, or less than 2,000 acres (809 hectares); and within the state (S) the threat level rank is "very threatened."

The California Native Plant Society (CNPS) List ranking of 1B.1 for Antioch Dunes evening primrose indicates that it is rare, threatened, or endangered in California (List 1B); the threat ranking (.1) indicates that it is considered by CNPS to be seriously threatened in California (high degree/immediacy of threat). Plants with a CNPS List rank of 1B are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

United States Fish and Wildlife Service (USFWS)-designated critical habitat that specifies the protection of Antioch Dunes evening primrose habitat lies in and adjacent to the USFWS Antioch Dunes National Wildlife Refuge (NWR) (43 FR 39042). This critical habitat was specifically established for this and two other endangered species. The designated critical habitat is entirely within the Plan Area.

A60.2 SPECIES DISTRIBUTION AND STATUS

A60.2.1 Range and Status

Antioch Dunes evening primrose has an extremely restricted range. It is found only on a 20-acre (8-hectare) remnant of a former 190-acre (77-hectare) dune (plus an unknown amount of two Pacific Gas & Electric [PG&E] parcels that total 12 acres [5 hectares]) near the city of Antioch, California and has been introduced into a sandy area on Brown Island and on sandy dredged material on Brannan Island (USFWS 1984, 2001, 2008, 2010) (Figure A-60a). There are CNDDB records indicating that it occurs just north of the town of Oakley, but according to herbarium records, those collections are apparently *Oenothera deltoides* ssp. *cognata* (CNDDB 2010, Consortium of California Herbaria 2010, USFWS 2010). Recent life history and molecular marker research is consistent with the morphological distinctness of the two taxa (Evans et al. 2005, 2007, 2009).

Figure A-60a. Antioch Dunes Evening-Primrose Statewide Recorded Occurrences

Antioch Dunes evening primrose is protected on the Antioch Dunes NWR, on two small adjacent parcels owned by PG&E, which manages the property in cooperation with USFWS, and on Brannan Island State Recreation Area (BISRA) (USFWS 1984, 2001, 2008, 2010).

A60.2.2 Distribution and Status in the Plan Area

The entire distribution of Antioch Dunes evening primrose is within the Plan Area on the Antioch Dunes NWR, PG&E, and BISRA properties as described above (Figure A-60b).

A60.3 Habitat Requirements and Special Considerations

Antioch Dunes evening primrose is restricted to the former dune near the city of Antioch, California (USFWS 1984, 2001, 2008, 2010). This soil of the dune has been mapped as Oakley sand (Carpenter and Cosby 1939) and Delhi sand, 2 to 9 percent slopes (NRCS 2010) and is an infertile, very uniform textured, fine sand with very little clay content. Experiments at Antioch Dunes NWR have found that Antioch Dunes evening primrose will grow and reproduce on soils with a slightly higher clay content if the soil is disturbed to break up the crust (Pavlik and Manning 1993).

A60.4 Life History

The Antioch Dunes evening-primrose is a short-lived perennial in the evening-primrose family (Onagraceae) (USFWS 2010). It forms large tufts with coarse, drooping, much branched stems from 4 to 40 inches (10 to 101 centimeters [cm]) long. Leaves are lance-like in outline, 1-5 inches (2.5-12.7 cm) long, 0.4-1.2 inches (1-3 cm) wide, with grayish hairs. It has white flowers and blooms from March to September. The petals are about one inch long and the stamens are yellow. Antioch Dunes evening-primrose is considered to be an out-breeding species pollinated by hawk moths at night and a variety of insects during the day and its reproductive ability may currently be reduced either by insufficient pollinators or by an insufficient number of compatible genotypes (Pavlik et al. 1993, Evans et al. 2005, USFWS 2008, Evans et al. 2009).

Invasive plants are one of the primary threats to Antioch Dunes evening primrose because they cause habitat loss and may compete for soil moisture (USFWS 2008, 2010). The most common invasive nonnative grasses and forbs found at the refuge include ripgut brome (*Bromus diandrus*), winter vetch, (*Vicia villosa*) and star thistle (*Centaurea solstitialis*). Wildfires started by trespassers on the Antioch Dunes NWR are another serious threat.

A60.5 Relevant Conservation Efforts

Antioch Dunes evening primrose was declining significantly at Antioch Dunes NWR and appeared to be headed towards extinction until an out-planting of nursery-grown stock and direct seeding into restored sandy habitat in 2005 and 2006 appears to have stopped the decline.

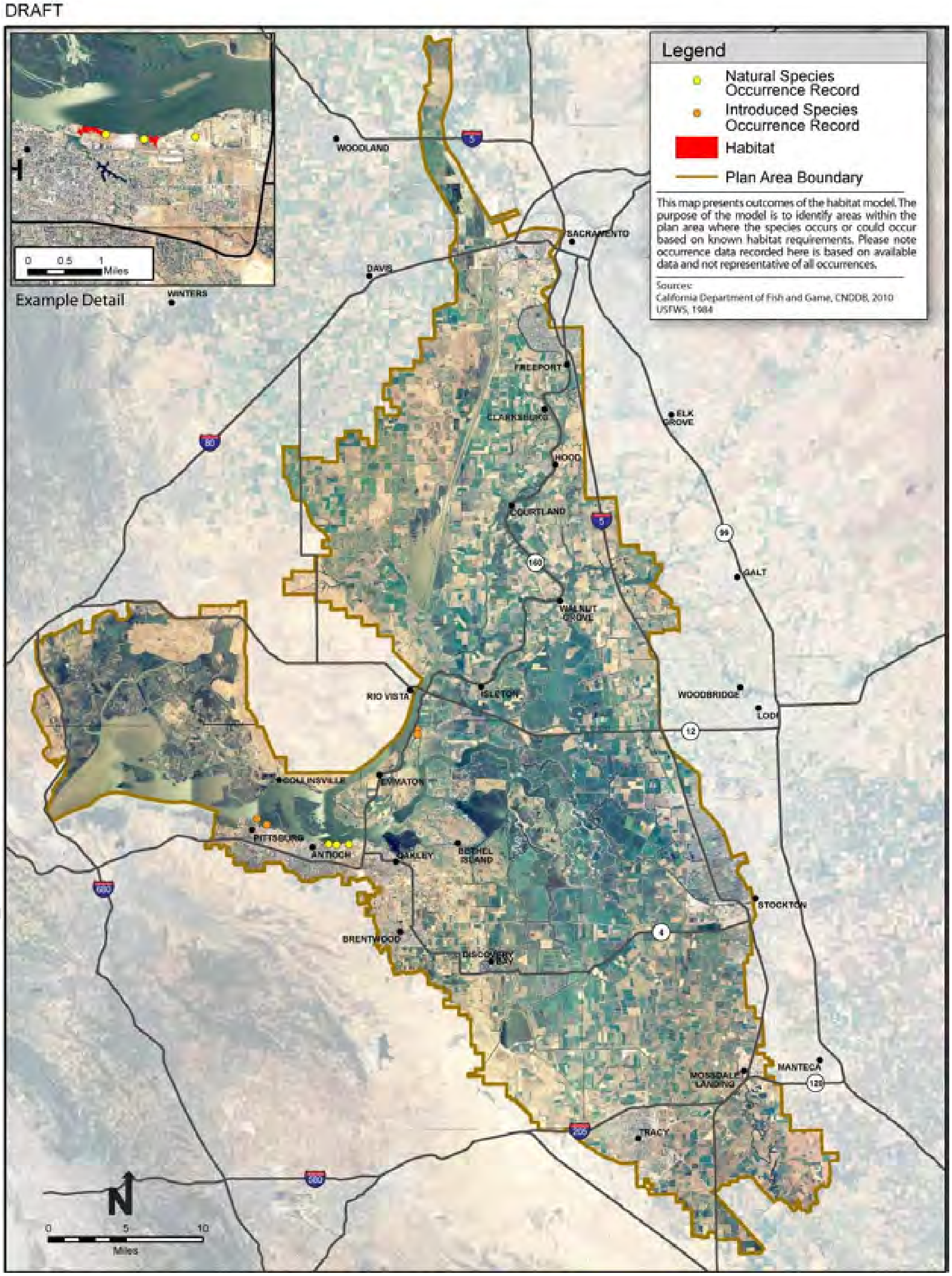

Figure A-60b. Antioch Dunes Evening-Primrose Habitat Model and Recorded Occurrences

Mowing is currently being used to control invasive species at Antioch Dunes NWR, and Antioch Dunes evening primrose appears to have increased in 2009 and 2010 (L.Terrazas in litt.). However, the population is not yet considered to be self-sustaining because of invasive species problems (USFWS 2008).

While the enhancement of the natural population through the out-planting and seeding of nursery grown material may have slowed or stopped its population decline, it is not clear that this management tactic will preserve the genetic uniqueness of this subspecies. First of all, Antioch Dunes evening primrose is considered to be a "microendemic" species that is adapted to a very unique set of environmental characteristics provided by a 120-foot (36.5-meter) high dune in the western Delta (Evans et al. 2005, Evans et al. 2009). Given the general windiness of that portion of the Delta, there would be large differences in temperature, wind velocity, and evapotranspiration rates between the pristine dune and the 30-foot (9-meter) high remnant where Antioch Dunes evening primrose persists through the augmentation program. The conditions acted on the genetic variation present in the ancestral genotype to produce the microendemic taxon that is the Antioch Dunes evening primrose. Neither the remnant dune environment nor the nursery growth conditions replicate the conditions of the pristine dune and will instead act as artificial selective agents to produce a new partially domesticated genotype that is distinct from the Antioch Dunes evening primrose as it existed prior to the destruction of the dune, development of the surrounding land, and recent recovery efforts. Secondly, survey data strongly suggest that Antioch Dunes evening primrose produces a dormant seed bank similar to other evening primrose species (USFWS 1984, 2001, Evans et al. 2005, USFWS 2008, Evans et al. 2009). Seed banks are a unique evolutionary response to unpredictable variation in the environment that represent a decrease in measures of fitness such as seed production in average environments by not germinating and remaining as a seed and increasing fitness over the long-term in exceptional environments (Evans et al. 2007). Again, neither the remnant dune environment nor the nursery growth conditions replicate the environmental conditions of the pristine dune and will instead act as artificial selective agents to produce a new partially domesticated genotype that is distinct from Antioch Dunes evening primrose.

The current management plan for the Antioch Dunes NWR provides for invasive nonnative plant species control efforts which are being implemented by hand pulling individual invasive plants through the efforts of volunteers, and targeted herbicide application (USFWS 2001, 2008). Controlled burns have been discontinued as a management tool (L. Terrazas in litt.).

A60.6 Species Habitat Suitability Model

Model Approach. The Bay Delta Conservation Plan (BDCP) species habitat suitability models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nevertheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lower probability of species occurrence compared with areas identified as suitable habitat.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided in Hickson and Keeler-Wolf 2007. Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include incorporating buffers, connectivity between habitat types, and specific land use types, such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life history requirements. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS Model Data Sources. The Antioch Dunes evening primrose habitat suitability model is based on the California Department of Fish and Game (DFG) mapping of Delta vegetation (Hickson and Keeler-Wolf 2007).

Habitat. The modeled habitat for Antioch Dunes evening primrose consists of two shrub dominated vegetation associations from the Antioch Dunes NWR (Hickson and Keeler-Wolf 2007).

Vegetation Units. The following vegetation subunits were selected from the DFG vegetation units (Hickson and Keeler-Wolf 2007):

- *Lupinus albifrons* Antioch Dunes Association
- *Lotus scoparius* Antioch Dunes Association

A60.7 Recovery Goals

A USFWS revised recovery plan for Antioch Dunes evening primrose was approved in 1984 but the very recent 5-year species review (USFWS 2008) found that there are no recovery criteria listed in the Recovery Plan. The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for Antioch Dunes evening primrose is "Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP has established a goal to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

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APPENDIX A61. SIDE-FLOWERING SKULLCAP (*SCUTELLARIA LATERIFLORA)*

A61.1 LEGAL STATUS

Side-flowering skullcap (*Scutellaria lateriflora*) is not listed under either federal or California endangered species acts. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G5/S1.2 which means that globally (G) the species population is secure or ineradicable due to being common outside of California, but within California (S) there are either less than six viable element occurrences, less than 1,000 individuals, or less than 2,000 acres (809 hectares) of occupied habitat. Its state threat level rank is “threatened.”

The California Native Plant Society (CNPS) List ranking of 2.2 for side-flowering skullcap indicates that it is rare, threatened, or endangered in California but more common elsewhere, and is considered by CNPS to be fairly endangered in California. Plants with a CNPS List rank of 2 are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

A61.2 SPECIES DISTRIBUTION AND STATUS

A61.2.1 Range and Status

The known range of side-flowering skullcap within California is limited to the Delta where it has been reported from two areas (Figure A-61a). In 1892 it was reported from Bouldin Island but that occurrence has not been relocated (CNDDB 2010). The other areas where it occurs are in the vicinity of Delta Meadows State Park where it was discovered during plant surveys in 1993; and in Sycamore Slough where it was discovered during the California Department of Water Resources/Delta Habitat Conservation and Conveyance Program (DWR/DHCCP) botanical survey of Delta waterways for the Bay Delta Conservation Plan (BDCP) in the summer of 2009 (CNDDB 2010). The DWR/DHCCP survey also found additional occurrences in the Delta Meadows State Park area (CNDDB 2010). At Delta Meadows Park side-flowering skullcap is found at upper tidal ranges growing on stumps and old pilings along tidal channels. It has also been recorded from a crop field on an herb farm in Gilroy in Santa Clara County (Hrusa 1999). A reported occurrence from Saline Valley in Inyo County has been determined to be erroneous (R. Bittman pers. com.) (CNDDB 2010).

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Figure A-61a. Side-Flowering Skullcap Statewide Recorded Occurrences

A61.2.2 Distribution and Status in the Plan Area

As noted above, side-flowering skullcap appears to occur in California only within the Plan Area on Bouldin Island in San Joaquin County and in the Delta Meadows State Park area in Sacramento County (Figure A-61b) (CNDDB 2010). The Bouldin Island location was recorded in 1892 and the exact location of the collection is unknown. The Delta Meadows State Park occurrence was recorded in 1993. During botanical surveys of the Plan Area conducted by DWR/DHCCP in the summer of 2009 it was found growing on rotting pilings and stumps in and along the channels of Snodgrass Slough, Lost Slough, and the Mokelumne River. No additional occurrences of this species were discovered during the 2009 surveys conducted along channels in the north, west, south, and central Delta.

A61.3 HABITAT REQUIREMENTS AND SPECIAL CONSIDERATIONS

Side-flowering skullcap is a widespread species of swamps, marshes, and bogs in the central and eastern US, but rarely is it abundant (USDA 2010). It occurs in wet meadows, seeps, marshes and swamps (Holman et al. 2007, CNDDB 2010, CNPS 2010, E-Flora BC 2010, University of Washington Herbarium 2010, USDA 2010). Most relevant to the Plan Area is its occurrence in freshwater tidal swamps along the Pacific Northwest and in the Carolinas that are dominated by a variety of tree species (Holman et al. 2007, E-Flora BC 2010, University of Washington Herbarium 2010). In the freshwater tidal swamps it is found almost exclusively on hummocks formed by stumps and downed wood which place it in the higher regions of the tidal range. This ensures that the plant is well watered but not growing in anaerobic soils.

In the Delta Meadows State Park area it co-occurs with marsh skullcap (*Scutellaria galericulata*), apparently on the same stumps and pilings, which before the DWR/DHCCP surveys was only known from the Delta in the vicinity of Woodward Island despite being common in the northern Sierra Nevada, and with false nettle (*Boehmeria cylindrica*), which is not native to California. All three species frequently co-occur in the Midwest and on the East Coast.

A61.4 LIFE HISTORY

Side-flowering skullcap is a perennial rhizomatous herb 7 to 24 inches (20 to 60 centimeters [cm]) long (Hickman 1993, CNPS 2010). The 0.5 to 1 inch (1.3 to 2.5 cm) opposite leaves crowd down toward the base of the stem and support blue-purple to white flowers of about the same size that are typically produced along the length of side branches that grow from nodes of the main stem. Flowers are grouped in pairs and oriented on one side of the stem. The stem can be erect, branched, or some other type, ranges from light green to pale reddish-green, and may be smooth or sparsely covered with short hairs < 0.02 inch (< 0.5 millimeter) long. It blooms from July to September (CNPS 2010. It can produce small, more or less spherical brown fruit (Hickman 1993). This species is also used as a medicinal herb.

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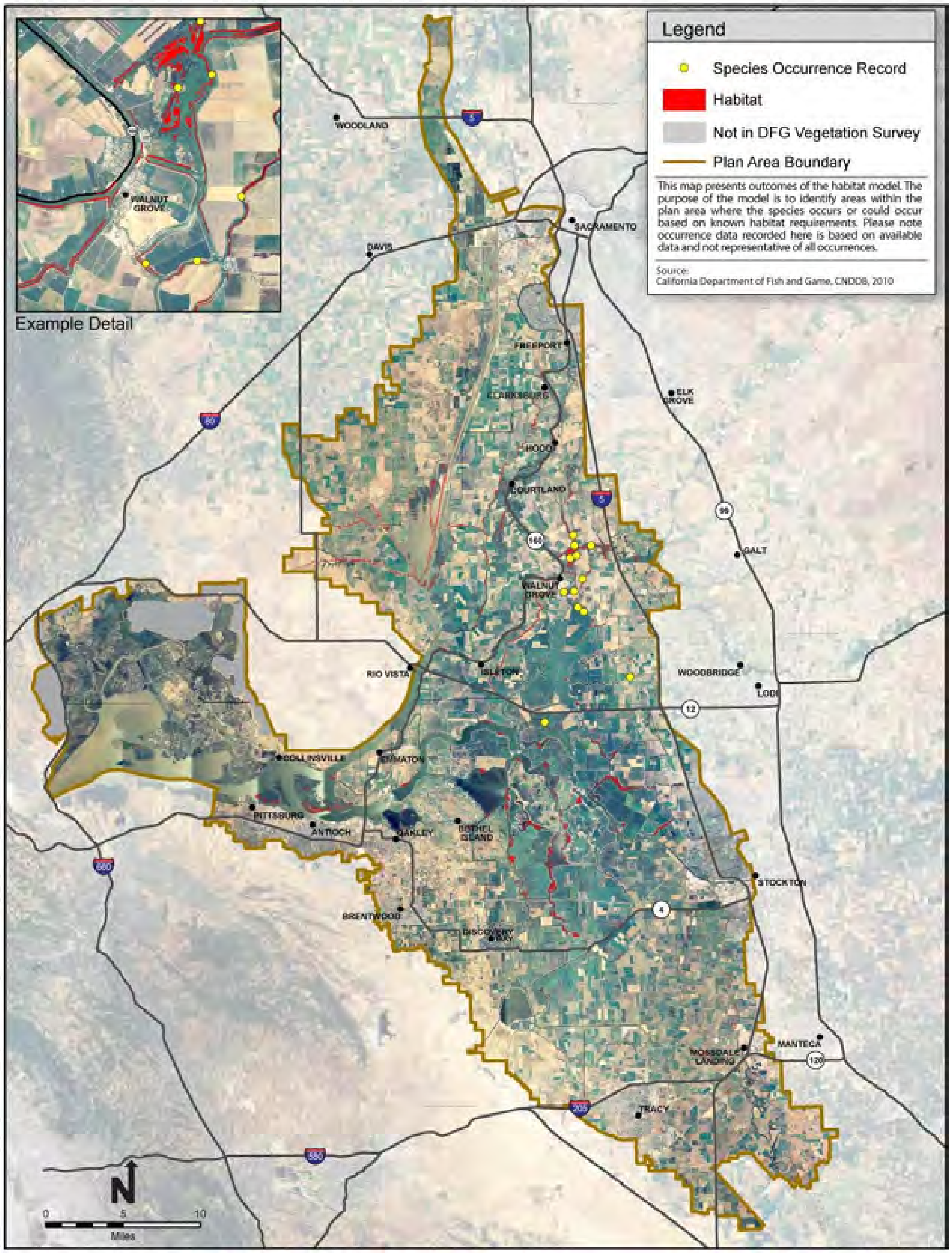

Figure A-61b. Side-Flowering Skullcap Habitat Model and Recorded Occurrences

A61.5 Threats and Stressors

While side-flowering skullcap populations are deemed secure globally (CNDDB 2010), general threats to wetland habitats around the world include development, intensive agriculture, and exotic plant species. Side-flowering skullcap grows on logs, stumps, and other large woody material along shoreline that supports primarily riparian and some marsh vegetation and lack of shoreline coarse woody material may be a limiting factor in parts of the Delta.

A61.6 Relevant Conservation Efforts

Most side-flowering skullcap plants found in the Plan Area are located within or directly adjacent to Delta Meadows State Park, a California State Park that was established to preserve and protect one of the last remaining areas of the northern Sacramento-San Joaquin River Delta that possesses large stands of fairly mature riparian vegetation (California State Parks 2010).

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for side-flowering skullcap is "Maintain" (CALFED Bay-Delta Program 2000). This designation indicates that the ERP will undertake actions to maintain the species by avoiding, minimizing, and compensating for any adverse effects to the species created by ERP restoration actions. It also means that the species' population and habitat are unlikely to be affected by ERP actions.

A61.7 Species Habitat Suitability Model

BDCP Species Habitat Suitability Models are formulated primarily using vegetation data from existing geographic information system (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to provide conservative results with respect to the extent of suitable habitat. The tendency is to overestimate suitable habitat by attempting to be as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, due to minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas that are below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small isolated habitats, such as vernal pools, individual trees, or small groups of trees. It is also possible, as with the side-flowering skullcap, to underestimate potentially-occupied habitat due to the lack of information on stumps and downed wood substrate on which it is found.

Still, for most species the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas identified as non-habitat; but instead indicate that non-habitat areas have a much lowered probability of species occurrence compared with areas identified as suitable habitat.

For each model, the mapping data sets and each vegetation type or association is identified. Finally, the assumptions used in the formulation of the model are described and if and how the model is expected to over- or under-estimate the extent of habitat in the Plan Area.

GIS model data sources. The side-flowering skullcap model is based on the following data set: Hickson and Keeler-Wolf 2007.

Vegetation Units. The following DFG vegetation subunits were selected from the BDCP Valley Riparian natural community as mapped by Hickson and Keeler Wolf 2007:

- *Alnus rhombifolia* / *Cornus sericea;*
- *Alnus rhombifolia* / *Salix exigua* (*Rosa californica*);
- California dogwood (*Cornus sericea*);
- *Cornus sericea* - *Salix exigua;*
- *Cornus sericea* - *Salix lasiolepis* / (*Phragmites australis*);
- *Quercus lobata* - *Alnus rhombifolia* (*Salix lasiolepis* - *Populus fremontii* - *Quercus agrifolia*);
- *Salix lasiolepis* - (*Cornus sericea*) / *Scirpus* spp.- (*Phragmites australis* - *Typha* spp.) complex unit;
- White alder (*Alnus rhombifolia*); and
- White alder (*Alnus rhombifolia*) - Arroyo willow (*Salix lasiolepis*) restoration.

Soils. Side-flowering skullcap is found primarily on stumps and downed wood both within the Delta Plan Area and regions that are similar to Delta habitats. Therefore, the presence of stumps and downed wood seems to be more of a determining factor of the presence of side-flowering skullcap than soil type. Moist soils with plenty of organic matter would most closely resemble woody substrate.

Assumptions. *Cornus sericea* is an appropriate species to use for a preliminary side-flowering skullcap species model due to its association with marsh skullcap and side-flowering skullcap and because it can provide the habitat characteristics that side-flowering skullcap seems to require, namely, woody substrate in freshwater tidal areas.

A61.8 Recovery Goals

Side-flowering skullcap is not a federally or state listed species. No recovery goals have been formulated for this species. Possible conservation measures could include avoidance, collection of clones by moving woody substrate with plants to new locations in the appropriate tidal range, and by the restoration of tree dominated vegetation along the uppermost limits of freshwater tidal areas in the Delta.

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APPENDIX A62. SUISUN MARSH ASTER *(SYMPHYOTRICHUM LENTUM, FORMERLY ASTER LENTUS)*

A62.1 LEGAL STATUS

Suisun Marsh aster (*Symphyotrichum lentum*, formerly *Aster lentus*) is not listed under either federal or California endangered species acts. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G2/S2.2, which means that globally (G) and within the state (S) there are either between six to 20 viable element occurrences of this species, 1,000 to 3,000 individuals of this species, or 2,000 to 10,000 acres (809 to 4,047 hectares) where this species occurs. The state threat level rank is "threatened."

The California Native Plant Society (CNPS) List rank of 1B.2 for Suisun Marsh aster indicates that it is rare, threatened, or endangered in California and elsewhere, and is considered by CNPS to be fairly endangered in California with between 20 to 80 percent of occurrences threatened. Plants with a CNPS List rank of 1B are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

A62.2 SPECIES DISTRIBUTION AND STATUS

A62.2.1 Range and Status

The range of Suisun Marsh aster extends from Napa and Solano counties in the north, to San Joaquin County in the south, to Contra Costa County in the west, and Sacramento County in the east (Figure A-62a). It is endemic to Suisun Marsh and the Sacramento-San Joaquin Delta (CNDDB 2008, CNPS 2008). Historically, it was known from marshes in the East Bay portion of San Francisco Bay (California State Coastal Conservancy 2003) and the Sonoma and Napa rivers (Goals Project 2000).

A62.2.2 Distribution and Status in the Plan Area

Within the Plan Area, Suisun Marsh aster occurs in tidal areas throughout the west and central Delta and Suisun Marsh with scattered occurrences in the north and south Delta (Figure A-62b). Suisun Marsh aster occurs at the upper margin and immediately above the tidal zones of fresh and brackish marshes and along rivers and creeks. It has been observed on Andrus Island, Terminous Tract, Rindge Tract, Bethel Island, Franks Tract, and near Collinsville and Antioch among other locations in the Plan Area (CNDDB 2008). A large single occurrence was once reported along Baker Slough and Lindsey Slough on the Calhoun Cut Ecological Reserve, but more recently it has been remapped as several smaller polygons (Witham and Kareofelas 1994) and many new occurrences were mapped in that same area in 1994 (Witham and Kareofelas).

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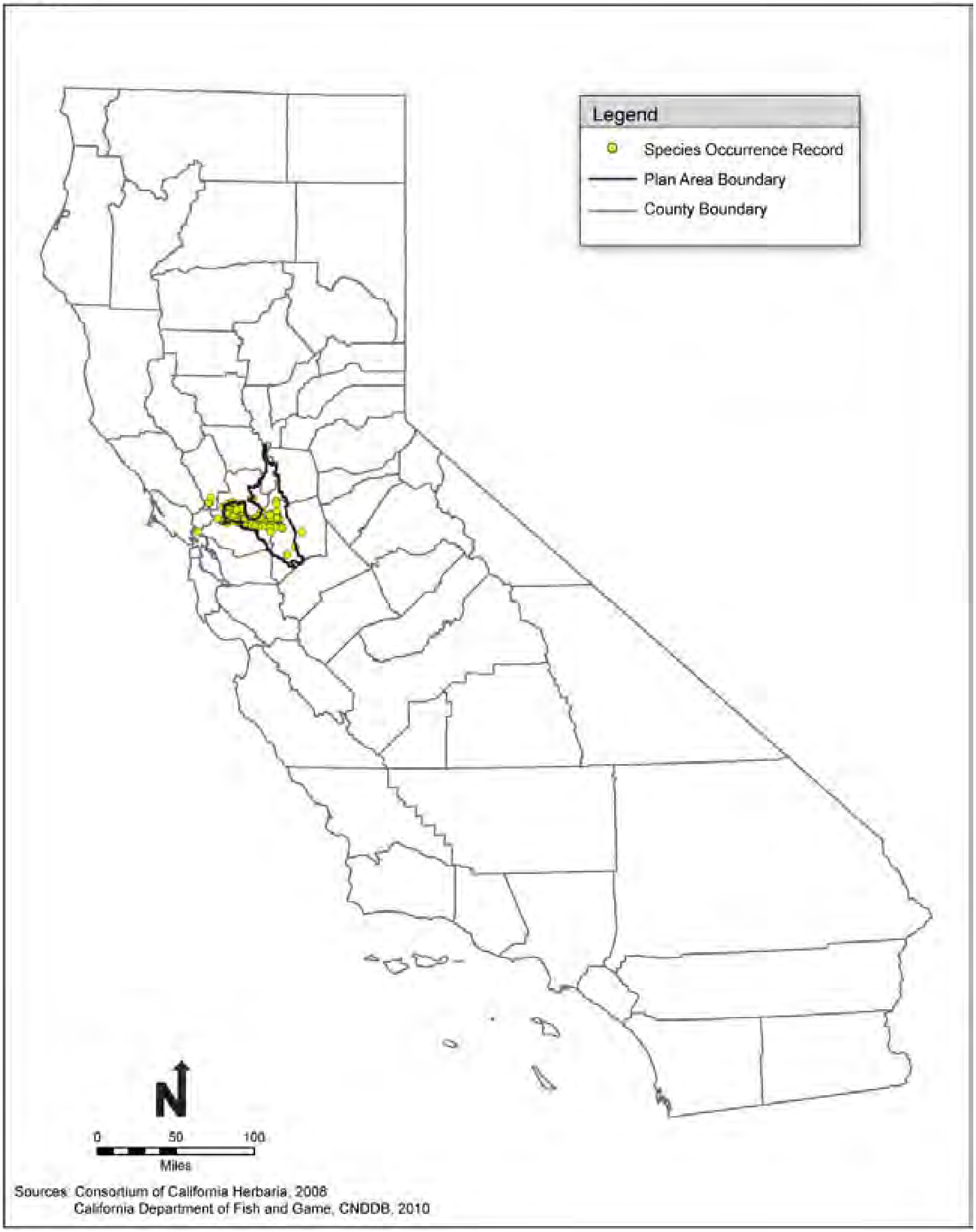

Figure A-62a. Suisun Marsh Aster Statewide Recorded Occurrences

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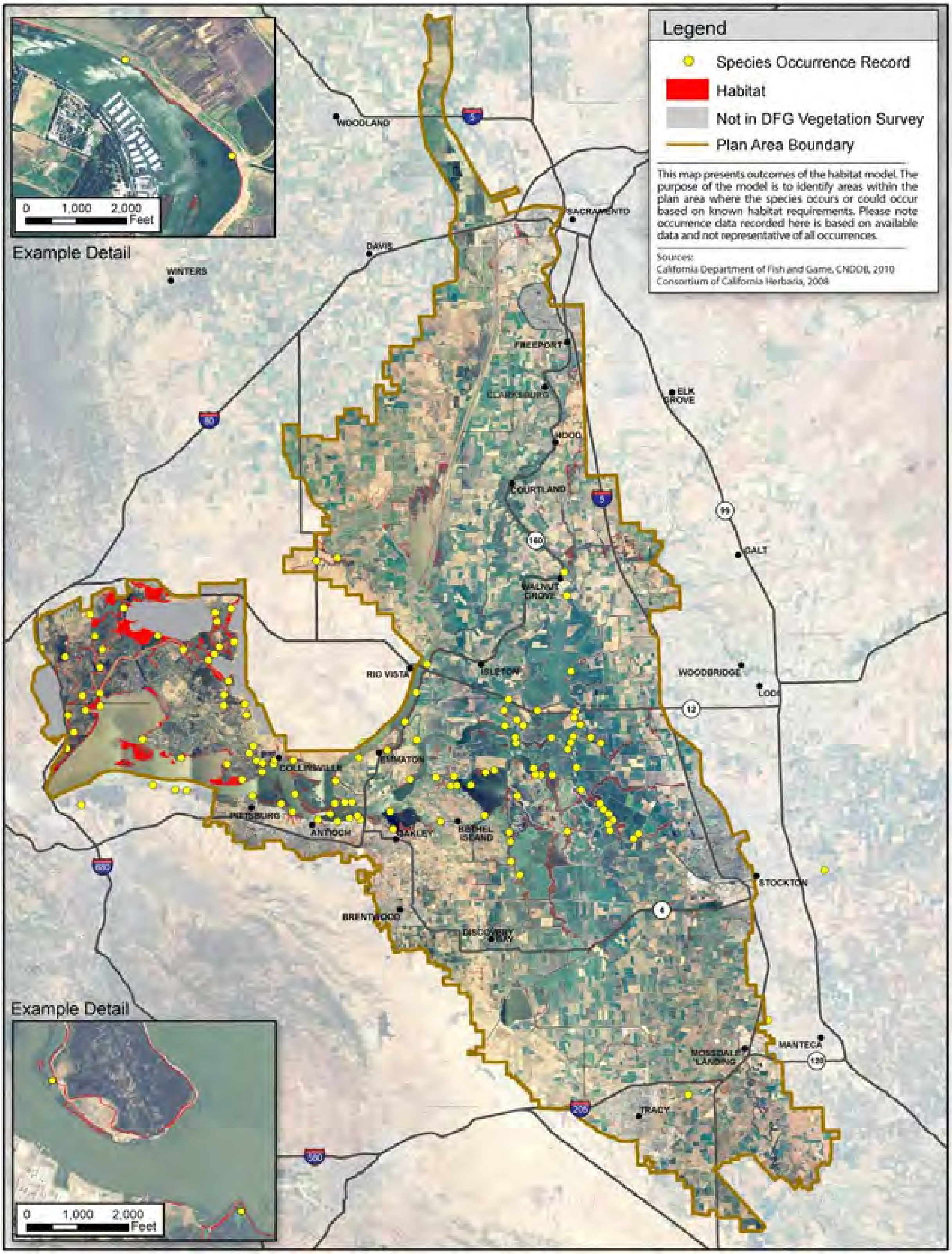

Figure A-62b. Suisun Marsh Aster Habitat Model and Recorded Occurrences

A62.3 Habitat Requirements and Special Considerations

Suisun Marsh aster grows on the upper margins of brackish and freshwater marshes in the ecotone with terrestrial habitats (Goals Project 2000) and above erosional cuts and along the banks of sloughs and watercourses, often occurring with common reed, cattails, bulrushes, and blackberry (Witham and Kareofelas 1994, May & Associates 2005). A 1994 report from the Calhoun Cut Ecological Reserve noted that many occurrences of Suisun Marsh aster were in relatively shaded areas either along north-facing banks or under overhanging trees (Witham and Kareofelas 1994). It has been observed in close proximity to other rare plant species including Mason's lilaeopsis (*Lilaeopsis masonii*), Delta Tule pea (*Lathyrus jepsonii* var. *jepsonii*), Delta mudwort (*Limosella subulata*), and soft bird's-beak (*Cordylanthus mollis* ssp. *mollis*) (Goals Project 2000, CNPS 2008, CNDDB 2008).

A62.4 Life History

Suisun Marsh aster is a perennial, rhizomatous herb in the aster tribe (Astereae) of the sunflower family (Asteraceae) (Hickman 1993). Some occurrences may be single plants with one to several main stems (Witham and Kareofelas 1994). It blooms from May through November, depending on environmental conditions. Suisun Marsh aster stems are 16 to 59 inches (41 to 150 centimeters [cm]) tall and have open inflorescences of several flowerheads with purple ray flowers (outer flowers) and yellow centers (disc flowers). Suisun Marsh aster hybridizes with the common California aster (*Aster chilensis*), but it can be recognized by its larger size and flowerheads without hairs on the involucre (leaflike bracts beneath the flowerhead), and its slightly succulent leaves which are thicker than those of the common California aster (Hickman 1993, CNPS 2008). It also closely resembles western goldentop (*Euthamia occidentalis*), but they are easily distinguished when flowering as western goldentop flowerheads are all-yellow (Baye 2007). Both the Suisun Marsh aster and the common California aster are local host plants for the Field Crescent butterfly (*Phyciodes campestris*) (Witham and Kareofelas 1994).

A62.5 Threats and Stressors

Historically, the marsh habitat suitable for Suisun Marsh aster has been lost mostly through development, dredge disposal, agricultural conversion, and diking. Diked marshes generally lack rare tidal marsh species. It is believed that the conditions brought about by dikes favor robust generalist species that can better tolerate the extremes of inundation and dryness in diked wetlands (Goals Project 2000). Such habitat losses from human activities still occur, but many of the large marshes are now parts of preserves or are in highly restrictive development zones. Current threats to Suisun Marsh aster include invasive plants, erosion, creek channelizing, levee maintenance and construction, and possibly herbicide applications (CNDDB 2008, CNPS 2008).

A62.6 RELEVANT CONSERVATION EFFORTS

The CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for the Suisun Marsh aster is "Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP has established a goal to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

Suisun Marsh aster is a covered species under the approved San Joaquin County Multi-species Habitat Conservation and Open Space Plan. It is proposed for coverage under the Solano County Multispecies Habitat Conservation Plan.

A62.7 SPECIES HABITAT SUITABILITY MODEL

Habitat. Habitat was modeled separately based upon the salinity of the water. For freshwater areas, essentially the area within the legal delta, Suisun Marsh aster habitat was identified as the area within 10 feet (3 meters) of the landward side of the landward boundary of tidal freshwater emergent wetland Bay Delta Conservation Plan (BDCP) land cover type exclusively where this land cover type is adjacent to grassland, vernal pool complex, valley/foothill riparian, or agricultural habitats land cover types. For brackish water areas in and near Suisun Marsh, the model used all tidal brackish emergent wetland polygons (SFEI 2005, Boul and Keeler-Wolf 2008) which, using the California Department of Water Resources (DWR) LiDAR data set as resampled at 10 meters (DWR 2007), were then intersected with an elevation range of 7 to 10 feet (2 to 3 meters) to capture elevations 1 foot (30 cm) below intertidal to 2 feet (60 cm) above intertidal (i.e. the upper limit of the intertidal range was estimated at 8 feet, NAVD88; Siegel estimated the intertidal range in Suisun to occur between 1 to 8 feet (30 cm to 2.4 meters), NAVD88 (Siegel 2007).

Assumptions. Historical and current records of this species indicate that its distribution extends throughout most of the Plan Area, having been observed in tidally influenced waters from Calhoun Cut and in the Sacramento River near Walnut Grove southward and from Tom Pain Slough near the southern boundary of the Plan Area northward (Figure A-62b) (Witham and Kareofelas 1994, CNDDB 2008). While there are no occurrences within the Plan Area north of Calhoun Cut and Walnut Grove, patches of suitable habitat extend into those areas. For purposes of this model, a 10 foot-wide (3 meter) buffer on the landward side of the landward boundaries of the tidal freshwater emergent wetland land and tidal brackish emergent wetland contained within the 7-10 foot elevation within Suisun Marsh have been included as the potential extent of habitat that supports Suisun Marsh aster.

A62.8 Recovery Goals

A USFWS recovery plan has not been prepared for this species and no recovery goals have been established; however, the CALFED Bay-Delta Ecosystem Restoration Program (ERP) Plan's Multi-Species Conservation Strategy designation for the Suisun Marsh aster is "Recovery" (CALFED Bay-Delta Program 2000). This means that the ERP has established a goal to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

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APPENDIX A63. CAPER-FRUITED TROPIDOCARPUM (*TROPIDOCARPUM CAPPARIDEUM*)

A63.1 LEGAL STATUS

Caper-fruited tropidocarpum (*Tropidocarpum capparideum*) is not listed under either federal or California endangered species acts. Its Heritage Ranking in the California Natural Diversity Database (CNDDB) is G1/S1.1 which means that globally (G) and within the state (S) there are less than 6 viable element occurrences, less than 1,000 individuals, or less than 2,000 acres (809 hectares) of occupied habitat; and the state threat level rank is “very threatened.”

The California Native Plant Society (CNPS) List ranking of 1B.1 for caper-fruited tropidocarpum indicates that it is rare, threatened, or endangered. It is endemic to California and is considered by CNPS to be seriously endangered with more than 80 percent of occurrences threatened. Plants with a CNPS List rank of 1B are considered by the CNPS to meet the definitions of Section 1901, Chapter 10 (Native Plant Protection Act) or Sections 2062 and 2067 (California Endangered Species Act) of the California Fish and Game Code.

A63.2 SPECIES DISTRIBUTION AND STATUS

A63.2.1 Range and Status

Caper-fruited tropidocarpum is endemic to California and its distribution is based on 19 observations (Figure A-63a). Its range extends from Glenn County in the north, to Monterey, San Luis Obispo, and Fresno counties in the south, to San Joaquin County in the east, and Alameda, Contra Costa, and Santa Clara counties in the west (CNPS 2009).

It was thought to have been extinct since the 1950s; however, it was observed on Fort Hunter Liggett, a United States Army fort in southern Monterey County, in 2000 and 2001 (Hickman 1993, Al-Shehbaz 2003, CNDDB 2009, CNPS 2009).

A63.2.2 Distribution and Status in the Plan Area

Within the Plan Area, caper-fruited tropidocarpum was observed historically at Byron Hot Springs, near the current location of the Clifton Court Forebay, near the City of Tracy, and near Mountain House (CNDDB 2009, Consortium of California Herbaria 2009) (Figure A-63b).

A63.3 HABITAT REQUIREMENTS AND SPECIAL CONSIDERATIONS

Caper-fruited tropidocarpum has been found in valley and foothill grassland habitats in moderately alkaline soils (CNPS 2009) or, on Fort Hunter Liggett, also in foothill oak woodland habitats on slightly alkaline clay soils (CNDDB 2009).

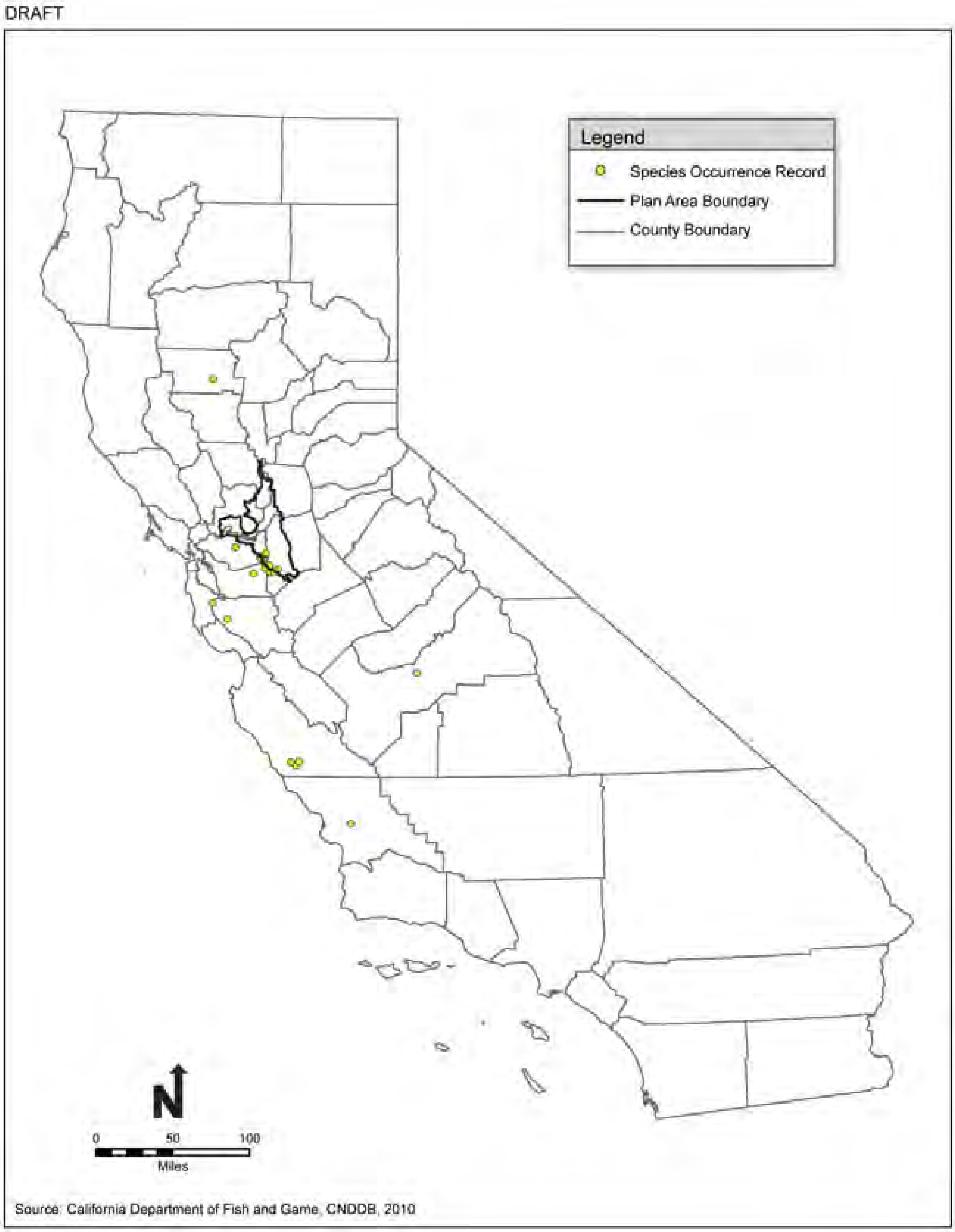

Figure A-63a. Caper-Fruited Tropidocarpum Statewide Recorded Occurrences

DRAFT

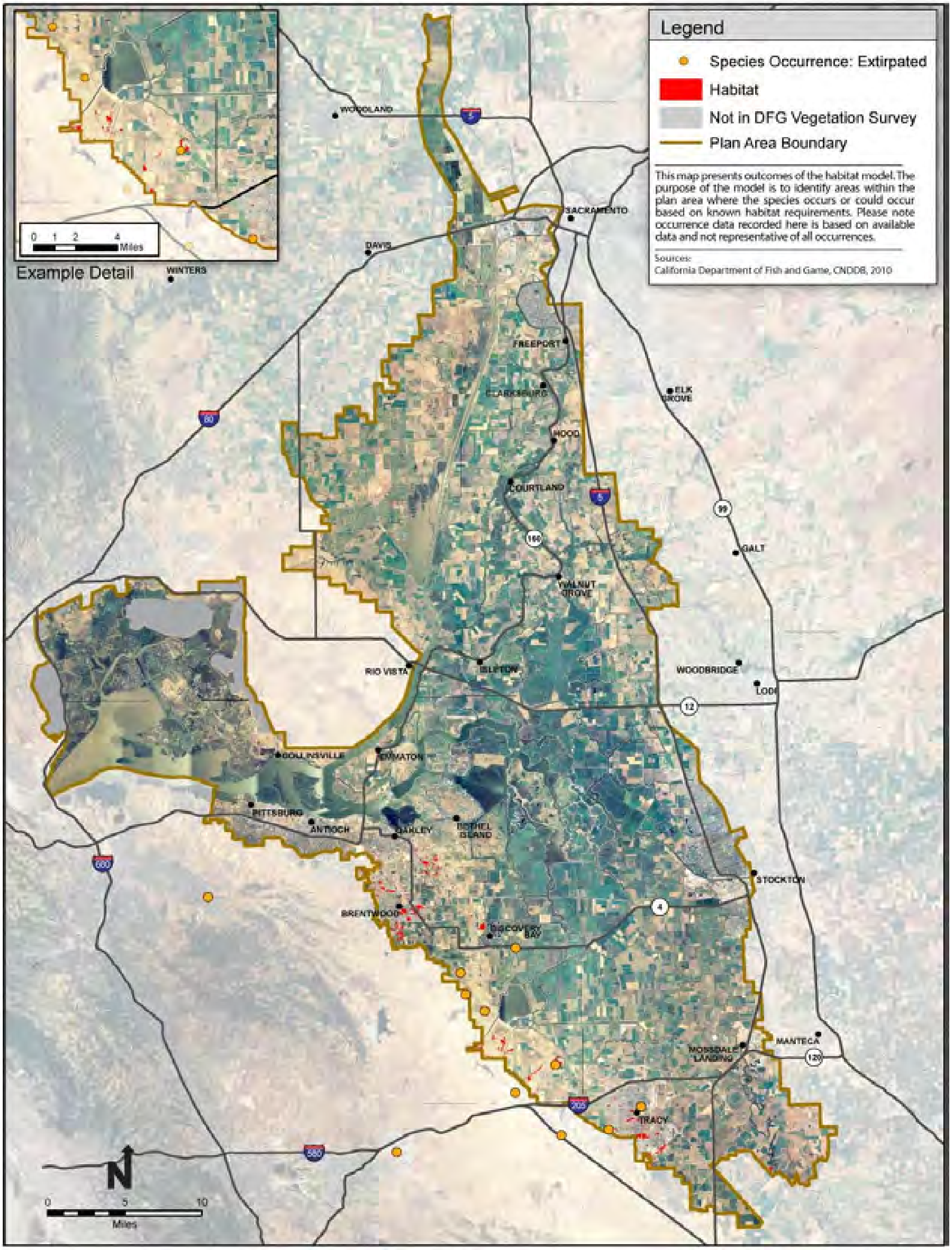

Figure A-63b. Caper-Fruited Tropidocarpum Habitat Model and Recorded Occurrences

The CNDDB locations on Fort Hunter Liggett overlaid on soils maps generally indicate that the species occurs on fine textured soils on gentle slopes in locations that are immediately above small drainages (NRCS 2009).

A63.4 Life History

Caper-fruited tropidocarpum is a small to medium-sized (8-20 inches [20–51 centimeters {cm}]) annual herb of the mustard family (Brassicaceae) that blooms from March to April (Hickman 1993, CNPS 2009). Caper-fruited tropidocarpum can be found at elevations of 3 to 1,500 feet (1 to 455 meters) (CNPS 2009). Its stems stand erect, are few-branched and slightly hairy. Its leaves are 1–2.5 inches (2-5 cm) long and also slightly hairy. The flowers are yellowish and have sparse hairs; and the petals are 0.2–0.3 inch (4-5 millimeters) long and spoon-shaped.

A63.5 Threats and Stressors

Reported threats to caper-fruited tropidocarpum are grazing, military activities, trampling, and nonnative plants (CNPS 2009). Based on its historical distribution in the Plan Area most impacts appear to have occurred through intensive agriculture and urbanization or other development activities.

A63.6 Relevant Conservation Efforts

The caper-fruited tropidocarpum is a covered species in the San Joaquin County Multi-species Habitat Conservation and Open Space Plan.

A63.7 Species Habitat Suitability Model

GIS Model Data Sources. The caper-fruited tropidocarpum model is based on an iterative analysis of the following data sets: SSURGO Soils (NRCS 2009), and BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007).

Vegetation Units. The following vegetation subunits were selected from the BDCP grassland natural community:

- *Bromus diandrus - Bromus hordeaceus;*
- California annual grasslands herbaceous;
- Italian rye-grass (*Lolium multiflorum*);
- *Lolium multiflorum - Convolvulus arvensis;*
- Pasture; and
- Upland annual grasslands and forbs formation.

Soils. Soils having clay content greater than 30 percent were selected in Alameda, Contra Costa, Sacramento, San Joaquin, Solano, and Yolo counties. Soils having a potential of hydrogen (pH) greater than 7 were then selected from those clay soils.

Soil Constraint Characteristics. From the selected soils the following subset of soils were further selected based upon fluvial geomorphic characteristics:

- alluvial fans, stream terraces, valleys;
- alluvial fans, terraces;
- alluvial fans, valleys;
- basin floors, valleys;
- fan terraces, valleys;
- fans, valley floors;
- rims on basin floors, valleys;
- terraces, valleys;
- valley floors; and
- valleys.

A spatial intersection of the vegetation types and soils was then used to identify potential suitable habitat. Locations found unsuitable because of hydrological conditions were removed.

A63.8 Recovery Goals

A United States Fish and Wildlife Service (USFWS) recovery plan has not been prepared for this species and no recovery goals have been established.

A63.9 References

A63.9.1 Literature Cited

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Appendix B

Common and Scientific Names of Species Mentioned in the Text

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Appendix B-1

Species Name by Common Name

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Type	*Common name*	*Scientific name*
Fish	American shad	*Alosa sapidissima*
Fish	Bigscale logperch	*Percina macrolepida*
Fish	Black bullhead	*Ameiurus melas*
Fish	Black crappie	*Pomoxis nigromaculatus*
Fish	Bluegill sunfish	*Lepomis macrochirus*
Fish	Brown bullhead	*Ameiurus nebulosus*
Fish	California Roach	*Hesperoleucus symmetricus*
Fish	Central Valley fall and late fall-run Chinook salmon	*Oncorhynchus tshawytscha*
Fish	Central Valley spring-run Chinook salmon	*Oncorhynchus tshawytscha*
Fish	Central Valley steelhead	*Oncorhynchus mykiss*
Fish	Chameleon Goby	*Tridentiger trigonocephalus*
Fish	Channel catfish	*Ictalurus punctatus*
Fish	Chinook salmon	*Oncorhynchus tshawytscha*
Fish	Common carp, Carp	*Cyprinus carpio carpio*
Fish	Delta smelt	*Hypomesus transpacificus*
Fish	Fathead minnow	*Pimephales promelas*
Fish	Golden shiner	*Notemigonus crysoleucas*
Fish	Goldfish	*Carassius auratus auratus*
Fish	Green sturgeon	*Acipenser medirostris*
Fish	Green sunfish	*Lepomis cyanellus*
Fish	Hardhead	*Mylopharodon conocephalus*
Fish	Hitch	*Lavinia exilicauda*
Fish	Inland silverside	*Menidia beryllina*
Fish	Largemouth bass	*Micropterus salmoides*
Fish	Longfin smelt	*Spirinchus thaleichthys*
Fish	Northern Anchovy	*Engraulis mordax*
Fish	Northern pike	*Esox lucius*
Fish	Pacific herring	*Clupea pallasii*
Fish	Pacific lamprey	*Entosphenus tridentatus*
Fish	Pacific Staghorn Sculpin	*Leptocottus armatus*
Fish	Prickly sculpin	*Cottus asper*
Fish	Pumpkinseed	*Lepomis gibbosus*
Fish	Rainbow Trout	*Oncorhynchus mykiss*
Fish	Rainwater killifish	*Lucania parva*
Fish	Red shiner	*Cyprinella lutrensis*
Fish	Redear sunfish	*Lepomis microlophus*
Fish	Redeye bass	*Micropterus coosae*
Fish	River lamprey	*Lampetra ayresii*
Fish	Sacramento Blackfish	*Orthodon microlepidotus*
Fish	Sacramento perch	*Archoplites interruptus*
Fish	Sacramento Pikeminnow	*Ptychocheilus grandis*
Fish	Sacramento River winter-run Chinook salmon	*Oncorhynchus tshawytscha*
Fish	Sacramento splittail	*Pogonichthys macrolepidotus*
Fish	Sacramento sucker	*Catostomus occidentalis*
Fish	Shimofuri goby	*Tridentiger bifasciatus*
Fish	Shokihaze goby	*Tridentiger barbatus*
Fish	Smallmouth bass	*Micropterus dolomieu*
Fish	Spotted bass	*Micropterus punctulatus*
Fish	Starry flounder	*Platichthys stellatus*
Fish	Steelhead	*Oncorhynchus mykiss*
Fish	Striped bass	*Morone saxatilis*
Fish	Sturgeon	*Acipenser* spp.

Type	*Common name*	*Scientific name*
Fish	Thicktail chub	*Gila crassicauda*
Fish	Threadfin shad	*Dorosoma petenense*
Fish	Threespine Stickleback	*Gasterosteus aculeatus*
Fish	Topsmelt	*Atherinops affinis*
Fish	Tule perch	*Hysterocarpus traskii*
Fish	Wakasagi	*Hypomesus nipponensis*
Fish	Warmouth	*Lepomis gulosus*
Fish	Western mosquitofish	*Gambusia affinis*
Fish	Whie crappie	*Pomoxis annularis*
Fish	White catfish	*Ameiurus catus*
Fish	White sturgeon	*Acipenser transmontanus*
Fish	Yellowfin goby	*Acanthogobius flavimanus*
Mammals	American badger	*Taxidea taxus*
Mammals	Beaver	*Castor canadensis*
Mammals	Black rat	*Rattus rattus*
Mammals	Black-tailed jackrabbit	*Lepus californicus*
Mammals	Bobcat	*Lynx rufus*
Mammals	California gray fox	*Urocyon cinereoargenteus*
Mammals	California ground squirrel	*Otospermophilus beecheyi*
Mammals	Cottontail	*Sylvilagus* spp.
Mammals	Coyote	*Canis latrans*
Mammals	Feral cat	*Felis domesticus*
Mammals	Feral pig	*Sus scrofa*
Mammals	Grizzly	*Ursus arctos*
Mammals	House mouse	*Mus musculus*
Mammals	Long-tailed weasel	*Mustela frenata*
Mammals	Mountain lion	*Puma concolor*
Mammals	Mule Deer	*Odocoileus hemionus*
Mammals	Muskrat	*Ondatra zibethicus*
Mammals	Nelson’s antelope ground squirrel	*Ammospermophilus nelsoni*
Mammals	Norway rat	*Rattus norvegicus*
Mammals	Pocket gopher	*Thomomys* spp.
Mammals	Pronghorn	*Antilocapra americana*
Mammals	Raccoon	*Procyon lotor*
Mammals	Rat	*Rattus* spp.
Mammals	Red fox	*Vulpes vulpes*
Mammals	Ringtail	*Bassariscus astutus*
Mammals	Riparian brush rabbit	*Sylvilagus bachmani riparius*
Mammals	Riparian woodrat	*Neotoma fuscipes riparia*
Mammals	River otter	*Lontra canadensis*
Mammals	Salt marsh harvest mouse	*Reithrodontomys raviventris*
Mammals	San Joaquin kit fox	*Vulpes macrotis mutica*
Mammals	Suisun shrew	*Sorex ornatus sinuosus*
Mammals	Townsend’s big-eared bat	*Corynorhinus townsendii*
Mammals	Townsend’s mole	*Scapanus townsendii*
Mammals	Tule elk	*Cervus canadensis nannodes*
Mammals	Woodrat	*Neotoma* spp.
Birds	American coot	*Fulica americana*
Birds	Bald eagle	*Haliaetus leucocephalus*
Birds	Bank swallow	*Riparia riparia*
Birds	Brown-headed cowbird	*Molothrus ater*
Birds	California black rail	*Laterallus jamaicensis coturniculus*

Type	*Common name*	*Scientific name*
Birds	California brown pelican	*Pelecanus occidentalis californicus*
Birds	California clapper rail	*Rallus longirostris obsoletus*
Birds	California least tern	*Sternula antillarum browni*
Birds	California yellow warbler	*Dendroica petechia*
Birds	Common yellowthroat	*Geothlypis trichas*
Birds	Cormorant	*Phalacrocorax spp.*
Birds	Cowbird	*Molothrus ater*
Birds	European starling	*Sturna vulgaris*
Birds	Gadwall	*Anas strepera*
Birds	Godwit	*Limosa* spp.
Birds	Greater sandhill crane	*Grus canadensis tabida*
Birds	Gull	*Larus* spp.
Birds	House sparrow	*Passer domesticus*
Birds	Least Bell's vireo	*Vireo bellii pusillus*
Birds	Loon	*Gavia* spp.
Birds	Mallard	*Anas platyrhynchos*
Birds	Mourning dove	*Zenaida macroura*
Birds	Osprey	*Pandion haliaetus*
Birds	Pelican	*Pelecanus* spp.
Birds	Red-tailed hawk	*Buteo jamaicensis*
Birds	Ring-necked pheasant	*Phasianus colchicus*
Birds	Sandhill crane	*Grus canadensis*
Birds	Sandpiper	*Calidris* spp.
Birds	Scaup	*Aythya* spp.
Birds	Suisun song sparrow	*Melospiza melodia maxillaris*
Birds	Surf scoter	*Melanitta perspicillata*
Birds	Swainson’s hawk	*Buteo swainsoni*
Birds	Tricolored blackbird	*Agelaius tricolor*
Birds	Western burrowing owl	*Athene cunicularia hypugaea*
Birds	Western yellow-billed cuckoo	*Coccyzus americanus occidentalis*
Birds	White-tailed kite	*Elanus leucurus*
Birds	Willet	*Catoptrophorus semipalmatus*
Birds	Wilson’s warbler	*Wilsonia pusilla*
Birds	Yellow-breasted chat	*Icteria virens*
Reptiles	Alameda whipsnake	*Masticophis lateralis euryxanthus*
Reptiles	Blunt-nosed leopard lizard	*Gambelia silus*
Reptiles	California legless lizard	*Anniella pulchra*
Reptiles	Coast horned lizard	*Phrynosoma coronatum*
Reptiles	Common side-blotched lizard	*Uta stansburiana*
Reptiles	Giant garter snake	*Thamnophis gigas*
Reptiles	Glossy snake	*Arizona elegans*
Reptiles	Gopher snake	*Pituophis melanoleucus*
Reptiles	Racer	*Coluber constrictor*
Reptiles	Red-eared slider	*Trachemys scripta elegans*
Reptiles	San Joaquin whipsnake	*Masticophis flagellum ruddocki*
Reptiles	Silvery legless lizard	*Anniella pulchra*
Reptiles	Western fence lizard	*Sceloporus occidentalis*
Reptiles	Western pond turtle	*Actinemys* (formerly *Clemmys* and *Emys*) *marmorata*
Amphibians	Bullfrog	*Rana catesbeiana*
Amphibians	California red-legged frog	*Rana draytonii*
Amphibians	California tiger salamander	*Ambystoma californiense*

Type	*Common name*	*Scientific name*
Amphibians	Western spadefoot toad	*Spea hammondii*
Invertebrates	Acanthomysis	*Acanthomysis bowmani*
Invertebrates	Asian clam	*Corbicula fluminea*
Invertebrates	California linderiella	*Linderiella occidentalis*
Invertebrates	Callippe silverspot	*Speyeria callippe callippe*
Invertebrates	Chinese mitten crab	*Eriocheir sinensis*
Invertebrates	Conservancy fairy shrimp	*Branchinecta conservatio*
Invertebrates	Copepod	*Acanthocyclops vernalis*
Invertebrates	Corophium	*Corophium* spp.
Invertebrates	Crayfish	e.g., *Procambarus clarkii, Astacoidea*
Invertebrates	Daphnia	*Daphnia parvula, Daphnia pulex*
Invertebrates	Diaptomus	*Diaptomus* spp.
Invertebrates	Eurytemora	*Eurytemora affinis*
Invertebrates	Giant flower-loving fly	*Thaphiomydas trochilus*
Invertebrates	Lange's metalmark butterfly	*Apodemia mormo langei*
Invertebrates	Limnocalanus	*Limnocalanus macrurus*
Invertebrates	Limnoithona	*Limnoithona tetraspina*
Invertebrates	Longhorn fairy shrimp	*Branchinecta longiantenna*
Invertebrates	Midvalley fairy shrimp	*Branchinecta mesovallensis*
Invertebrates	Neomysis	*Neomysis mercedis*
Invertebrates	Overbite clam	*Corbula amurensis*
Invertebrates	Pseudodiaptomus	*Pseudodiaptomus forbesi*
Invertebrates	Valley elderberry longhorn beetle	*Desmocerus californicus dimorphus*
Invertebrates	Vernal pool fairy shrimp	*Branchinecta lynchi*
Invertebrates	Vernal pool tadpole shrimp	*Lepidurus packardi*
Plants	Alder	*Alnus* spp.
Plants	Alkali bulrush	*Schoenoplectus* (formerly *Scirpus*) maritimus
Plants	Alkali heath	*Frankenia salina*
Plants	Alkali milk-vetch	*Astragalus tener var. tener*
Plants	Alkali peppergrass	*Lepidium dictyotum var. dictyotum*
Plants	Alkali ryegrass	*Leymus triticoides*
Plants	Annual hairgrass	*Deschampsia danthonioides*
Plants	Annual ryegrass	*Lolium multiflorum*
Plants	Antioch dunes evening-primrose	*Oenothera deltoides* ssp. *howellii*
Plants	Arrowleaf	*Sagittaria* spp.
Plants	Arroyo willow	*Salix lasiolepis*
Plants	Baltic rush	*Juncus balticus*
Plants	Barbgrass	*Hainardia cylindrical*
Plants	barnyard grass	*Echinochloa crus-galli*
Plants	Bermuda grass	*Cynodon dactylon*
Plants	Black locust	*Robinia pseudoacacia*
Plants	Blackberries	*Rubus* spp.
Plants	Blue dicks	*Dichelostemma capitatum*
Plants	Blue elderberry	*Sambucus cerulea*
Plants	Blue wildrye	*Elymus glaucus*
Plants	Blue-green algae	*Anabaena azollae*
Plants	Bluegum eucalyptus	*Eucalyptus globulus*
Plants	Boggs Lake hedge-hyssop	*Gratiola heterosepala*
Plants	Box elder	*Acer negundo*
Plants	Brass buttons	*Cotula coronopifolia*
Plants	Brazilian waterweed	*Egeria densa*

Type	*Common name*	*Scientific name*
Plants	Bristled downingia	*Downingia bicornuta var. bicornuta*
Plants	Brittlescale	*Atriplex depressa*
Plants	Broadleaf filaree	*Erodium botrys*
Plants	Bull thistle	*Cirsium vulgare*
Plants	Bulrush	*Schoenoplectus* (formerly *Scirpus*) spp.
Plants	Burhead	*Echinodorus berteroi*
Plants	Bush seepweed	*Suaeda moquinii*
Plants	Buttonbush	*Cephalanthus occidentalis* var. *californicus*
Plants	California brome	*Bromus carinatus*
Plants	California bulrush	*Schoenoplectus* (formerly *Scirpus*) *californicus*
Plants	California croton	*Croton californicus*
Plants	California hair-grass	*Deschampsia caespitosa*
Plants	California matchweed	*Gutierrezia californica*
Plants	California melic	*Melica californica*
Plants	California poppy	*Eschscholzia californica*
Plants	California sycamore	*Platanus racemosa*
Plants	California wild grape	*Vitis californica*
Plants	California wild rose	*Rosa californica*
Plants	Caper-fruited tropidocarpum	*Tropidocarpum capparideum*
Plants	Carquinez goldenbush	*Isocoma arguta*
Plants	Cattail	*Typha* spp.
Plants	Chinese tallow tree	*Triadica sebifera*
Plants	Coast live oak	*Quercus agrifolia*
Plants	Colusa grass	*Neostapfia colusana*
Plants	Common cattail	*Typha latifolia*
Plants	Common muilla	*Muilla maritima*
Plants	Common reed	*Phragmites australis*
Plants	Common spikerush	*Eleocharis macrostachya*
Plants	Contra Costa wallflower	*Erysimum capitatum* var. *angustatum*
Plants	Cordgrass	*Spartina* spp.
Plants	Cottonwood	*Populus fremontii*
Plants	Coyote thistle	*Eryngium vaseyi*
Plants	Creeping wildrye	*Leymus triticoides*
Plants	Curved sicklegrass	*Parapholis incurva*
Plants	Cyanobacteria	*Microcystis aeruginosa*
Plants	Dallisgrass	*Paspalum dilatatum*
Plants	Deerweed	*Lotus scoparius*
Plants	Delta button-celery	*Eryngium racemosum*
Plants	Delta mudwort	*Limosella subulata*
Plants	Delta tule pea	*Lathyrus jepsonii* var. *jepsonii*
Plants	Devil's-lettuce	*Amsinckia tessellata*
Plants	Downingia	*Downingia* spp.
Plants	Duckweed	*Lemna* spp.
Plants	Dwarf downingia	*Downingia pusilla*
Plants	Eared naked buckwheat	*Eriogonum nudum* var. *auriculatum*
Plants	Eel grass	*Zostera marina*
Plants	Elderberry	*Sambucus* spp.
Plants	Elegant clarkia	*Clarkia unguiculata*
Plants	Eurasian watermilfoil	*Myriophyllum spicatum*
Plants	Fennel	*Foeniculum vulgare*

Type	***Common name***	***Scientific name***
Plants	Fiddleneck	*Amsinckia* spp.
Plants	Fig	*Ficus* spp.
Plants	Filarees	*Erodium* spp.
Plants	Flatsedges	*Cyperus* spp.
Plants	Floating primrose	*Ludwigia peploides*
Plants	Floating water fern	*Azolla filiculoides*
Plants	Foxtail fescue	*Vulpia myuros*
Plants	Fremont's cottonwood	*Populus fremontii*
Plants	Giant reed	*Arundo donax*
Plants	Gold nugget	*Calochortus luteus*
Plants	Goldfields	*Lasthenia fremontii*
Plants	Gooding's black willow	*Salix gooddingii*
Plants	Grain Sorghum	*Sorghum bicolor*
Plants	Grand redstem	*Ammania* spp.
Plants	Greene's tuctoria	*Tuctoria greenei*
Plants	Grindelia	*Grindelia* spp.
Plants	Gum plant	*Grindelia stricta*
Plants	Hairy orcutt grass	*Orcuttia pilosa*
Plants	Hard-stem bulrush	*Schoenoplectus* (formerly *Scirpus*) *acutus* var. *acutus*
Plants	Harvest brodiaea	*Brodiaea coronaria*
Plants	Heartscale	*Atriplex cordulata*
Plants	Heckard's peppergrass	*Lepidium latipes var. heckardii*
Plants	Himalayan blackberry	*Rubus discolor*
Plants	Hinds' walnut	*Juglans californica* var. *hindsii*
Plants	Honeysuckle	*Lonicera* spp.
Plants	Idaho fescue	*Festuca idahoensis*
Plants	Iodine bush	*Allenrolfea occidentalis*
Plants	Italian ryegrass	*Lolium multiflorum*
Plants	Ithuriel's spear	*Triteleia laxa*
Plants	Johnson grass	*Sorghum halepense*
Plants	Legenere	*Legenere limosa*
Plants	Lesser saltscale	*Atriplex minuscula*
Plants	Lessingia	*Lessingia glandulifera*
Plants	Lotus	*Lotus* spp.
Plants	Low mannagrass	*Glyceria declinata*
Plants	Mason's lilaeopsis	*Lilaeopsis masonii*
Plants	Meadow barley	*Hordeum brachyantherum*
Plants	Meadowfoam	*Limnanthes alba*
Plants	Medusahead	*Taeniatherum caput-medusae*
Plants	Mexican elderberry	*Sambucus mexicana*
Plants	Mexican rush	*Juncus mexicanus*
Plant	Microcystis	*Microcystis aeruginosa*
Plants	Mojave seablight	*Suaeda moquinii*
Plants	Monkeyflowers	*Mimulus* spp.
Plants	Mule fat	*Baccharis salicifolia*
Plants	Naked stem buckwheat	*Eriogonum nudum* var. *auriculatum*
Plants	Narrow-leaf cattail	*Typha angustifolia*
Plants	Narrow-leaf willow	*Salix exigua*
Plants	Narrow-leaved soap plant	*Chlorogalum angustifolium*
Plants	Navarretia	*Navarretia leucocephala* ssp. *plieantha*
Plants	Oak	*Quercus* spp.

Type	*Common name*	*Scientific name*
Plants	One-sided bluegrass	*Poa secunda*
Plants	Oregon ash	*Fraxinus latifolia*
Plants	Pacific foxtail	*Alopecurus saccatus*
Plants	Pacific willow	*Salix lucida* ssp. *lasiandra*
Plants	Pampas grass	*Cortaderia selloana*
Plants	Paper onion	*Allium amplectens*
Plants	Perennial pepperweed	*Lepidium latifolium*
Plants	Perennial pepperweed	*Lepidium latifolium*
Plants	Pickleweed	*Sarcocornia pacifica* (formerly *Salicornia virginica*)
Plants	Poison hemlock	*Conium maculatum*
Plants	Poison oak	*Toxicodendron diversilobum*
Plants	Pondweed	*Potamogeton* spp.
Plants	Prostrate pigweed	*Amaranthus blitoides*
Plants	Purple needlegrass	*Nassella pulchra*
Plants	Rabbitsfoot grass	*Polypogon monspeliensis*
Plants	Rayless goldfields	*Lasthenia glaberrima*
Plants	Red alder	*Alnus rubus*
Plants	Red brome	*Bromus madritensis* ssp. *rubens*
Plants	Red elderberry	*Sambucus racemosa*
Plants	Red fescue	*Festuca rubra*
Plants	Red willow	*Salix laevigata*
Plants	Redosier dogwood	*Cornus sericea*
Plants	Redstem filaree	*Erodium cicutarium*
Plants	Ripgut brome	*Bromus diandrus*
Plants	Rush	*Juncus* spp.
Plants	Russian olive	*Elaeagnus angustifolia*
Plants	Russian thistle	*Salsola tragus*
Plants	Sacramento mesamint	*Pogogyne zizyphoroides*
Plants	Sacramento orcutt grass	*Orcuttia viscida*
Plants	Salt marsh dodder	*Cuscuta salina*
Plants	Saltgrass	*Distichlis spicata*
Plants	San Joaquin spearscale	*Atriplex joaquiniana*
Plants	San Joaquin Valley orcutt grass	*Orcuttia inaequalis*
Plants	Santa Barbara sedge	*Carex barbarae*
Plants	Seaside arrowgrass	*Triglochin maritima*
Plants	Sedge	*Carex* spp.
Plants	Shining peppergrass	*Lepidium nitidum var. nitidum*
Plants	Side-flowering skullcap	*Scutellaria lateriflora*
Plants	Slender orcutt grass	*Orcuttia tenuis*
Plants	Sliver bush lupine	*Lupinus albifrons*
Plants	Slough thistle	*Cirsium crassicaule*
Plants	Small stipitate popcorn flowers	*Plagiobothrys stipitatus* var. *micranthus*
Plants	Smartweed	*Polygonum* spp.
Plants	Soft bird's beak	*Cordylanthus mollis* ssp. *mollis*
Plants	Soft chess	*Bromus hordeaceus*
Plants	Solano grass	*Tuctoria mucronata*
Plants	Spearscale	*Atriplex triangularis*
Plants	Stinging nettle	*Urtica dioica*
Plants	Strawberry clover	*Trifolium fragiferum*
Plants	Succulent owl’s clover	*Castilleja campestris* ssp. *succulenta*
Plants	Sudan Grass	*Sorghum vulgare* var. *sudanense*

Type	***Common name***	***Scientific name***
Plants	Suisun marsh aster	*Symphyotrichum lentum*
Plants	Suisun thistle	*Cirsium hydrophilum var. hydrophilum*
Plants	Swamp grass	*Crypsis* spp.
Plants	Swamp timothy	*Crypsis schoenoides*
Plants	Sycamore	*Platanus* spp.
Plants	Tall fescue	*Festuca arundinacea*
Plants	Tamarisk	*Tamarix ramosissima*
Plants	Telegraph weed	*Heterotheca grandiflora*
Plants	Toad rush	*Juncus bufonius*
Plants	Tree-of-heaven	*Ailanthus altissima*
Plants	True clovers	*Trifolium* spp.
Plants	Tufted hairgrass	*Deschampsia cespitosa*
Plants	Tule	*Schoenoplectus* (formerly *Scirpus*) spp.
Plants	Tule bulrush	*Schoenoplectus* (formerly *Scirpus*) *acutus*
Plants	Turkey mullein	*Eremocarpus setigerus*
Plants	Valley oak	*Quercus lobata*
Plants	Vetch	*Vicia* spp.
Plants	Walnut	*Juglans* spp.
Plants	Water hyacinth	*Eichhornia crassipes*
Plants	Water primrose	*Ludwigia peploides* var. *peploides*
Plants	Watercress	*Rorippa nasturtium-aquaticum*
Plants	White alder	*Alnus rhombifolia*
Plants	White clover	*Trifolium repens*
Plants	White hyacinth	*Triteleia hyacinthina*
Plants	Wild barley	*Hordeum spontaneum*
Plants	Wild mustard	*Hirschfeldia incana, Brassica nigra*
Plants	Wild oats	*Avena* spp.
Plants	Wild rose	*Rosa* spp.
Plants	Willow	*Salix* spp.
Plants	Woolly marbles	*Psilocarphus brevissimus*
Plants	Yellow starthistle	*Centaurea solstitialis*

Appendix B-2

B2. Species Name by Scientific Name

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Fish	Yellowfin goby	*Acanthogobius flavimanus*
Fish	Green sturgeon	*Acipenser medirostris*
Fish	Sturgeon	*Acipenser* spp.
Fish	White sturgeon	*Acipenser transmontanus*
Fish	American shad	*Alosa sapidissima*
Fish	White catfish	*Ameiurus catus*
Fish	Black bullhead	*Ameiurus melas*
Fish	Brown bullhead	*Ameiurus nebulosus*
Fish	Sacramento perch	*Archoplites interruptus*
Fish	Topsmelt	*Atherinops affinis*
Fish	Goldfish	*Carassius auratus auratus*
Fish	Sacramento sucker	*Catostomus occidentalis*
Fish	Pacific herring	*Clupea pallasii*
Fish	Prickly sculpin	*Cottus asper*
Fish	Red shiner	*Cyprinella lutrensis*
Fish	Common carp, Carp	*Cyprinus carpio carpio*
Fish	Threadfin shad	*Dorosoma petenense*
Fish	Northern Anchovy	*Engraulis mordax*
Fish	Northern pike	*Esox lucius*
Fish	Western mosquitofish	*Gambusia affinis*
Fish	Threespine Stickleback	*Gasterosteus aculeatus*
Fish	Thicktail chub	*Gila crassicauda*
Fish	California Roach	*Hesperoleucus symmetricus*
Fish	Wakasagi	*Hypomesus nipponensis*
Fish	Delta smelt	*Hypomesus transpacificus*
Fish	Tule perch	*Hysterocarpus traskii*
Fish	Channel catfish	*Ictalurus punctatus*
Fish	River lamprey	*Lampetra ayresii*
Fish	Pacific lamprey	*Entosphenus tridentatus*
Fish	Hitch	*Lavinia exilicauda*
Fish	Green sunfish	*Lepomis cyanellus*
Fish	Pumpkinseed	*Lepomis gibbosus*
Fish	Warmouth	*Lepomis gulosus*
Fish	Bluegill sunfish	*Lepomis macrochirus*
Fish	Redear sunfish	*Lepomis microlophus*
Fish	Pacific Staghorn Sculpin	*Leptocottus armatus*
Fish	Rainwater killifish	*Lucania parva*
Fish	Inland silverside	*Menidia beryllina*
Fish	Redeye bass	*Micropterus coosae*
Fish	Smallmouth bass	*Micropterus dolomieu*
Fish	Spotted bass	*Micropterus punctulatus*
Fish	Largemouth bass	*Micropterus salmoides*
Fish	Striped bass	*Morone saxatilis*
Fish	Hardhead	*Mylopharodon conocephalus*
Fish	Golden shiner	*Notemigonus crysoleucas*
Fish	Central Valley steelhead	*Oncorhynchus mykiss*
Fish	Rainbow Trout	*Oncorhynchus mykiss*
Fish	Steelhead	*Oncorhynchus mykiss*
Fish	Central Valley fall and late fall-run Chinook salmon	*Oncorhynchus tshawytscha*
Fish	Central Valley spring-run Chinook salmon	*Oncorhynchus tshawytscha*
Fish	Chinook salmon	*Oncorhynchus tshawytscha*
Fish	Sacramento River winter-run Chinook salmon	*Oncorhynchus tshawytscha*

Fish	Sacramento Blackfish	*Orthodon microlepidotus*
Fish	Bigscale logperch	*Percina macrolepida*
Fish	Fathead minnow	*Pimephales promelas*
Fish	Starry flounder	*Platichthys stellatus*
Fish	Sacramento splittail	*Pogonichthys macrolepidotus*
Fish	Whie crappie	*Pomoxis annularis*
Fish	Black crappie	*Pomoxis nigromaculatus*
Fish	Sacramento Pikeminnow	*Ptychocheilus grandis*
Fish	Longfin smelt	*Spirinchus thaleichthys*
Fish	Shokihaze goby	*Tridentiger barbatus*
Fish	Shimofuri goby	*Tridentiger bifasciatus*
Fish	Chameleon Goby	*Tridentiger trigonocephalus*
Mammals	Nelson's antelope ground squirrel	*Ammospermophilus nelsoni*
Mammals	Pronghorn	*Antilocapra americana*
Mammals	Ringtail	*Bassariscus astutus*
Mammals	Coyote	*Canis latrans*
Mammals	Beaver	*Castor canadensis*
Mammals	Tule elk	*Cervus canadensis nannodes*
Mammals	Townsend's big-eared bat	*Corynorhinus townsendii*
Mammals	Feral cat	*Felis domesticus*
Mammals	Black-tailed jackrabbit	*Lepus californicus*
Mammals	River otter	*Lontra canadensis*
Mammals	Bobcat	*Lynx rufus*
Mammals	House mouse	*Mus musculus*
Mammals	Long-tailed weasel	*Mustela frenata*
Mammals	Riparian woodrat	*Neotoma fuscipes riparia*
Mammals	Woodrat	*Neotoma* spp.
Mammals	Mule Deer	*Odocoileus hemionus*
Mammals	Muskrat	*Ondatra zibethicus*
Mammals	California ground squirrel	*Otospermophilus beecheyi*
Mammals	Raccoon	*Procyon lotor*
Mammals	Mountain lion	*Puma concolor*
Mammals	Norway rat	*Rattus norvegicus*
Mammals	Black rat	*Rattus rattus*
Mammals	Rat	*Rattus* spp.
Mammals	Salt marsh harvest mouse	*Reithrodontomys raviventris*
Mammals	Townsend's mole	*Scapanus townsendii*
Mammals	Suisun shrew	*Sorex ornatus sinuosus*
Mammals	Feral pig	*Sus scrofa*
Mammals	Riparian brush rabbit	*Sylvilagus bachmani riparius*
Mammals	Cottontail	*Sylvilagus* spp.
Mammals	American badger	*Taxidea taxus*
Mammals	Pocket gopher	*Thomomys* spp.
Mammals	California gray fox	*Urocyon cinereoargenteus*
Mammals	Grizzly	*Ursus arctos*
Mammals	San Joaquin kit fox	*Vulpes macrotis mutica*
Mammals	Red fox	*Vulpes vulpes*
Birds	Tricolored blackbird	*Agelaius tricolor*
Birds	Mallard	*Anas platyrhynchos*
Birds	Gadwall	*Anas strepera*
Birds	Western burrowing owl	*Athene cunicularia hypugaea*
Birds	Scaup	*Aythya spp.*
Birds	Red-tailed hawk	*Buteo jamaicensis*

Birds	Swainson's hawk	*Buteo swainsoni*
Birds	Sandpiper	*Calidris spp.*
Birds	Willet	*Catoptrophorus semipalmatus*
Birds	Western yellow-billed cuckoo	*Coccyzus americanus occidentalis*
Birds	California yellow warbler	*Dendroica petechia*
Birds	White-tailed kite	*Elanus leucurus*
Birds	American coot	*Fulica americana*
Birds	Loon	*Gavia spp.*
Birds	Common yellowthroat	*Geothlypis trichas*
Birds	Sandhill cranes	*Grus canadensis*
Birds	Greater sandhill crane	*Grus canadensis tabida*
Birds	Bald eagle	*Haliaetus leucocephalus*
Birds	Yellow-breasted chat	*Icteria virens*
Birds	Gull	*Larus spp.*
Birds	California black rail	*Laterallus jamaicensis coturniculus*
Birds	Godwit	*Limosa spp.*
Birds	Surf scoter	*Melanitta perspicillata*
Birds	Suisun song sparrow	*Melospiza melodia maxillaris*
Birds	Brown-headed cowbird	*Molothrus ater*
Birds	Cowbird	*Molothrus ater*
Birds	Osprey	*Pandion haliaetus*
Birds	House sparrow	*Passer domesticus*
Birds	California brown pelican	*Pelecanus occidentalis californicus*
Birds	Pelican	*Pelecanus spp.*
Birds	Cormorant	*Phalacrocorax spp.*
Birds	Ring-necked pheasant	*Phasianus colchicus*
Birds	California clapper rail	*Rallus longirostris obsoletus*
Birds	Bank swallow	*Riparia riparia*
Birds	California least tern	*Sternula antillarum browni*
Birds	European starling	*Sturna vulgaris*
Birds	Least Bell's vireo	*Vireo bellii pusillus*
Birds	Wilson's warbler	*Wilsonia pusilla*
Birds	Mourning dove	*Zenaida macroura*
Reptiles	Western pond turtle	*Actinemys (formerly Clemmys and Emys) marmorata*
Reptiles	California legless lizard	*Anniella pulchra*
Reptiles	Silvery legless lizard	*Anniella pulchra*
Reptiles	Glossy snake	*Arizona elegans*
Reptiles	Racer	*Coluber constrictor*
Reptiles	Blunt-nosed leopard lizard	*Gambelia silus*
Reptiles	San Joaquin whipsnake	*Masticophis flagellum ruddocki*
Reptiles	Alameda whipsnake	*Masticophis lateralis euryxanthus*
Reptiles	Coast horned lizard	*Phrynosoma coronatum*
Reptiles	Gopher snake	*Pituophis melanoleucus*
Reptiles	Western fence lizard	*Sceloporus occidentalis*
Reptiles	Giant garter snake	*Thamnophis gigas*
Reptiles	Red-eared slider	*Trachemys scripta elegans*
Reptiles	Common side-blotched lizard	*Uta stansburiana*
Amphibians	California tiger salamander	*Ambystoma californiense*
Amphibians	Bullfrog	*Rana catesbeiana*
Amphibians	California red-legged frog	*Rana draytonii*
Amphibians	Western spadefoot toad	*Spea hammondii*
Invertebrates	Copepod	*Acanthocyclops vernalis*

Invertebrates	Acanthomysis	*Acanthomysis bowmani*
Invertebrates	Lange's metalmark butterfly	*Apodemia mormo langei*
Invertebrates	Conservancy fairy shrimp	*Branchinecta conservatio*
Invertebrates	Longhorn fairy shrimp	*Branchinecta longiantenna*
Invertebrates	Vernal pool fairy shrimp	*Branchinecta lynchi*
Invertebrates	Midvalley fairy shrimp	*Branchinecta mesovallensis*
Invertebrates	Asian clam	*Corbicula fluminea*
Invertebrates	Overbite clam	*Corbula amurensis*
Invertebrates	Corophium	*Corophium* spp.
Invertebrates	Daphnia	*Daphnia parvula, Daphnia pulex*
Invertebrates	Valley elderberry longhorn beetle	*Desmocerus californicus dimorphus*
Invertebrates	Diaptomus	*Diaptomus* spp.
Invertebrates	Chinese mitten crab	*Eriocheir sinensis*
Invertebrates	Eurytemora	*Eurytemora affinis*
Invertebrates	Vernal pool tadpole shrimp	*Lepidurus packardi*
Invertebrates	Limnocalanus	*Limnocalanus macrurus*
Invertebrates	Limnoithona	*Limnoithona tetraspina*
Invertebrates	California linderiella	*Linderiella occidentalis*
Invertebrates	Neomysis	*Neomysis mercedis*
Invertebrates	Crayfish	e.g., *Procambarus clarkii, Astacoidea*
Invertebrates	Pseudodiaptomus	*Pseudodiaptomus forbesi*
Invertebrates	Callippe silverspot	*Speyeria callippe callippe*
Invertebrates	Giant flower-loving fly	*Thaphiomydas trochilus*
Plants	Cordgrass	*Spartina* spp.
Plants	Box elder	*Acer negundo*
Plants	Tree-of-heaven	*Ailanthus altissima*
Plants	Iodine bush	*Allenrolfea occidentalis*
Plants	Paper onion	*Allium amplectens*
Plants	White alder	*Alnus rhombifolia*
Plants	Red alder	*Alnus rubus*
Plants	Alder	*Alnus* spp.
Plants	Pacific foxtail	*Alopecurus saccatus*
Plants	Prostrate pigweed	*Amaranthus blitoides*
Plants	Grand redstem	*Ammania* spp.
Plants	Fiddleneck	*Amsinckia* spp.
Plants	Devil's-lettuce	*Amsinckia tessellata*
Plants	Blue-green algae	*Anabaena azollae*
Plants	Giant reed	*Arundo donax*
Plants	Alkali milk-vetch	*Astragalus tener var. tener*
Plants	Heartscale	*Atriplex cordulata*
Plants	Brittlescale	*Atriplex depressa*
Plants	San Joaquin spearscale	*Atriplex joaquiniana*
Plants	Lesser saltscale	*Atriplex minuscula*
Plants	Spearscale	*Atriplex triangularis*
Plants	Wild oats	*Avena* spp.
Plants	Floating water fern	*Azolla filiculoides*
Plants	Mule fat	*Baccharis salicifolia*
Plants	Harvest brodiaea	*Brodiaea coronaria*
Plants	California brome	*Bromus carinatus*
Plants	Ripgut brome	*Bromus diandrus*
Plants	Soft chess	*Bromus hordeaceus*
Plants	Red brome	*Bromus madritensis* ssp. *rubens*
Plants	Gold nugget	*Calochortus luteus*

Plants	Santa Barbara sedge	*Carex barbarae*
Plants	Sedge	*Carex* spp.
Plants	Succulent owl’s clover	*Castilleja campestris* ssp. *succulenta*
Plants	Yellow starthistle	*Centaurea solstitialis*
Plants	Buttonbush	*Cephalanthus occidentalis* var. *californicus*
Plants	Narrow-leaved soap plant	*Chlorogalum angustifolium*
Plants	Slough thistle	*Cirsium crassicaule*
Plants	Suisun thistle	*Cirsium hydrophilum var. hydrophilum*
Plants	Bull thistle	*Cirsium vulgare*
Plants	Elegant clarkia	*Clarkia unguiculata*
Plants	Poison hemlock	*Conium maculatum*
Plants	Soft bird's beak	*Cordylanthus mollis* ssp. *mollis*
Plants	Redosier dogwood	*Cornus sericea*
Plants	Pampas grass	*Cortaderia selloana*
Plants	Brass buttons	*Cotula coronopifolia*
Plants	California croton	*Croton californicus*
Plants	Swamp timothy	*Crypsis schoenoides*
Plants	Swamp grass	*Crypsis* spp.
Plants	Salt marsh dodder	*Cuscuta salina*
Plants	Bermuda grass	*Cynodon dactylon*
Plants	Flatsedges	*Cyperus* spp.
Plants	California hair-grass	*Deschampsia caespitosa*
Plants	Tufted hairgrass	*Deschampsia cespitosa*
Plants	Annual hairgrass	*Deschampsia danthonioides*
Plants	Blue dicks	*Dichelostemma capitatum*
Plants	Saltgrass	*Distichlis spicata*
Plants	Bristled downingia	*Downingia bicornuta var. bicornuta*
Plants	Dwarf downingia	*Downingia pusilla*
Plants	Downingia	*Downingia* spp.
Plants	barnyard grass	*Echinochloa crus-galli*
Plants	Burhead	*Echinodorus berteroi*
Plants	Brazilian waterweed	*Egeria densa*
Plants	Water hyacinth	*Eichhornia crassipes*
Plants	Russian olive	*Elaeagnus angustifolia*
Plants	Common spikerush	*Eleocharis macrostachya*
Plants	Blue wildrye	*Elymus glaucus*
Plants	Turkey mullein	*Eremocarpus setigerus*
Plants	Naked stem buckwheat	*Eriogonum nudum* var. *auriculatum*
Plants	Eared naked buckwheat	*Eriogonum nudum* var. *auriculatum*
Plants	Broadleaf filaree	*Erodium botrys*
Plants	Redstem filaree	*Erodium cicutarium*
Plants	Filarees	*Erodium* spp.
Plants	Delta button-celery	*Eryngium racemosum*
Plants	Coyote thistle	*Eryngium vaseyi*
Plants	Contra Costa wallflower	*Erysimum capitatum* var. *angustatum*
Plants	California poppy	*Eschscholzia californica*
Plants	Bluegum eucalyptus	*Eucalyptus globulus*
Plants	Tall fescue	*Festuca arundinacea*
Plants	Idaho fescue	*Festuca idahoensis*
Plants	Red fescue	*Festuca rubra*
Plants	Fig	*Ficus* spp.
Plants	Fennel	*Foeniculum vulgare*
Plants	Alkali heath	*Frankenia salina*

Plants	Oregon ash	*Fraxinus latifolia*
Plants	Low mannagrass	*Glyceria declinata*
Plants	Boggs Lake hedge-hyssop	*Gratiola heterosepala*
Plants	Grindelia	*Grindelia* spp.
Plants	Gum plant	*Grindelia stricta*
Plants	California matchweed	*Gutierrezia californica*
Plants	Barbgrass	*Hainardia cylindrical*
Plants	Telegraph weed	*Heterotheca grandiflora*
Plants	Wild mustard	*Hirschfeldia incana, Brassica nigra*
Plants	Meadow barley	*Hordeum brachyantherum*
Plants	Wild barley	*Hordeum spontaneum*
Plants	Carquinez goldenbush	*Isocoma arguta*
Plants	Hinds' walnut	*Juglans californica* var. *hindsii*
Plants	Walnut	*Juglans* spp.
Plants	Baltic rush	*Juncus balticus*
Plants	Toad rush	*Juncus bufonius*
Plants	Mexican rush	*Juncus mexicanus*
Plants	Rush	*Juncus* spp.
Plants	Goldfields	*Lasthenia fremontii*
Plants	Rayless goldfields	*Lasthenia glaberrima*
Plants	Delta tule pea	*Lathyrus jepsonii* var. *jepsonii*
Plants	Legenere	*Legenere limosa*
Plants	Duckweed	*Lemna* spp.
Plants	Alkali peppergrass	*Lepidium dictyotum var. dictyotum*
Plants	Perennial pepperweed	*Lepidium latifolium*
Plants	Perennial pepperweed	*Lepidium latifolium*
Plants	Heckard's peppergrass	*Lepidium latipes var. heckardii*
Plants	Shining peppergrass	*Lepidium nitidum var. nitidum*
Plants	Lessingia	*Lessingia glandulifera*
Plants	Alkali ryegrass	*Leymus triticoides*
Plants	Creeping wildrye	*Leymus triticoides*
Plants	Mason's lilaeopsis	*Lilaeopsis masonii*
Plants	Meadowfoam	*Limnanthes alba*
Plants	Delta mudwort	*Limosella subulata*
Plants	Annual ryegrass	*Lolium multiflorum*
Plants	Italian ryegrass	*Lolium multiflorum*
Plants	Honeysuckle	*Lonicera* spp.
Plants	Deerweed	*Lotus scoparius*
Plants	Lotus	*Lotus* spp.
Plants	Floating primrose	*Ludwigia peploides*
Plants	Water primrose	*Ludwigia peploides* var. *peploides*
Plants	Sliver bush lupine	*Lupinus albifrons*
Plants	California melic	*Melica californica*
Plants	Cyanobacteria	*Microcystis aeruginosa*
Plants	Microcystis	*Microcystis aeruginosa*
Plants	Monkeyflowers	*Mimulus* spp.
Plants	Common muilla	*Muilla maritima*
Plants	Eurasian watermilfoil	*Myriophyllum spicatum*
Plants	Purple needlegrass	*Nassella pulchra*
Plants	Navarretia	*Navarretia leucocephala* ssp. *plieantha*
Plants	Colusa grass	*Neostapfia colusana*
Plants	Antioch dunes evening-primrose	*Oenothera deltoides* ssp. *howellii*
Plants	San Joaquin Valley orcutt grass	*Orcuttia inaequalis*

Plants	Hairy orcutt grass	*Orcuttia pilosa*
Plants	Slender orcutt grass	*Orcuttia tenuis*
Plants	Sacramento orcutt grass	*Orcuttia viscida*
Plants	Curved sicklegrass	*Parapholis incurva*
Plants	Dallisgrass	*Paspalum dilatatum*
Plants	Common reed	*Phragmites australis*
Plants	Small stipitate popcorn flowers	*Plagiobothrys stipitatus* var. *micranthus*
Plants	California sycamore	*Platanus racemosa*
Plants	Sycamore	*Platanus* spp.
Plants	One-sided bluegrass	*Poa secunda*
Plants	Sacramento mesamint	*Pogogyne zizyphoroides*
Plants	Smartweed	*Polygonum* spp.
Plants	Rabbitsfoot grass	*Polypogon monspeliensis*
Plants	Cottonwood	*Populus fremontii*
Plants	Fremont's cottonwood	*Populus fremontii*
Plants	Pondweed	*Potamogeton* spp.
Plants	Woolly marbles	*Psilocarphus brevissimus*
Plants	Coast live oak	*Quercus agrifolia*
Plants	Valley oak	*Quercus lobata*
Plants	Oak	*Quercus* spp.
Plants	Black locust	*Robinia pseudoacacia*
Plants	Watercress	*Rorippa nasturtium-aquaticum*
Plants	California wild rose	*Rosa californica*
Plants	Wild rose	*Rosa* spp.
Plants	Himalayan blackberry	*Rubus discolor*
Plants	Blackberries	*Rubus* spp.
Plants	Arrowleaf	*Sagittaria* spp.
Plants	Narrow-leaf willow	*Salix exigua*
Plants	Gooding's black willow	*Salix gooddingii*
Plants	Red willow	*Salix laevigata*
Plants	Arroyo willow	*Salix lasiolepis*
Plants	Pacific willow	*Salix lucida* ssp. *lasiandra*
Plants	Willow	*Salix* spp.
Plants	Russian thistle	*Salsola tragus*
Plants	Blue elderberry	*Sambucus cerulea*
Plants	Mexican elderberry	*Sambucus mexicana*
Plants	Red elderberry	*Sambucus racemosa*
Plants	Elderberry	*Sambucus* spp.
Plants	Pickleweed	*Sarcocornia pacifica* (formerly *Salicornia virginica*)
Plants	Tule	*Schoenoplectus* (formerly *Scirpus*) spp.
Plants	Tule bulrush	*Schoenoplectus* (formerly *Scirpus*) *acutus*
Plants	Hard-stem bulrush	*Schoenoplectus* (formerly *Scirpus*) *acutus* var. *acutus*
Plants	California bulrush	*Schoenoplectus* (formerly *Scirpus*) *californicus*
Plants	Alkali bulrush	*Schoenoplectus* (formerly *Scirpus*) maritimus
Plants	Bulrush	*Schoenoplectus* (formerly *Scirpus*) spp.
Plants	Side-flowering skullcap	*Scutellaria lateriflora*
Plants	Grain Sorghum	*Sorghum bicolor*
Plants	Johnson grass	*Sorghum halepense*
Plants	Sudan Grass	*Sorghum vulgare* var. *sudanense*
Plants	Bush seepweed	*Suaeda moquinii*
Plants	Mojave seablight	*Suaeda moquinii*

Plants	Suisun marsh aster	*Symphyotrichum lentum*
Plants	Medusahead	*Taeniatherum caput-medusae*
Plants	Tamarisk	*Tamarix ramosissima*
Plants	Poison oak	*Toxicodendron diversilobum*
Plants	Chinese tallow tree	*Triadica sebifera*
Plants	Strawberry clover	*Trifolium fragiferum*
Plants	White clover	*Trifolium repens*
Plants	True clovers	*Trifolium* spp.
Plants	Seaside arrowgrass	*Triglochin maritima*
Plants	White hyacinth	*Triteleia hyacinthina*
Plants	Ithuriel's spear	*Triteleia laxa*
Plants	Caper-fruited tropidocarpum	*Tropidocarpum capparideum*
Plants	Greene’s tuctoria	*Tuctoria greenei*
Plants	Solano grass	*Tuctoria mucronata*
Plants	Narrow-leaf cattail	*Typha angustifolia*
Plants	Common cattail	*Typha latifolia*
Plants	Cattail	*Typha* spp.
Plants	Stinging nettle	*Urtica dioica*
Plants	Vetch	*Vicia* spp.
Plants	California wild grape	*Vitis californica*
Plants	Foxtail fescue	*Vulpia myuros*
Plants	Eel grass	*Zostera marina*

Appendix C

Covered Species Evaluation

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Appendix C. Evaluation of Species Considered for Coverage

The table in this appendix presents results of the BDCP evaluation of 234 special-status species to identify species to be proposed for coverage under the BDCP. Species considered for BDCP coverage were limited to special-status species that are known or believed to occur in the vicinity of the Plan Area and, thus potentially occur within the Plan Area. Special-status species were defined as species that are:

- listed as threatened or endangered under the ESA;
- proposed or candidates for listing under ESA;
- listed as threatened or endangered under the California Endangered Species Act (CESA);
- candidates for listing under CESA;
- California species of special concern;
- California fully protected species;
- U.S. Fish and Wildlife Service (USFWS) birds of conservation concern;
- National Marine Fisheries Service (NMFS) species of concern;
- plants listed as rare under the California Native Plant Protection Act (NPPA); or
- plants included in the California Native Plant Society (CNPS) List 1A, 1B, or 2.

The evaluation process relied primarily on four criteria to determine which special-status species would be included on the list of species proposed for coverage under the BDCP. The selection criteria are as follows:

1. Listing status of the species.
2. Likelihood that the species is present in the Plan Area or other areas within the geographic scope.
3. Potential for the species to be adversely affected by BDCP covered activities, including the implementation of conservation measures.
4. Level of information available to determine potential impacts to species and to identify effective conservation measures.

Those species that meet all four of these criteria are proposed for coverage under the BDCP and these "covered species" are identified with a "Yes" in the column "Consider for Coverage?" in the table below. See Section 1.4.3, *Covered Species*, for a list of just the proposed covered species.

Scientific Name/ Common Name	*Status[A] (Federal/State/ CNPS)*	*Selection Criteria For Coverage[B]*				*Consider for Coverage?*	*Comments*
		Listing Potential	**Occurrence in the Plan Area**	**Potential to Adversely Affect[C]**	**Sufficient Information**		
Fish							
1. Sacramento perch *Archoplites interruptus*	-/-/-	-	-	-	+	No	This species has been extirpated from the Plan Area and, therefore, is not recommended for coverage.
2. Tule perch, Sacramento subspecies *(Hysterocarpus traskii traskii)*	-/SSC/-	-	+	+ (AD, H, ID, O)	+	No	This species is not recommended for coverage under the BDCP. It has no federal or state status and is not likely to be listed. They are very common in large tributaries of the Sacramento River (e.g., American and Feather Rivers) and, in the San Joaquin watershed, have a persisting population in the Stanislaus River. The species appears to be in long-term decline in the San Francisco Estuary.
3. Steelhead, Central Valley DPS *Oncorhynchus mykiss*	T/-/-	+	+	+ (AD, H, ID, O)	+	Yes	Meets all four criteria. Identified as a covered species in the BDCP Planning Agreement.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	Status[A] (Federal/State/ CNPS)	Selection Criteria For Coverage[B]				Consider for Coverage?	Coverage Comments
		Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information		
4. Chinook salmon, Sacramento River winter-run *Oncorhynchus tshawytscha*	E/E/-	+	+	+ (AD, H, ID, O)	+	Yes	Meets all four criteria. Identified as a covered species in the BDCP Planning Agreement.
5. Chinook salmon, Central Valley spring-run *Oncorhynchus tshawytscha*	T/T/-	+	+	+ (AD, H, ID, O)	+	Yes	Meets all four criteria. Identified as a covered species in the BDCP Planning Agreement.
6. Chinook salmon, Central Valley fall-/late fall-run *Oncorhynchus tshawytscha*	NSC /SSC/-	+	+	+ (ID, O)	+	Yes	Meets all four criteria. Identified as a covered species in the BDCP Planning Agreement.
7. Longfin smelt *Spirinchus thaleichthys*	-/T/-	+	+	+ (AD, H, ID, O)	+	Yes	Meets all four criteria. Identified as a covered species in the BDCP Planning Agreement.
8. Pacific smelt *Thaleichthys pacificus*	-[1]/SSC/-	+	U	U	+	No	This species is not recommended as a BDCP covered species. A 2007 petition to list the southern distinct population segment of pacific smelt under ESA[1] documented one source[2] reporting that the species may have been seen in the Sacramento River. However, numerous other available scientific sources[3] state that the species range does not include the Sacramento-San Joaquin River watersheds.
9. Delta smelt *Hypomesus transpacificus*	T/T/-	+	+	+ (AD, H, ID, O)	+	Yes	Meets all four criteria. Identified as a covered species in the BDCP Planning Agreement.
10. Hardhead *Mylopharadon conocephalus*	-/SSC/-	-	+	+ (AD, H, ID, O)	+	No	This species is not recommended for coverage under the BDCP. It has no federal or state status. The species is common throughout the Sacramento-San Joaquin watershed and is not likely to become listed. The species is widely distributed in foothill streams.
11. Sacramento splittail *Pogonichthys macrolepidotus*	-/SSC/-	+	+	+ (AD, H, ID, O)	+	Yes	Meets all four criteria. Identified as a covered species in the BDCP Planning Agreement.

[1] Cowlitz Indian Tribe. 2007. Petition to list the southern eulachon (*Thaleichthys pacificus*) distinct population segment as threatened or endangered under the federal endangered species act. November 9, 2007. Available at: http://www.nwr.noaa.gov/Other-Marine-Species/upload/Smelt_Petition_11_07.pdf

[2] Minckley, W. L., D. A. Hendrickson, and C. E. Bond. 1986. Geography of western North American freshwater fishes: description and relationships to intracontinental tectonism, pp 519–613. In: The Zoogeography of North American Freshwater Fishes. Hocutt, C. H. and E. O. Wiley, editors. John Wiley and Sons. New York.

[3] Eschmeyer, W.S., E.S. Herald, and H. Hammann. 1984. *A field guide to Pacific coast fishes of North America.* Houghton Mifflin Co., Boston, MA. 336 pp. McGinnis, S.M. 1984. *Freshwater Fishes of California.* University of California Press, Berkeley and Los Angeles, CA. 316 pp. Page, L.M. and B.M. Burr. 1991. *A field guide to freshwater fishes of North America north of Mexico.* Houghton Mifflin Co., Boston, MA. 432 pp. Moyle, P.B. 2002. *Inland Fishes of California.* University of California Press, Berkeley, CA. 503 pp.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	*Status*[A] *(Federal/State/ CNPS)*	*Selection Criteria For Coverage*[B] Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information	*Consider for Coverage?*	*Coverage Comments*
12. California roach, Sacramento-San Joaquin subspecies *Lavinia symmetricus* ssp. *symmetricus*	-/SSC/-	-	+	+ (AD, H, ID, O)	+	No	This species is not recommended for coverage under the BDCP. It has no federal or state status and is not likely to be listed. The subspecies is abundant in a large number of streams throughout the Sacramento-San Joaquin watershed, although it has been locally extirpated from many streams since 1970.
13. Hitch *Lavinia exilicauda*	-/SSC/-	-	+	+ (AD, H, ID, O)	+	No	This species is not recommended for coverage under the BDCP. It has no federal or state status and is not likely to be listed. The species has scattered populations throughout the Central Valley, from the Tulare Lake basin in the southern San Joaquin River drainage to the Shasta Reservoir in the northern Sacramento River drainage.
14. White sturgeon *Acipenser transmontanus*	-/-e/-		+	+ (AD, H, ID, O)	+	Yes	Meets all four criteria. Identified as a covered species in the BDCP Planning Agreement.
15. Green sturgeon *Acipenser medirostris*	T/SSC/- +	+	+	+ (AD, H, ID, O)	+	Yes	Meets all four criteria. Identified as a covered species in the BDCP Planning Agreement.
16. Pacific lamprey *Entosphenus tridentatus*	-/-/-		+	+ (AD, ID, O)	+	Yes	Meets all four criteria. Although this species has no regulatory or conservation status, it has a similar life history characteristics to those of the river lamprey and populations are in decline. Potential effects could occur through water operations and in-Delta conveyance construction.
17. River lamprey *Lampetra ayresii*	-/SSC/- +	+	+	+ (AD, ID, O)	+	Yes	Meets all four criteria. This species is a state species of concern. It is a covered species under the Butte County HCP.
Mammals							
1. American badger *Taxidea taxus*	-/SSC/-	-	+	+ (AD)	+	No	Although a special-status species that has experienced local declines in some areas of the state, there is no indication that it has experienced declines sufficient to warrant listing over the term of the BDCP. While there are no documented occurrences, this species could potentially occur in grassland habitats on and near the Stone Lakes National Wildlife Refuge and along the western edge of the Plan Area from Yolo County to San Joaquin County.
2. Ringtail *Bassariscus astutus*	-/FP/-	+	-	-	+	No	The ringtail is a state Fully Protected species. It is being considered for coverage under the South Sacramento County HCP and the Yolo HCP/NCCP. While the species is known to occur in dense riparian woodlands, the limited extent of riparian habitat in the Plan Area limits the potential for occurrence and the potential for affect. The possible exception is the Cosumnes River Preserve east of Interstate 5 that would not be affected by covered activities.
3. San Joaquin kit fox *Vulpes macrotis mutica*	E/T/-	+	+	+ (AD)	+	Yes	Meets all four criteria. There is potential for affect if this species is found to occur in the grassland habitats along the western edge of the Plan Area between approximately Brentwood and Clifton Court Forebay.
4. Riparian woodrat *Neotoma fuscipes riparia*	E/SSC, SA/-	+	U	U (ID/AD/H)	+	Yes	Though it does not meet all four criteria, due to this species' rarity and dependence on limited specialized habitat that is found in the Plan Area, it is proposed for coverage under the BDCP. In addition to being a state species of special concern, this species is also considered a Special Animal because it is included on the IUCN Red List as Critically Endangered. This species is also a covered species under the San Joaquin County HCP. This species is restricted to riparian habitats. While occurrence in the Plan Area is unknown, it is known to occur immediately adjacent to the Plan Area and there are patches of suitable habitat that potentially support this species.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	*Status[A] (Federal/State/ CNPS)*	*Selection Criteria For Coverage[B]*				*Consider for Coverage?*	*Coverage Comments*
		Listing Potential	**Occurrence in the Plan Area**	**Potential to Adversely Affect[C]**	**Sufficient Information**		
5. Salt marsh harvest mouse *Reithrodontomys raviventris*	E/E,FP/-	+	+	+ (H)	+	Yes	Meets all four criteria. This species is also being considered as a covered species in the Solano HCP/NCCP. This species is closely associated with tidal marsh habitats. It occurs in the western extreme of the Plan Area where restoration activities could affect occupied habitats.
6. San Joaquin pocket mouse *Perognathus inornatus inornatus*	-/SA/-		+	+ (ID, AD)	+	No	This species is considered a Special Animal by DFG because it is included on the IUCN Red List, under which it is designated as Least Concern. It has no legal or other conservation status. This species is a covered species under the San Joaquin County HCP. However, there is no other indication that this species would be listed during the timeframe of the plan and the potential for affecting this species is minimal. So, while this conflicts with the criteria that includes "…covered under permits by other HCPs in northern California", it is not considered for coverage. This species potentially occurs in grassland habitats on the western edge of the Plan Area where it could be affected by activities associates with conveyance construction.
7. Berkeley kangaroo rat *Dipodomys heermanni berkeleyensis*	- -/SA/-	+	-	-	+	No	This species is considered a Special Animal by DFG because it is included on the IUCN Red List, for which it is designated as Vulnerable. It has no legal or other conservation status. It is a covered species under the San Joaquin HCP. This species has a very limited distribution and is known primarily from short grass prairies west of the Plan Area. It is unlikely to occur in the Plan Area and would therefore not be subject to project impacts.
8. Riparian brush rabbit *Sylvilagus bachmani riparius*	E/E/-	+	+	+ (H, ID, AD)	+	Yes	Meets all four criteria. This species is restricted to riparian habitats that could potentially be affected by conveyance and restoration activities.
Big free-tailed bat *9. Nyctinomops macrotis*	-/SSC/-	+	-	-	+	No	In addition to being a state species of special concern, this species is designated as Moderate-High Priority by the Western Bat Working Group (WBWG). It is also designated as Least Concern on the IUCN Red List. This species has a very restricted distribution in the San Francisco Bay Area. Due to its status and restricted range, it is reasonable to assume that this species could become listed over the term of the BDCP. The range of this species does not extend into or near the Plan Area and thus would not be affected by covered activities.
10. Western mastiff bat *Eumopsperotis californicus*	-/SSC/-	+	+	-	+	No	In addition to being a state species of special concern, this species is also included on the IUCN Red List as Least Concern and is designated as High Priority by WBWG. It is reasonable to conclude that this species could be listed over the term of the BDCP. It is not being considered for coverage under any other overlapping HCP/NCCPs. This colonial species uses caves and rock outcrops for roosting. Thus, while the species could potentially occur in the Plan Area for foraging, because the area lacks suitable roosting habitat, there is no potential to adversely affect this species.
11. Pallid bat *Antrozous pallidus*	-/SSC/-	-	+	+ (ID/AD)	+	No	In addition to being a state species of special concern, this species is also included on the IUCN Red List as Least Concern and is designated as High Priority by WBWG. While declines of this species have been reported, the pallid bat is widespread throughout California. There are insufficient data to indicate that listing of this species would be warranted over the term of the BDCP. This widely distributed species roosts in small colonies in caves, rock crevices, and tree hollows, but will also use bridges and buildings. Potential to adversely affect is based on the potential for removal of occupied trees, buildings, and bridges.
12. Yuma Myotis bat *Myotis yumanensis*	-/SA/-		+	+ (ID/AD)	+	No	This species is considered a Special Animal by DFG because it is included on the IUCN Red List, for which it is designated as Least Concern, and on the WBWG list, for which it is designated as Low-Medium Priority. It has no legal or other conservation status. There is no indication that it would be listed over the term of the BDCPover the term of the BDCP. This species is being considered as a covered species in the South Sacramento HCP. It is widely distributed and so likely occurs in Plan Area, but the limited extent of riparian forests suggests that there are few areas where roosting or maternity colonies are possible. The species more likely occurs during feeding and during migration. Potential to adversely affect based on the limited potential for removing occupied trees.

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Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	*Status[A] (Federal/State/ CNPS)*	*Selection Criteria For Coverage[B]*				*Consider for Coverage?*	*Coverage Comments*
		Listing Potential	**Occurrence in the Plan Area**	**Potential to Adversely Affect[C]**	**Sufficient Information**		
13. Silver-haired bat *Lasionycteris noctivagans*	-/SA/-		+	+ (ID/AD)	+	No	This species is considered a Special Animal by DFG because it is included on the IUCN Red List, for which it is designated as Least Concern, and on the WBWG list, for which it is designated as Medium Priority. It has no legal or other conservation status. There is no indication that it would be listed over the term of the BDCP. It is not a covered species under any of the overlapping permitted or in-process HCPs/NCCPs. Typically a higher elevation forest-dwelling species, it can occur in mature riparian forests in the Central Valley; however, the limited extent of riparian forests in the Plan Area may be insufficient to support this species, at least in abundance. The species more likely occurs during feeding and during migration. Potential to adversely affect is based on the unlikely possibility of removing active roosting or maternity sites in riparian habitat.
14. Western red bat *Lasiurus blossevillii*	- -/SSC/-	-	+	+ (ID/AD)	+	No	In addition to being a state species of special concern, this species is also designated as High Priority by WBWG. It is reasonable to conclude that this species could become listed over the term of the BDCP. It is also being considered as a covered species in the South Sacramento HCP and the Yolo HCP/NCCP. This species roosts in trees and is usually solitary. In the Plan Area, potentially occupied habitat includes mature riparian – usually cottonwood/sycamore riparian woodland. Potential to affect based on the potential for removal of active roost trees. While declines of this species have been reported, the red bat is widespread throughout California. There are insufficient data to indicate that listing of this species would be warranted over the term of the BDCP.
15. Hoary bat *Lasiurus cinereus*	-/SA/-		+	+ (ID/AD)	+	No	This species is considered a Special Animal by DFG because it is included on the IUCN Red List, for which it is designated as Least Concern, and on the WBWG list, for which it is designated as Medium Priority. It has no legal or other conservation status. There is no indication that it would be listed over the term of the BDCP. It is not a covered species under any of the overlapping permitted or in-process HCPs/NCCPs. This is a solitary bat that does not nest or roost colonially. It ranges widely, but populations in the Central Valley are most likely non-reproductive or migratory. Roosts in large trees in mature riparian – usually cottonwood/sycamore, which is limited in study area. Potential to affect based on the potential for removal of active roost trees.
16. Townsend's big-eared bat *Corynorhinus townsendii*	- -/SSC/-	+	+	+ (ID/AD)	+	Yes	Meets all four criteria. In addition to being a state species of special concern, this species is also included on the IUCN Red List as Vulnerable and is designated as High Priority by WBWG. It is reasonable to conclude that this species could be listed over the term of the BDCP. It is also included as a covered species in the East Contra Costa HCP/NCCP and is being considered for coverage under the Yolo HCP/NCCP. This is a highly colonial bat that typically occupies natural caves; however, it is also known to colonize old structures such as barns. It is widely distributed throughout most of California and while there are no known roosts or maternity sites from the Plan Area, there is potential for use of old barns and other structures.
17. Suisun shrew *Sorex ornatus sinuosus*	-/SSC/-	+	+	+ (H)	+	Yes	Meets all four criteria. This species is also being considered as a covered species in the Solano HCP/NCCP. This species is closely associated with tidal marsh habitats and could potentially be listed in the future. It occurs in the western extreme of the Plan Area where restoration activities could affect occupied habitats.
Birds							
1. Yellow-headed blackbird *Xanthocephalus xanthocephalus*	-/SSC/-	-	+	+ (H, AD)	+	No	Priority 3 as a state species of special concern with relatively stable populations since 1980. Not covered or considered for coverage on other overlapping HCP/NCCPs. Potentially affected from removal of occupied breeding habitat associated with conveyance and restoration activities, but not sufficient to adversely affect the species.
2. Tricolored blackbird *Agelaius tricolor*	BCC/SSC/-	+	+	+ (H, AD, ID)	+	Yes	Meets all four criteria. Significant and dramatic population declines and covered or considered for coverage under all overlapping HCP/NCCPs. Potential adverse effects from removal or disturbance to occupied breeding sites associated with conveyance and restoration activities.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	*Status[A] (Federal/State/ CNPS)*	*Selection Criteria For Coverage[B]*				*Consider for Coverage?*	*Coverage Comments*
		Listing Potential	**Occurrence in the Plan Area**	**Potential to Adversely Affect[C]**	**Sufficient Information**		
3. Grasshopper sparrow *Ammodramus savannarum*	-/SSC/-	-	+	+ (AD, ID, H)	+	No	While population declines are reported, the population trend data is unreliable and insufficient to indicate that a listing would be warranted over the term of the BDCP. Also being considered for coverage in the Yolo HCP/NCCP. Breeding has been documented at Cosumnes River and Yolo Bypass. Potential adverse effects from conveyance construction and possibly from restoration activities in the Yolo Basin.
4. Bell's sage sparrow *Amphispiza belli belli*	BCC/SA/-	-	-	-	+	No	This species is a former state species of special concern and currently remains on the DFG Watch List. It is also designated as Least Concern on the IUCN Red List. There is no indication that this species would become listed over the term of the BDCP. This species occurs in chaparral habitats and is not known to occur in the Plan Area. Therefore, covered activities are not expected to adversely affect this species.
5. Song sparrow "Modesto"*Melospiza melodia*	-/SSC/-	-	+	+ (H)	+	No	Because it is a Priority 3 state species of special concern, it is not covered by any other overlapping HCP/NCCPs, and because there is ongoing debate regarding whether this population is a valid subspecies, there is no indication that it would become listed over the term of the BDCP. In addition, while it could be affected – particularly associated with restoration actions – this species may benefit from restoration activities in the long term.
6. Suisun song sparrow *Melospiza melodia maxillaris*	BCC/SSC/-	+	+	+	+	Yes	Meets all four criteria. This species is also being considered as a covered species in the Solano HCP/NCCP. This species is closely associated with tidal marsh habitats and has a restricted distribution within the Delta and Suisun Marsh. It could potentially be listed over the term of the BDCP. It occurs in the western extreme of the Plan Area and Suisun Marsh where restoration activities could affect occupied habitats.
Samuels (San Pablo) *7.* song sparrow *Melospiza melodia samuelis*	BCC/SSC/-	+	-	-	+	No	This species' range does not extend into the Plan Area and thus would not be affected by project actions.
8. California yellow warbler *Dendroica petechia*	-/SCC/-	+	+	-	+	No	Populations of this species continue to trend downward. It is a covered species in the San Joaquin County HCP. It is reasonable to suggest that this species would become listed over the term of the BDCP. The species does not nest within the Plan Area, but can be observed during migration. There is also limited potential for nesting, particularly on portions of the Cosumnes River Preserve, but these areas are not expected to be affected by covered activities.
9. Yellow-breasted chat *Icteria viriens*	-/SSC/-	+	+	+ (H, AD, ID)	+	Yes	Meets all four criteria. Negative population trend since 1980. Also covered under the San Joaquin HCP and considered for coverage under the Solano and Yolo HCP/NCCPs and the South Sacramento County HCP. It is reasonable to suggest that this species would become listed over the term of the BDCP. This species occurs in riparian habitat and could be affected by conveyance and possibly restoration activities.
10. Salt Marsh Common Yellowthroat *Geothlypis trichas sinuosa*	BCC/SSC/-	+	-	-	+	No	This species' range does not extend into the Plan Area and thus would not be affected by project actions.
11. Purple martin *Progne subis*	-/SSC/-	+	+	-	+	No	This species is considered extirpated from the Plan Area, but birds that nest in the Sacramento urban area may occasionally occur in the Plan Area. Due to substantial population declines since the 1960s, it is reasonable to suggest that this species could become listed over the term of the BDCP. It is being considered for coverage under the Yolo HCP/NCCP. Because the species does not nest within the Plan Area with the exception of the Sacramento urban area, and is absent from the Central Valley; and because major riparian corridors would be avoided through tunneling, covered activities are not expected to adversely affect this species.
12. Bank swallow *Riparia riparia*	-/T/-	+	+	-	+	No	Possibility for nesting colonies along the Sacramento River near Fremont Weir. This species is covered in the San Joaquin and Natomas Basin HCPs, and is considered for coverage in the Yolo HCP/NCCP. However, BDCP activities are not expected to disturb potential habitat.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	*Status[A] (Federal/State/ CNPS)*	*Selection Criteria For Coverage[B]* Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information	*Consider for Coverage?*	*Coverage Comments*
13. California horned lark *Eremophila alpestris actia*	-/SA/-	-	+	-	+	No	This species is on the DFG Watch List and is designated as Least Concern on the IUCN Red List. It is not covered under any overlapping HCP/NCCPs. There is no indication that it would become listed over the term of the BDCP. This is a relatively common species and is considered an agricultural pest.
14. Least Bell's vireo *Vireo bellii pusillus*	SE/FE/-	+	+	+	+	Yes	Meets all four criteria. Two individual male least Bell's vireo spent the spring and summer of 2010 within the Plan Area in the Yolo Bypass Wildlife Area singing and attempting to attract mates. This increases the likelihood of individuals returning to the Plan Area in subsequent years and perhaps establishing a breeding pair over the term of the BDCP. The potential for the project to affect this species also increases with these new occurrences.
15. Loggerhead shrike *Lanius ludovicianus*	BCC/SSC/-	-	+	+ (H, AD, ID)	+	No	While somewhat stabilized recently, significant negative population trend since 1968. Also a covered species under the San Joaquin HCP and Natomas Basin HCP and considered for coverage in the South Sacramento County HCP and Yolo County HCP/NCCP. This species potentially occurs throughout the Plan Area and could be affected by conveyance and possibly restoration activities. However, it is unlikely that the species would become listed during the time period that covered activities that could affect the species would be implemented.
16. Lewis's woodpecker *Melanerpes lewis*	BCC/SA/-	-	+	+	+	No	This species is designated as Least Priority on the IUCN Red List. There is no indication that it would become listed over the term of the BDCP.
17. Western burrowing owl *Athene cunicularia hypugaea*	BCC/SSC/-	+	+	+ (AD, ID, H)	+	Yes	Meets all four criteria. This species is a covered species under all overlapping HCP/NCCPs. Burrowing owls could potentially be affected from removal of grassland and pastureland habitats associated with conveyance activities, and possibly restoration activities in the Yolo Basin.
18. Long-eared owl *Asio otus*	-/SSC/-	-	+	+ (H, AD, ID)	+	No	This species has been a state species of special concern since 1978. Its range includes all of California with the exception of much of the Central Valley. There is little recent reliable data on the abundance of this species and insufficient data to indicate that a listing is warranted over the term of the BDCP. Although there are no recently reported occurrences of this species from the plan area, long-eared owl could potentially be affected from removal of riparian woodland and grassland/seasonal wetland habitats associated with conveyance and restoration activities.
19. Short-eared owl *Asio flammeus*	-/SSC/-	-	+	+ (H, AD)	+	No	This species has been a state species of special concern since 1978. While local population declines have been reported, there is insufficient data on statewide populations to indicate that a listing would be warranted over the term of the BDCP.
20. Western yellow-billed cuckoo *Coccyzus americanus occidentalis*	C,BCC /E/-	+	+	-	+	Yes	Though it does not meet all four criteria, due to this species' rarity and dependence on limited specialized habitat that is found in the Plan Area, it is proposed for coverage under the BDCP. This species has been observed within the Plan Area during migration in riparian patches too small to support breeding habitat, but that can still serve as migratory corridors. Potential breeding habitat for cuckoos in the Plan Area is restricted to the Cosumnes River Preserve, which would not be affected by covered activities. Riparian restoration actions under the BDCP could allow the re-establishment of sufficiently large areas of riparian habitat that will permit the re-colonization of the Plan Area by breeding cuckoos.
21. California gull *Larus californicus*	-/SA/-		+	+ (H)	+	No	This species is a former state species of special concern and remains on the DFG Watch List. It is also designated as a Least Concern species on the IUCN Red List. No other overlapping HCP/NCCPs include this species as a covered species. There is no indication that this species would become listed over the term of the BDCP. There are no California gull breeding colonies within the Plan Area with the possible exception of small colonies in the far western end of the Plan Area that could be affected by restoration activities.

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Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	*Status[A] (Federal/State/ CNPS)*	*Selection Criteria For Coverage[B]*				*Consider for Coverage?*	*Coverage Comments*
		Listing Potential	**Occurrence in the Plan Area**	**Potential to Adversely Affect[C]**	**Sufficient Information**		
22. Black tern *Chlidonias niger*	-/SSC/-	-	+	+ (H)	+	No	This species was recently designated a state species of special concern and is a proposed covered species under the yolo County HCP/NCCP. While local population declines have been reported, particularly from the Central Valley, there is no indication that listing of this species would be warranted over the term of the BDCP. This species has been documented in the Yolo Basin, where it is associated with rice fields. The effects of covered activities on this species are expected to be minimal.
23. California least tern *Sterna antillarum browni*	E/E,FP/-	+	+	+ (H)	+	Yes	Meets all four criteria. This species occurs in discrete locations within the Plan Area in small breeding colonies. Habitat restoration actions could attract or affect nesting terns.
24. Long-billed curlew *Numenius americanus*	BCC/SA/-	-	+	+ (H, AD)	+	No	This species is a former state species of special concern and remains on the DFG Watch List. It is also a federal bird of conservation concern. There is no indication that this species would become listed over the term of the BDCP. Curlews only winter in the Plan Area and thus effects would be limited to temporary displacement from winter foraging habitats and possibly loss of winter foraging habitats from conveyance construction and restoration activities.
25. Snowy plover (interior population) *Charadrius alexandrinus*	BCC/SSC/-	+	+	-	+	No	The range of the inland population of the snowy plover includes a small portion of the Plan Area in the Yolo Basin. This population is a state species of special concern and a federal bird of conservation concern. It is reasonable to suggest that this population (along with the coastal population that is currently federally listed) could become listed over the term of the BDCP. There are few breeding records of this species from the Yolo Bypass Wildlife Area, but none from anywhere else in the Plan Area. Potential effects would be limited to restoration activities planned for the Yolo Basin. It is assumed that this site would be protected from impacts resulting from restoration activities, and that the project would be unlikely to adversely affect this species.
26. Snowy plover (coastal population) *Charadrius alexandrinus*	T/-/-	+	-	-	+	No	The coastal population of snowy plover is federally listed but has no state status. This population occurs primarily along the coast and none of the recovery units, which generally define the range of the species, occur within the Plan Area. Thus, this population does not occur in the Plan Area and would not be affected by covered activities.
27. Mountain plover *Charadrius montanu*	BCC/SSC/-	-	+	+ (H, AD)	+	No	In addition to being a state species of special concern and federal bird of conservation concern, the mountain plover is also designated as Vulnerable on the IUCN Red List. The species is being considered as a covered species on the Solano County and Yolo County HCP/NCCPs. There is no indication that the species would become federally listed over the term of the BDCP, and since the species only winters in California, it is unlikely that the species would become state listed. Mountain plovers do not breed in California, but the species has been reported during winter at several sites in Yolo and Solano Counties, including occasional occurrences in the Yolo Basin. However, given that the species only winters in a small portion of the Plan Area, potential impacts are limited to temporary displacement during winter foraging, and thus covered activities are not expected to affect this species.
28. Lesser sandhill crane *Grus canadensis canadensis*	-/SSC/-	-	+	+ (H, AD, ID)	+	No	This species was recently designated a state species of special concern. While there is concern that agricultural conversions could continue to reduce habitat for this species, the range size and population trend have remained fairly stable and there is no indication that the species would become listed over the term of the BDCP. This species does not nest in the Plan Area, but the Plan Area encompasses the majority of the traditional winter range of this species in the Delta. It occurs in seasonal wetland and agricultural habitats where it roosts and forages. Potential effects include displacement of foraging habitats from conveyance and restoration activities.
29. Greater sandhill crane *Grus canadensis tabida*	-/T,FP/-	+	+	+ (H, AD, ID)	+	Yes	Meets all four criteria. This species is also a covered species in the Natomas and San Joaquin HCPs and is being considered for coverage in the South Sacramento HCP. This species does not nest in the Plan Area, but the Plan Area encompasses the majority of the traditional winter range of this species in the Delta. It occurs in seasonal wetland and agricultural habitats where it roosts and forages. Potential effects include displacement and possible removal of roosting and foraging habitats from conveyance and restoration activities.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	Status[A] (Federal/State/ CNPS)	Selection Criteria For Coverage[B]: Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information	Consider for Coverage?	Coverage Comments
30. California black rail *Laterallus jamaicensis coturniculus*	BCC /T,FP/-	+	+	+ (H, ID, AD)	+	Yes	Meets all four criteria. This species is also being considered as a covered species in the Solano HCP/NCCP, and is a covered species in the San Joaquin County HCP. This species is closely associated with tidal marsh habitats. It occurs throughout the Western and Central Delta and could be affected by conveyance and restoration activities.
31. California clapper rail *Rallus longirostris obsoletus*	E/E,FP/-	+	+	+ (H)	+	Yes	Meets all four criteria. This species is also being considered as a covered species in the Solano HCP/NCCP. This species is closely associated with tidal marsh habitats. It occurs in the western extreme of the Plan Area where restoration activities could affect occupied habitats.
32. Merlin *Falco columbarius*	-/SA/-	-	+	-	+	No	The merlin is a former state species of special concern and currently remains on the DFG Watch List. It is also designated as Least Concern on the IUCN Red List. It is being considered for coverage in the South Sacramento HCP; however, the species has no state or federal status and there is no indication that the species would become listed over the term of the BDCP. The merlin does not nest in California. It is observed occasionally during winter in the Plan Area. Potential affects would be limited to temporary displacement from foraging habitat during project construction. It is therefore not expected to be adversely affected by the project.
33. American Peregrine Falcon *Falco peregrinus anatum*	BCC/E,FP/-	+	+	-	+	No	The peregrine falcon was recently delisted by the USFWS. It remains state endangered and fully protected; and is a federal bird of conservation concern. It is a covered species in the Natomas Basin HCP, and is being considered for coverage in the Yolo HCP/NCCP and South Sacramento County HCP. This species does not nest within or near the Plan Area. It is occasionally observed foraging in the Plan Area during the winter. Potential affects are limited to temporary displacement of foraging individuals during winter. Thus, the project is not expected to adversely affect this species.
34. Prairie falcon *Falco mexicanus*	BCC/SA/-	-	+	-	+	No	The prairie falcon is a former state species of special concern and currently remains on the DFG Watch List. It is also a federal Bird of Conservation Concern and is designated Least Concern on the IUCN Red List. It is a covered species in the San Joaquin HCP probably a result of its previous status as a species of special concern. The prairie falcon does not nest in the Plan Area. It is, however, occasionally observed foraging in the Plan Area, mostly during the winter. Potential affects are limited to possible temporary displacement from foraging areas during covered activities. It is therefore not expected to be adversely affected by the project.
35. Bald eagle *Haliaeetus leucocephalus*	-/E,FP/-	+	+	-	+	No	The bald eagle was recently delisted by the USFWS and currently has no federal status. It remains a state endangered species and state fully protected species. The species is being considered for coverage under the South Sacramento County HCP. However, there are several traditional use areas in the south Sacramento County Plan Area (primarily the upper American River) and an important winter use area and one nest location in the Yolo County Plan Area. This species does not nest in the Plan Area. It is occasionally observed foraging in the Plan Area during the winter, but there are no traditionally used bald eagle roosts or winter foraging habitats in the Plan Area, with the possible exception of a portion of the Cosumnes River Preserve that would not be affected by project actions. Thus, covered activities are not expected to adversely affect this species.
36. Northern harrier *Circus cyaneus*	-/SSC/-	-	+	+ (H, ID, AD)	+	No	This is a covered species under the San Joaquin HCP and is being considered for coverage under the Yolo HCP/NCCP, Solano HCP/NCCP, and South Sacramento HCP. This species occurs throughout the Plan Area and could be affected by conveyance and restoration activities. While declines of this species have been documented, it remains widespread throughout California and is unlikely to become listed over the term of the BDCP.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	Status[A] (Federal/State/ CNPS)	Selection Criteria For Coverage[B]				Consider for Coverage?	Coverage Comments
		Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information		
37. Sharp-shinned Hawk *Accipiter striatus*	-/SA/-	-	+	-	+	No	This species was formerly a state species of concern, but was removed from that list and is currently on DFG's Watch List. It is also designated as a Least Concern species on the IUCN Red List. It is a covered species in the San Joaquin County HCP. It is also currently considered for coverage under the South Sacramento HCP and the Solano HCP/NCCP. While it may be a covered species in other HCP/NCCPs that overlap the Plan Area, there is no indication that this species would become listed over the term of the BDCP. This species only winters in the Plan Area and so would not be affected by covered activities.
38. Cooper's Hawk *Accipiter cooperii*	-/SA/-		+	+ (ID, AD)	+	No	This species was formerly a state species of special concern, but was removed from that list and is currently on DFG's Watch List. It is also designated as a Least Concern species on the IUCN Red List. It is a covered species in the San Joaquin County HCP. It is also currently considered for coverage under the South Sacramento HCP and the Solano HCP/NCCP. While it may be a covered species in other HCP/NCCPs that overlap the Plan Area, there is no indication that this species would become listed over the term of the BDCP. This species occurs in riparian and other woodland habitats and could be affected by conveyance or restoration activities.
39. White-tailed kite *Elanus leucurus*	-/FP/-	+	+	+ (H, ID, AD)	+	Yes	Meets all four criteria. The white-tailed kite is a state Fully Protected species. It is also being considered for coverage under the South Sacramento County HCP and the Yolo HCP/NCCP. The kite occurs in riparian and other woodland habitats and could be affected through conveyance or restoration activities that remove trees or disturb active nests.
40. Swainson's hawk *Buteo swainsoni*	BCC /T/-	+	+	+ (H, ID, AD)	+	Yes	Meets all four criteria. Swainson's hawk is a covered species or is being considered for coverage in all overlapping HCPs/NCCPs. Swainson's hawks nest in riparian woodlands, roadside trees, tree rows, isolated trees, woodlots, and trees in farmyards and rural residences. They forage in grasslands and agricultural fields. Nest sites and foraging habitat would be affected by conveyance facilities and possibly by restoration activities.
41. Ferruginous hawk *Buteo regalis*	BCC/SA/-	-	+	-	+	No	The ferruginous hawk is a former state species of special concern and remains on the DFG Watch List. It is also a federal bird species of conservation concern and is designated as Near Threatened on the IUCN Red List. The species does not breed in California and only winters in relatively small numbers in the Plan Area. There is no indication that the species would become listed over the term of the BDCP. It is being considered as a covered species in the South Sacramento HCP, but was initially considered due to its former status as a state species of special concern. Because this species only winters in the Plan Area, it is not expected to be affected by covered activities.
42. Golden eagle *Aquina chrysaetos*	BCC/FP/-	+	+	-	+	No	The golden eagle is a state Fully Protected species. The species was formerly a state species of concern, but was removed from that list and is currently on DFG's Watch List. It is also designated as a Least Concern species on the IUCN Red List and is a federal Bird of Conservation Concern. The East Contra Costa HCP/NCCP and San Joaquin HCP both include the golden eagle as a covered species, and the Solano and Yolo HCP/NCCPs and the Sacramento HCP are considered the species for coverage. However, each of these plans includes Plan Areas that could support nesting golden eagles. Golden eagles do not currently and are not expected to nest within the Plan Area. While they may forage occasionally in the Plan Area, affects would be limited to temporary displacement of foraging birds. Thus, the species is not likely to be adversely affected by covered activities.
43. Osprey *Pandion haliaetus*	-/SA/-	-	+	-	+	No	The osprey is a former state species of special concern and remains on the DFG Watch List. It is also included on the IUCN Red List, for which it is designated as Least Concern. While there are occasional wintering occurrences, the species is not known to nest in the Plan Area. The species is a covered species in the San Joaquin County HCP. Ospreys would typically be found roosting in riparian areas or trees or artificial structures around water bodies. Because it is not expected to nest in the Plan Area, affects are limited to displacement of foraging birds. Thus, covered activities are not expected to adversely affect this species.
44. Cackling (Aleutian Canada) goose *Branta hutchinsii leucopareia*	-/SA/-		+	+ (H)	+	No	This species was delisted by the USFWS. It remains on the DFG Special Animal list but has no status designation. There is no indication that this species would become listed over the term of the BDCP. It is not covered in any other neighboring HCP/NCCP except San Joaquin HCP due to its previous listing. Winters in the Yolo Basin and various locations in the Delta and could potentially be affected by restoration activities.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	Status[A] (Federal/State/ CNPS)	Selection Criteria For Coverage[B]				Consider for Coverage?	Coverage Comments
		Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information		
45. Tule white-fronted goose (wintering) *Anser albifrons elgasi*	-/SSC/-	-	+	+ (H)	+	No	Although this is a species of special concern, it is also a species closely managed by DFG on its wintering grounds. There is no indication that this species would become listed over the term of the BDCP. This species only winters in California where it relies on dense tule-cattail marsh habitat. It has been documented within the Plan Area west of Sherman Island and in various locations in the Suisun Marsh. It could potentially be affected by restoration activities, but because the species occurs only during the winter, impacts can be avoided. Also, in the long term the species would benefit from these activities.
46. Redhead (nesting) *Aythya Americana*	-/SSC/-	-	+	+ (H)	+	No	This species has declined throughout much of its range in California in recent years. Restricted primarily to state and federal refuges, restoration activities in these areas have failed to restore deep water habitats required by redhead. However, this species would likely respond to changes in refuge management and thus there is no indication that it would become listed over the term of the BDCP. It is not covered or being considered for coverage in other overlapping HCPs/NCCPs. This species breeds in the Yolo Bypass. It could be affected by restoration activities occurring in the Yolo Bypass.
47. White-faced Ibis *Plegadis chihi*	-/SA/-		+	+ (H, ID, AD)	+	No	White-faced ibis *rookeries* are considered sensitive colonial breeding sites for this species and are thus included on the DFG Special Animals list. The species is also included on the DFG Watch List and on the IUCN Red List, where it is designated Least Concern. The San Joaquin County HCP and the Natomas Basin HCP include this species as a covered species; and the South Sacramento HCP is considering the species for coverage. However, this species was recently removed from the state bird species of special concern list due to significantly increased populations and there is no indication that this species would be listed over the term of the BDCP. It is therefore not recommended for coverage. White-faced ibis rookeries could occur in emergent marsh habitats and could be affected by conveyance and restoration activities.
48. Snowy Egret *Egretta thula*	-/SA/-		+	+ (H, ID, AD)	+	No	Snowy egret *rookeries* are considered sensitive colonial breeding sites for this species and are thus included on the DFG Special Animals list. They are also included on the DFG Watch List and on the IUCN Red List, where it is designated as Least Concern. The San Joaquin County HCP includes this species as a covered species; however, there is no indication that this species would be listed over the term of the BDCP and so is not recommended for coverage. Snowy egret rookeries could occur in riparian habitat or other woodland habitats or in emergent marsh habitats, and could be affected by conveyance and restoration activities.
49. Least bittern (nesting)*Ixobrychus exilis*	-/SSC/-	-	+	+ (H, ID, AD)	+	No	This species has been documented more regularly in recent years, and while possibly attributed to an increase in observer coverage, information on population trends are unreliable. While this species has declined as a result of loss of freshwater marsh habitats, there is no indication that a listing of this species would be warranted over the term of the BDCP. This species occurs in fresh water marsh habitats in the Yolo Bypass, east of the Sacramento River, and in the western Delta. It could be affected by restoration and conveyance activities.
50. Great egret *Ardea albus* (rookery)	-/SA/-		+	+ (H, ID, AD)	+	No	Great egret *rookeries* are considered sensitive colonial breeding sites for this species and are thus included on the DFG Special Animals list. It is also included on the IUCN Red List, where it is designated as Least Concern. The San Joaquin County HCP includes this species as a covered species; however, there is no indication that this species would be listed over the term of the BDCP and so is not recommended for coverage. Rookeries could occur in riparian habitat or in other woodland habitats, including eucalyptus groves in the Plan Area, and could be affected by conveyance and restoration activities.
51. Black-crowned night heron *Nycticorax nycticoraxs*	-/SA/-		+	+ (H, ID, AD)	+	No	Black-crown night heron *rookeries* are considered sensitive colonial breeding sites for this species and are thus included on the DFG Special Animals list. It is also included on the IUCN Red List, where it is designated as Least Concern. The San Joaquin County HCP includes this species as a covered species; however, there is no indication that this species would be listed over the term of the BDCP and so is not recommended for coverage. Black-crowned night heron rookeries could occur in riparian habitat or other woodland habitats or in emergent marsh habitats, and could be affected by conveyance and restoration activities.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	Status[A] (Federal/State/ CNPS)	Selection Criteria For Coverage[B]				Consider for Coverage?	Coverage Comments
		Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information		
52. Great blue heron *Ardea herodias* (rookery)	-/SA/-		+	+ (H, ID, AD)	+	No	Great blue heron *rookeries* are considered sensitive colonial breeding sites for this species and are thus included on the DFG Special Animals list. It is also included on the IUCN Red List, where it is designated as Least Concern. The San Joaquin County HCP includes this species as a covered species; however, there is no indication that this species would be listed over the term of the BDCP and so is not recommended for coverage. Rookeries could occur in riparian habitat or in other woodland habitats, including eucalyptus groves in the Plan Area, and could be affected by conveyance and restoration activities.
53. Double-crested cormorant *Phalacrocorax auritus*	- -/SA/-		+	+ (H, ID, AD)	+	No	Double-crested cormorant is a former state species of special concern; however, only *rookeries* were considered sensitive. It remains on DFG's Special Animals list as a Watch List species, which includes primarily delisted species or species that do not meet the criteria as a species of special concern. It is also is included on the IUCN Red List, where it is designated as Least Concern. The species has no legal or other conservation status. This is a covered species under the San Joaquin County HCP. There is no indication that this species is likely to be listed over the term of the BDCP. This species potentially nests in small rookeries in riparian habitats or some artificial structures in the Plan Area and could be affected by conveyance and restoration activities.
54. Western grebe *Aechmophorus occidentalis*	- -/-/-		+	+ (ID)	+	No	Western grebe has no legal or conservation status. The San Joaquin County HCP includes it as a covered species and it is on the IUCN Red List designated as a species of Least Concern. While there have been concerns regarding the status of breeding populations, there is no indication that the species would become listed over the term of the BDCP. There is one known breeding location in the Plan Area – within the Bouldin Island quadrangle, which could potentially be affected by the in-Delta conveyance activities; but otherwise it occurs mainly during the winter.
Reptiles							
1. Giant garter snake *Thamnophis gigas*	T/T/-	+	+	+ (H, ID, AD)	+	Yes	Meets all four criteria. This species is covered under all overlapping HCP/NCCPs. Potential affects could occur through disturbance of watercourses and adjacent upland habitats from conveyance and restoration activities.
2. Alameda whipsnake *Masticophis lateralis euryxanthus*	T/T/-	+	-	-	+	No	The East Contra Costa HCP/NCCP is the only overlapping plan to cover this species due to its distribution within the Contra Costa County. This species' range does not extend into the Plan Area and thus covered activities are not expected to adversely affect this species.
3. San Joaquin whipsnake *Masticophis flagellum ruddocki*	-/SSC/-	-	+	-	+	No	The San Joaquin County HCP is the only overlapping plan to cover this species with occurrences from Corral Hollow inSan Joaquin County. While the species may be found along the western edge of the Plan Area, it is unlikely to occur in the vicinity of conveyance or restoration activities and thus is not expected to be adversely affected by the project.
4. Silvery legless lizard *Anniella pulchra pulchra*	-/SSC/-	+	+	-	+	No	The East Contra Costa HCP/NCCP is the only overlapping plan to cover this species. That plan documented occurrences and potential habitat along the western edge of the Plan Area; however, none are in the vicinity of proposed conveyance or restoration activities.
5. Coast horned lizard *Phrynosoma coronatum frontale*	-/SSC/-	-	+	+ (AD)	+	No	This species is covered under the San Joaquin HCP. Documented occurrences in the grasslands on the western edge of the Plan Area in the vicinity of Clifton Court Forebay. Likelihood for impacts are low and the species is unlikely to become listed in the foreseeable future.
6. Western pond turtle *Actinemys marmorata*	-/SSC/-	+	+	+ (H, ID, AD)	+	Yes	Meets all four criteria. In addition to being a state species of special concern, this species is also designated as Vulnerable on the IUCN Red List. It is covered or considered for coverage on all overlapping HCP/NCCPs. It is reasonable to suggest that this species could become listed over the term of the BDCP. This species could potentially be affected by ground disturbances in watercourses and adjacent uplands associated with conveyance and possibly restoration activities.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	Status[A] (Federal/State/ CNPS)	Selection Criteria For Coverage[B]: Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information	Consider for Coverage?	Coverage Comments
Amphibians							
1. California red-legged frog *Rana aurora draytonii*	T/SSC/-	+	+	+ (AD)	+	Yes	Meets all four criteria. This species is covered under the East Contra Costa HCP/NCCP and the San Joaquin County HCP and is considered for coverage under the Yolo and Solano HCP/NCCPs. There are reported occurrences of this species in grassland/pond habitats in the vicinity of Clifton Court Forebay. Potential affects could occur through disturbance of occupied ponds or streams.
2. Foothill yellow-legged Frog *Rana boylii*	-/SSC/-	+	-	-	+	No	This species is covered under the East Contra Costa HCP/NCCP and the San Joaquin County HCP and is considered for coverage under the Yolo and Solano HCP/NCCPs. Each of these Plan Areas include potential habitat for this species. There are no occurrence records and no potential habitat for foothill yellow-legged frog in the Plan Area and thus covered activities are not expected to affect this species.
3. Western spadefoot toad *Spea hammondii*	-/SSC/-	+	+	+ (H, AD)	+	Yes	Meets all four criteria. This species is covered under the San Joaquin HCP and is considered for coverage under the Yolo County HCP/NCCP and the South Sacramento County HCP. Potential effects could occur through disturbance of vernal pools and intermittent streams and adjacent grassland habitats from conveyance and restoration activities.
4. California tiger salamander (Central Valley DPS) *Ambystoma californiense*	T/SSC/-	+	+	+ (H, AD)	+	Yes	Meets all four criteria. This species is covered or is being considered for coverage under all overlapping HCP/NCCPs. Potential affects could occur through disturbance of vernal pools and ponds and adjacent grassland habitats from conveyance and restoration activities. As of February 2009 this species is a candidate for state listing as endangered.
Invertebrates							
1. Blennosperma vernal pool andrenid bee *Andrena blennospermatis*	-/-/-		+	+ (AD)	+	No	This species has no regulatory or conservation status and is not covered or considered for coverage in any overlapping HCP/NCCP. There is no indication that it would become listed over the term of the BDCP.
2. Redheaded sphecid wasp *Eucerceris ruficeps*	-/-/-	-	U	U	-	No	This species has no regulatory or conservation status and is not covered or considered for coverage in any overlapping HCP/NCCP. There is no indication that it would become listed over the term of the BDCP.
3. Antioch multilid wasp *Myrmosula pacifica*	-/-/-	-	+	-	+	No	This species has no regulatory or conservation status and is not covered or considered for coverage in any overlapping HCP/NCCP. There is no indication that it would become listed over the term of the BDCP. It is known from Antioch Dunes and thus is not expected to be affected by covered activities.
4. Antioch adrenid bee *Perdita scitula antiochensis*	-/-/-	-	+	-	+	No	This species has no regulatory or conservation status and is not covered or considered for coverage in any overlapping HCP/NCCP. There is no indication that it would become listed over the term of the BDCP. It is known from Antioch Dunes and thus is not expected to be affected by covered activities.
5. Antioch specid wasp *Philanthus nasalis*	-/-/-	-	+	-	+	No	This species has no regulatory or conservation status and is not covered or considered for coverage in any overlapping HCP/NCCP. There is no indication that it would become listed over the term of the BDCP. It is known from Antioch Dunes and thus is not expected to be affected by covered activities.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	*Status[A] (Federal/State/ CNPS)*	*Selection Criteria For Coverage[B]* Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information	*Consider for Coverage?*	*Coverage Comments*
6. Antioch Dunes halcitid bee *Sphecodogastra antiochensis*	-/-/-	-	+	-	+	No	This species has no regulatory or conservation status and is not covered or considered for coverage in any overlapping HCP/NCCP. There is no indication that it would become listed over the term of the BDCP. It is known from Antioch Dunes and thus is not expected to be affected by covered activities.
7. Lange's metalmark butterfly *Apodemia mormo langei*	E/-/-	+	+	-	+	Yes	Though it does not meet all four criteria, due to this species' rarity and dependence on limited specialized habitat that is found in the Plan Area, it is proposed for coverage under the BDCP. This species is known only from the Antioch Dunes within the Antioch Dunes Wildlife Refuge and is not expected to be affected by covered activities. It is proposed for coverage because it is a listed species associated with the inland dune scrub natural community.
8. San Bruno elfin butterfly *Callophrys mossii bayensis*	E/-/-	+	-	-	+	No	This species' range does not extend into the Plan Area and thus it is not expected to be affected by covered activities.
9. Monarch butterfly *Danaus plexippus*	-/-/-	-	-	-	+	No	This species has no regulatory or conservation status. It is not a covered species in any overlapping HCP/NCCP. There is no indication that it would become listed over the term of the BDCP. There are no records of monarch roosts from within the Plan Area and thus covered activities are unlikely to affect this species.
10. Callippe Silverspot Butterfly *Speyeria callippe callippe*	E/-/-	+	-	-	+	No	Range does not appear to extend into the Plan Area and is thus not expected to be affected by covered activities.
11. Antioch efferian robberfly *Efferia antiochi*	-/-/-	-	+	-	-	No	This species has no regulatory or conservation status and is not covered or considered for coverage in any overlapping HCP/NCCPs. There is no indication that it would become listed over the term of the BDCP. This species is known only from the Antioch area within the Plan Area and is not expected to be affected by covered activities.
12. Hurd's metapogon robberfly *Metapogon hurdi*	-/-/-	-	+	-	-	No	This species has no regulatory or conservation status and is not covered or considered for coverage in any overlapping HCP/NCCPs. There is no indication that it would become listed over the term of the BDCP. This species is known only from the Antioch area within the Plan Area and is not expected to be affected by covered activities.
13. Ciervo aegialian scarab beetle *Aegialia concinna*	-/SA/-	-	+	-	+	No	This species is designated as Vulnerable by the IUCN Red List. It has no regulatory or conservation status. It is a covered species under the San Joaquin County HCP. However, there is no indication that it would become listed over the term of the BDCP. It occurs in loose sands and sand dunes and is unlikely to be affected by covered activities.
14. Antioch Dunes anthicid beetle *Anthicus antiochensis*	-/-/-	-	+	-	-	No	This species has no regularly or conservation status. It is not covered or considered for coverage in any overlapping HCP/NCCP. There is no indication that it could become listed over the term of the BDCP. It occurs in loose sands and sand dunes and is unlikely to be adversely affected by covered activities.
15. Sacramento anthicid beetle *Anthicus sacramento*	-/SA/-	-	+	-	-	No	This species is designated as Endangered on the IUCN Red List. It has no regularly or conservation status and is not covered or considered for coverage in any overlapping HCP/NCCP. There is no indication that it could become listed over the term of the BDCP. It occurs in loose sands and sand dunes and is unlikely to be adversely affected by covered activities.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	Status[A] (Federal/State/ CNPS)	Selection Criteria For Coverage[B]				Consider for Coverage?	Coverage Comments
		Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information		
16. Sacramento Valley tiger beetle *Cicindela hirticollis abrupta*	-/-/-	-	U	U	-	No	USFWS recently denied listing petition due to insufficient information. It has no regulatory or conservation status and is not covered or considered for coverage in any overlapping HCP/NCCP. All known populations are extirpated and recent surveys suggest the species is extinct. There is no indication that this species would be listed over the term of the BDCP.
17. San Joaquin dune beetle *Coelus gracilis*	-/SA/-		+	+ (AD)	-	No	This species is designated as Vulnerable on the IUCN Red List. It has no regularly or conservation status and is not covered or considered for coverage in any overlapping HCP/NCCP. There is no indication that it could become listed over the term of the BDCP. It occurs in loose sands and small sand dunes along the western edge of San Joaquin Valley and could potentially be affected by conveyance facilities.
18. Valley elderberry longhorn beetle *Desmocerus californicus dimorphus*	T/-/-	+	+	+ (H, ID, AD)	+	Yes	Meets all four criteria. Potentially occupied shrubs could be affected by activities associated with conveyance and restoration activities.
19. Delta green ground beetle *Elaphrus viridis*	E/-/-	+	+	-	+	No	This species is being considered for coverage in the Solano County HCP/NCCP. Its restricted distribution may extend into the northwestern portion of the Plan Area. However, it does not occur in the vicinity of conveyance or restoration activities and thus is not expected to be affected by the project.
20. Ricksecker's water Beetle *Hydrochara rickseckeri*	-/-/-		+	+ (AD)	+	No	This species has no regulatory or conservation status and there is no indication that it would become listed over the term of the BDCP. However, it is being considered for coverage in the Solano HCP/NCCP and the South Sacramento County HCP. This is a vernal pool-associated species and could be affected by activities associated with conveyance activities.
21. Curved-foot diving beetle *Hygrotus curvipes*	-/-/-		+	+ (AD)	+	No	This species has no regulatory or conservation status and there is no indication that it would become listed over the term of the BDCP. However, it is a covered species in the San Joaquin HCP. This is a vernal pool/seasonal wetland-associated species and could be affected by activities associated with conveyance activities. .
22. Moestan blister beetle *Lytta moesta*	-/-/-	-	-	-	+	No	This species has no regulatory or conservation status. It is not a covered species in any overlapping HCP/NCCP. There is no indication that it would become listed over the term of the BDCP. Its known range does not extend into the Plan Area and thus covered activities would not affect this species.
23. Molestan blister beetle *Lytta molesta*	-/-/-		+	+ (AD)	+	No	This species has no regulatory or conservation status and is not covered or considered for coverage in any overlapping HCP/NCCPs. There is no indication that it would become listed over the term of the BDCP. This is a vernal pool/seasonal wetland-associated species and could be affected by activities associated with conveyance activities.
24. San Francisco lacewing *Nothochrysa californica*	-/-/-	-	-	-	-	No	This species has no regulatory or conservation status. It is not a covered species in any overlapping HCP/NCCP. There is no indication that it would become listed over the term of the BDCP. Its known range does not extend into the Plan Area and thus covered activities would not affect this species.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	*Status[A] (Federal/State/ CNPS)*	*Selection Criteria For Coverage[B]*				*Consider for Coverage?*	*Coverage Comments*
		Listing Potential	**Occurrence in the Plan Area**	**Potential to Adversely Affect[C]**	**Sufficient Information**		
25. Wilbur Springs shorebug *Saldula usingeri Polhemus*	-/-/-	-	-	-	+	No	This species has no regulatory or conservation status. It is not a covered species in any overlapping HCP/NCCP. There is no indication that it would become listed over the term of the BDCP. Its known range does not extend into the Plan Area and thus covered activities would not affect this species.
26. Middlekauff's shieldback katydid *Idiostatus middlekauffi*	-/SA/-	-	U	U	-	No	This species is designated as Critically Endangered by the IUCN Red List. It has no regulatory or conservation status. There is no indication that it would become listed over the term of the BDCP. It is not covered or considered for coverage in any overlapping HCP/NCCPs.
27. Hairy water flea *Dumontia oregonensis*	-/-/-	-	-	-	+	No	This species has no regulatory or conservation status. It is not a covered species in any overlapping HCP/NCCP. There is no indication that it would become listed over the term of the BDCP. Its known range does not extend into the Plan Area and thus covered activities would not affect this species.
28. Vernal pool tadpole shrimp *Lepidurus packardi*	E/-/-	+	+	+ (H, AD)	+	Yes	Meets all four criteria. This species could be affected through disturbances to vernal pool and other seasonal wetland habitats associated with conveyance and restoration activities.
29. Conservancy fairy shrimp *Branchinecta conservatio*	E/-/-	+	+	+ (H, AD)	+	Yes	Meets all four criteria. This species could be affected through disturbances to vernal pool and other seasonal wetland habitats associated with conveyance and restoration activities.
30. Longhorn fairy shrimp *Branchinecta longiantenna*	E/-/-	+	+	+ (H, AD)	+	Yes	Meets all four criteria. This species could be affected through disturbances to vernal pool and other seasonal wetland habitats associated with conveyance and restoration activities.
31. Vernal pool fairy shrimp *Branchinecta lynchi*	T/-/-	+	+	+ (H, AD)	+	Yes	Meets all four criteria. This species could be affected through disturbances to vernal pool and other seasonal wetland habitats associated with conveyance and restoration activities.
32. Mid Valley Fairy Shrimp *Branchinecta mesovalleyensis*	-/-/-		+	+ (H, AD)	+	Yes	Meets all four criteria. This species is thought to have a very restricted range. A 2001 petition for listing was rejected by the USFWS in 2004 on the basis of insufficient data. However, it is reasonable to assume that this species could become listed over the term of the BDCP. This species is covered in all overlapping HCP/NCCPs. This species could be affected through disturbances to vernal pool and other seasonal wetland habitats associated with conveyance and restoration activities.
33. California linderiella *Linderiella occidentalis*	-/SA/-[+]	+	+	+ (H, AD)	+	Yes	Meets all four criteria. USFWS indicated likelihood of this species becoming listed within the term of the permit. This species is designated as Near Threatened on the IUCN Red List. It has no regulatory or conservation status. It is relatively common throughout its range, but occurs in association with listed vernal pool species that could be affected by covered activities.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

		Selection Criteria For Coverage[B]					
Scientific Name/ Common Name	***Status**[A]* ***(Federal/State/ CNPS)***	**Listing Potential**	**Occurrence in the Plan Area**	**Potential to Adversely Affect**[C]	**Sufficient Information**	***Consider for Coverage?***	***Coverage Comments***
34. Bridges' coast range shoulderband *Helminthoglypta nickliniana bridgesi*	-/SA/-	-	-	-	-	No	This species is designated as Data Deficient on the IUCN Red List. It has no regulatory or conservation status. It is not covered under other overlapping HCP/NCCPs. This species' range does not extend into the Plan Area and thus covered activities are not expected to affect this species.
Plants							
1. Santa Clara thorn-mint *Acanthomintha lanceolata*	-/-/4	-	-	-	+	No	This species is widely distributed on hillsides in the inner Coast Range southwest of the Delta and does not occur within the Plan Area.
2. Purdy's onion *Allium fimbriatum* var. *purdyi*	-/-/4	-	-	-	+	No	This variety is widely distributed in the inner Coast Range north of the Delta and does not occur within the Plan Area.
3. Large-flowered fiddleneck *Amsinckia grandiflora*	E/E/1B	+	-	-	+	No	This species is found in a very few occurrences that are all located in the inner Coast Range southwest of the Delta and does not occur present within the Plan Area.
4. Bent flowered fiddleneck *Amsinckia lunaris*	-/-/1B	-	-	-	+	No	This species is widely distributed in the inner and outer Coast Ranges from Colusa and Lake Counties in the north to Santa Cruz County in the south and does not occur within the Plan Area.
5. California androsace *Androsace elongata* ssp. *Acuta*	-/-/4	-	-	-	+	No	This subspecies is widely distributed in the inner and outer Coast Ranges from Tehama County in the north and southward to the Peninsular Range in San Diego County and does not occur within the Plan Area.
6. Slender silver moss *Anomobryum julaceum*	-/-/2	-	-	-	+	No	This species is widely distributed in forests of the inner and outer Coast Ranges and Sierra Nevada on road cuts and rocks and in seeps and streams and does not occur within the Plan Area.
7. Twig-like snapdragon *Antirrhinum virga*	-/-/4	-	-	-	+	No	This species is widely distributed in the inner Coast Range in Lake, Mendocino, and Sonoma Counties and does not occur within the Plan Area.
8. Coast rock cress *Arabis blepharophylla*	-/-/4	-	-	-	+	No	This species is widely distributed in the inner Coast Range from Marin County south to Monterrey County and does not occur within the Plan Area.
9. Modest rock cress *Arabis modesta*	-/-/4	-	-	-	+	No	This species is widely distributed in the Klamath Range and in the Blue Ridge of Napa and Solano Counties and does not occur within the Plan Area.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	*Status[A] (Federal/State/ CNPS)*	*Selection Criteria For Coverage[B]* Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information	*Consider for Coverage?*	*Coverage Comments*
10. Mt. Diablo manzanita *Arctostaphylos auriculata*	-/-/1B	_	+	-	+	No	This species is distributed in chaparral on the hillsides of Mt. Diablo and does not occur within the Plan Area.
11. Contra Costa manzanita *Arctostaphylos manzanita* ssp. *Laevigata*	-/-/1B	-	-	-	+	No	This subspecies is distributed in chaparral on the hillsides of Mt. Diablo and does not occur within the Plan Area.
12. Serpentine milkweed *Asclepias solanoana*	-/-/4	-	-	-	+	No	This species is found at high elevations elevation in the inner Coast Range from Tehama County south to Solano County and does not occur within the Plan Area.
13. Carlotta Hall's lace fern *Aspidotis carlotta-halliae*	-/-/4	-	-	-	+	No	This species is broadly distributed in the inner and outer Coast Ranges from Marin County south to San Luis Obispo County and does not occur within the Plan Area.
14. Brewer's milk-vetch *Astragalus breweri*	-/-/4	-	-	-	+	No	This species is broadly distributed in the outer Coast Range from Mendocino County south to Marin County and does not occur within the Plan Area.
15. Cleveland's milk-vetch *Astragalus clevelandii*	-/-/4	-	-	-	+	No	This species is broadly distributed along streams, springs, and seeps in the inner Coast Range from Tehama County south to Napa County and does not occur within the Plan Area.
16. Ocean bluff milk-vetch *Astragalus nuttallii* var. *nuttallii*	-/-/4	-	-	-	+	No	This variety is broadly distributed along the coast from Marin County to Santa Barbara County and does not occur within the Plan Area.
17. Jepson's milk-vetch *Astragalus rattanii* var. *jepsonianus*	-/-/1B	-	-	-	+	No	This variety is broadly distributed on serpentine soils in the inner Coast Range from Tehama County to Yolo County and does not occur within the Plan Area.
18. Ferris' milk-vetch *Astragalus tener* var. *ferrisiae*	-/-/1B	+	+	-	+	No	While this variety is present within the Plan Area in large playa pools at the Jepson Prairie Preserve and CDFG Tule Ranch Preserves, those areas will not be impacted.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	Status[A] (Federal/State/ CNPS)	Selection Criteria For Coverage[B]				Consider for Coverage?	Coverage Comments
		Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information		
19. Alkali milk-vetch *Astragalus tener* var. *tener*	-/-/1B	+	+	+ (H, AD)	+	Yes	Meets all four criteria. Alkali milk-vetch is almost always found on alkaline or saline soils occurring in vernally wet playas, flats, fallowed rice fields, and vernal swales in valley/foothill grasslands below 500 ft (Solano HCP, 2007; San Joaquin HCP 2000). It is covered in the Solano and San Joaquin HCPs and proposed for coverage in the Yolo County HCP. Locally, it is found in the Jepson Prairie Area, the CDFG Tule Ranch Preserve, and the Montezuma Wetlands in vernally flooded swales and flood plains of playa pools. There is a single historical occurrence near Stockton but that location has been completely developed. There are other historical collections within impacts areas at the lower margins of uplands in the Cache Slough and Suisun Marsh areas but that habitat has been lost through intensive agriculture. There is the potential for the listing of this species within the plan period due to development impacts in the south San Francisco Bay area and agricultural impacts in the Central Valley.
20. Heartscale *Atriplex cordulata*	-/-/1B	+	+	+ (H, AD)	+	Yes	Meets all four criteria. Heartscale grows in sandy, saline or alkaline flats and scalds, in chenopod scrub, meadows, and valley/foothill grassland (Solano HCP 2007; San Joaquin HCP 2000). It is covered in the Solano and San Joaquin HCPs and the ISA Report recommends that this species be retained for consideration of coverage. It occurs within the Plan Area and potentially at the lower margins of uplands in the Cache Slough area and possibly in the Clifton Court Forebay area that could be affected by covered activities. While heartscale is a widespread species, it may be declining due to loss of habitat through current and future development which may lead to listing during the plan period.
21. Crownscale *Atriplex coronata* var. *coronata*	-/-/4	-	+	-	+	No	This variety is widely distributed in the northern Sacramento Valley and central and southern San Joaquin Valley and is present at scattered alkaline soil areas in the inner Coast Range from Alameda County southward . Subspecies var *vallicola* was found in the Clifton Court Forebay area by DHCCP survey teams in 2009 and 2010.
22. Lost Hills Crownscale *Atriplex coronata var. vallicola*	-/-/1B	-	+	?	+	No	Lost Hills Crownscale is widely distributed in the San Joaquin Valley (alkaline clay soils on the valley bottom and gypsum clay soils on the hills of the Coast Range) and on alkaline clay soils of the Carrizo Plain. It was discovered on BDCP surveys in the vicinity of the Clifton Court Forebay. It is not covered by any HCPs.
23. Brittlescale *Atriplex depressa*	-/-/1B	+	+	+ (H, AD)	+	Yes	Meets all four criteria. Brittlescale grows on alkaline or clay soils occurring in grasslands contained by valleys or foothills, meadows saltbrush, vernal pools, and at the edge of playas (San Joaquin HCP 2000; Solano HCP 2007; ECCC HCP, 2007). It is covered in the Solano and San Joaquin HCPs and the ISA Report recommends that this species be retained for consideration of coverage. It occurs within the Plan Area and potentially at the lower margins of uplands in the Cache Slough area and possibly in the Clifton Court Forebay area that could be affected by covered activities. While brittlescale is a widespread species it may be declining due to loss of habitat through current and future development which may lead to listing during the plan period.
24. San Joaquin spearscale *Atriplex joaquiniana*	-/-/1B	+	+	+ (H, AD)	+	Yes	Meets all four criteria. San Joaquin spearscale grows on alkaline clay soils in alkali grasslands and meadows or on the margins of alkali scrub, (ECCC HCP 2007) and is also found in seasonal alkali wetlands and sinks in chenopod scrub, meadows, playas, and valley/grassland foothills (Solano HCP 2007). It is covered in the Solano and East Contra Costa County HCPs and proposed for coverage in the Yolo County HCP. The ISA Report recommends that this species be retained for consideration of coverage. It occurs within the Plan Area and potentially at the lower margins of uplands in the Cache Slough area that could be affected by covered activities. While San Joaquin spearscale is a widespread species it may be declining due to loss of habitat through current and future development which may lead to listing during the plan period.
25. Lesser saltscale *Atriplex minuscula*	-/-/1B	+	-	-	+	No	Lesser saltscale grows on alkaline or clay soils occurring in grasslands contained by valleys or foothills, meadows saltbrush, vernal pools, and at the edge of playas. Although there are no documented occurrences in the Plan Area, lesser saltscale is assumed to be within the Plan Area because of several herbarium specimens. These specimens have been reannotated as *A. depressa* from *A. minuscula*. Consequently, it is no longer considered as being present in the Plan Area.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	*Status[A] (Federal/State/ CNPS)*	*Selection Criteria For Coverage[B]* Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information	*Consider for Coverage?*	*Coverage Comments*
26. Vernal pool smallscale *Atriplex persistens*	-/-/1B	+	-	-	+	No	This species has been reported from alkaline playas on the Jepson Prairie Preserve immediately outside of the Plan Area but those playas will not be affected by restoration activities.
27. Big-scale balsamroot *Balsamorhiza macrolepis* var. *macrolepis*	-/-/1B	-	-	-	+	No	This variety is widely distributed on hill slope soils derived from serpentinite or basalt in the inner Coast Range from Tehama County south to Kern County and is sporadically distributed on sandy soils along the lower margin of the Sierra foothills but does not occur within the Plan Area.
28. Big tarplant *Blepharizonia plumosa*	-/-/1B	-	+	-	+	No	This species is broadly distributed on hillsides on sites with shrink/swell clay soils, does not appear to be declining, and is not likely to be listed within the period of this plan. Additionally, there are no documented collections within impacts areas with the exception of a single occurrence near Tracy from along railroad tracks west of town.
29. Brewer's calandrinia *Calandrinia breweri*	-/-/4	-	-	-	+	No	This species is widely distributed in the Peninsular Range from San Diego County northward and on serpentine soils in the Coast Range north and south of the San Francisco Bay area but does not occur within the Plan Area.
30. Round-leafed filaree *California macrophyllum*	-/-/2	-	+	-	+	No	This species is broadly distributed throughout California on sites with shrink/swell clay soils, does not appear to be declining, and not likely to be listed within the period of this plan. Additionally, there are no documented occurrences within impacts areas.
31. Mt. Diablo fairy-lantern *Calochortus pulchellus*	-/-/1B	-	-	-	+	No	This species is widely distributed in the Peninsular Range from San Diego County northward and on serpentine soils in the Coast Range north and south of the San Francisco Bay area but does not occur within the Plan Area.
32. Oakland star-tulip *Calochortus umbellatus*	-/-/4	-	-	-	+	No	This species is broadly distributed on Mount Diablo and on adjacent hills but does not occur within the Plan Area.
33. Butte County morning-glory *Calystegia atriplicifolia* ssp. *Buttensis*	-/-/1B	-	-	-	+	No	This subspecies is widely distributed in Butte, Del Norte, and Tehama Counties in foothill coniferous forests but does not occur within the Plan Area.
34. Chaparral harebell *Campanula exigua*	-/-/1B	-	-	-	+	No	This species is broadly distributed on scree and talus slopes in the inner Coast Range from San Benito County northwards to Contra Costa County but does not occur within the Plan Area.
35. Bristly sedge *Carex comosa*	-/-/2	-	+	+ (H, AD, ID, O)	+	No	This species is broadly distributed throughout North America but spotty in California (its seed is eaten and likely dispersed by waterfowl). It does not appear to be declining and is not likely to be listed within the period of this plan.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	*Status[A] (Federal/State/ CNPS)*	*Selection Criteria For Coverage[B]*				*Consider for Coverage?*	*Coverage Comments*
		Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information		
36. Fox sedge *Carex vulpinoidea*	-/-/2	-	+	+ (H, AD, ID, O)	+	No	This species is broadly distributed throughout North America but spotty in California (its seed is eaten and likely dispersed by waterfowl). The Flora of North America indicates that it is weedy along ditches, etc.
37. Succulent owl's clover *Castilleja campestris* ssp. *succulenta*	T/E/1B	+	-	-	+	No	This subspecies is broadly distributed in hardpan vernal pools along the east side of the Central Valley but does not occur within the Plan Area.
38. Lemmon's jewelflower *Caulanthus coulteri* var. *lemmonii*	-/-/1B	-	-	-	+	No	This variety is widely distributed on loose slopes in the Transverse Range in Ventura County northwards and in the inner Coast Range to Alameda County but does not occur within the Plan Area.
39. Congdon's tarplant *Centromadia parryi* spp. *congdonii*	-/-/1B	-	-	-	+	No	This subspecies is broadly distributed throughout central California, does not appear to be declining, and does not occur within the Plan Area.
40. Pappose tarplant *Centromadia parryi ssp. Parryi*	-/-/1B	-	-	+ (H)	+	No	While this subspecies occurs within the Suisun Marsh impacts area, it is broadly distributed throughout central California in brackish marshes, salt springs, hot springs, and other areas, does not appear to be declining, and is not likely to be listed within the period of this plan.
41. Parry's red tarplant *Centromadia parryi* ssp. *Rudis*	-/-/4	-	+	-	+	No	This subspecies is not likely to be listed during the plan period and while it is present on alkali soils in the Sacramento Valley on USFWS and CDFG preserves, it is not expected to be affected by the covered activities.
42. Slough thistle *Cirsium crassicaule*	FSC/-/1B	+	+	+ (H)	+	Yes	Meets all four criteria. Slough thistle is known from two locations in the Legal Delta, one about 5 miles west of Manteca and one about 10 miles southeast of Tracy. It is also present within in the habitat restoration area upstream of the Mossdale Bridge. It is very uncommon across its limited range in the San Joaquin Valley and subjected to numerous negative impacts which may lead to listing during the plan period.
43. Suisun thistle *Cirsium hydrophilum* var. *hydrophilum*	E/-/1B	+	+	+ (H)	+	Yes	Meets all four criteria. Suisun thistle is present within the Suisun Marsh and could be affected by habitat restoration actions.
44. Brewer's clarkia *Clarkia breweri*	-/-/4	-	-	-	+	No	This species is broadly distributed in the inner Coast Range from Monterrey County north to Alameda County but does not occur within the Plan Area.
45. Santa Clara red ribbons *Clarkia concinna* ssp. *automixa*	-/-/4	-	-	-	+	No	This subspecies is broadly distributed in the inner Coast Range from Alameda County north to Trinity County but does not occur within the Plan Area.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	*Status[A] (Federal/State/ CNPS)*	*Selection Criteria For Coverage[B]*				*Consider for Coverage?*	*Coverage Comments*
		Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information		
46. Serpentine collomia *Collomia diversifolia*	-/-/4	-	-	-	+	No	This species is broadly distributed on rocky serpentine hill slopes from Contra Costa County north to Siskiyou County but does not occur within the Plan Area.
47. Small-flowered morning-glory *Convolvulus simulans*	-/-/4	-	-	-	+	No	This species is broadly distributed on hill slopes from San Diego County north to Contra Costa County but does not occur within the Plan Area.
48. Hispid bird's-beak *Cordylanthus mollis* ssp. *hispidus*	-/-/1B	-	-	-	+	No	This subspecies is broadly distributed in alkaline sink habitat in the San Joaquin Valley and Livermore Valley, in alkaline seeps near Rocklin, and along the margins of alkaline seasonal wetlands and vernal pools near Travis Air Force Base in Solano County but does not occur within the Plan Area.
49. Soft bird's-beak *Cordylanthus mollis* ssp. *mollis*	E/R/IB	+	+	+ (H)	+	Yes	Meets all four criteria. This subspecies occurs within Suisun Marsh and could be affected by habitat restoration actions.
50. Mt. Diablo bird's-beak *Cordylanthus nidularius*	-/SR/1B	-	-	-	+	No	This species it is known from a single occurrence on Bald Ridge within the Mt. Diablo park system and does not occur within the Plan Area.
51. Palmate-bracted bird's-beak *Cordylanthus palmatus*	E/E/1B	+	-	-	+	No	This species does not occur within Plan Area. CNDDB records show that the Stockton occurrence was last seen in 1881 and could not be relocated in the 1960's.
52. Hoover's cryptantha *Cryptantha hooveri*	-/-/1A	+	+	-	+	No	While this species occurs within the Plan Area it is limited to sandy areas near Antioch Dunes which are not within an impact area.
53. Livermore tarplant *Deinandra bacigalupi*	-/-/1B	-	-	-	+	No	This species occurs on alkaline soils in the Livermore Valley and does not occur within the Plan Area.
54. Hospital Canyon larkspur *Delphinium californica* ssp.*interius*	-/-/1B	-	-	-	+	No	This subspecies is broadly distributed in seeps and dried creek bottoms in the inner Coast Range from San Benito County north to Contra Costa County but does not occur within the Plan Area.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	*Status*[A] *(Federal/State/ CNPS)*	*Selection Criteria For Coverage*[B] Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information	*Consider for Coverage?*	*Coverage Comments*
55. Gypsum-loving larkspur *Delphinium gypsophilum* ssp. *Gypsophilum*	-/-/4	-	-	-	+	No	This subspecies is broadly distributed in the inner Coast Range from Ventura County north to Stanislaus County but does not occur within the Plan Area.
56. Recurved larkspur *Delphinium recurvatum*	-/-/1B	U	+	-	+	No	While there are occurrences of this species in the Clifton Court Forebay area, those occurrences are to the west of the potential impact areas in relatively undisturbed alkaline vegetation in contrast to the intensive agriculture of the impact areas. Listing potential is uncertain as while this species has a broad historical distribution in the San Joaquin Valley its populations are described as very small, subject to extirpation, and many have not been surveyed for a number of years.
57. Norris' beard moss *Didymodon norrisii*	-/-/2	-	-	-	+	No	This species is widespread on mesic rock outcrops from Tulare County to Humboldt County but does not occur within the Plan Area.
58. Dwarf downingia *Downingia pusilla*	-/-/2	-	+	+ (H)	+	Yes	Meets all four criteria. USFWS indicated likelihood of this species becoming listed within the term of the permit. This species is broadly distributed throughout California in seasonal marshes and vernal pools and is not likely to be listed within the period of this plan. It does occur in areas near Cache Slough and in the Stone Lakes area but those occurrences are not within impact areas.
59. Small spikerush *Eleocharis parvula*	-/-/4	-	-	-	+	No	This species is widely distributed from Orange County in the south to Humboldt and Lassen Counties in the north but does not occur in the Plan Area.
60. Brandegee's eriastrum *Eriastrum brandegeeae*	-/-/1B	-	-	-	+	No	This species occurs on rock outcrops and rocky soils on hill slopes from Santa Clara County to Shasta County but does not occur within the Plan Area.
61. Mt. Diablo buckwheat *Eriogonum truncatum*	-/-/1B	+	-	-	+	No	This species occurs on hill slope outcrops of the Tehama geological formation on the slopes of Mt. Diablo and in the Portrero Hills but does not occur within the Plan Area. The two CNDDB occurrences that were mapped in the Plan Area are best guesses based on very old herbarium collections and the actual collection sites were most likely on nearby hill slopes.
62. Bay buckwheat *Eriogonum umbellatum* var. *bahiiforme*	-/-/4	-	-	-	+	No	This variety occurs on hill slopes from Los Angeles County to Siskiyou County but does not occur within the Plan Area.
63. Jepson's woolly sunflower *Eriophyllum jepsonii*	-/-/4	-	-	-	+	No	This species occurs on hill slopes and in canyons from Ventura County to Contra Costa County but does not occur within the Plan Area.
64. Delta button celery *Eryngium racemosum*	-/E/1B	+	+	+ (H, AD, ID, O)	+	Yes	Meets all four criteria. Delta button celery is found in riparian scrub and subalkaline swales in the San Joaquin River bed (CDFG 2000; SJ HCP 2000). It is also found in chenopod scrub and alkaline grasslands near Discovery Bay. It is covered in the San Joaquin HCP. It has the potential to occur near Clifton Court Forebay and the San Joaquin River upstream of the Mossdale Bridge.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	Status[A] (Federal/State/ CNPS)	Selection Criteria For Coverage[B]: Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information	Consider for Coverage?	Coverage Comments
65. Contra Costa wallflower *Erysimum capitatum* var. *angustatum*	E/E/1B	+	+	-	+	Yes	Though it does not meet all four criteria, due to this species' rarity and dependence on limited specialized habitat that is found in the Plan Area, it is proposed for coverage under the BDCP. This subspecies only occurs in the Antioch Dunes which are within the plan area but does not occur within the impacts area. It is proposed for coverage because it is a listed species associated with the inland dune scrub natural community.
66. Diamond-petaled California poppy *Eschscholzia rhombipetala*	-/-/1B	-	+	- (AD)	+	No	This species is broadly distributed throughout the inner central and southern Coast Range on clay soils and is not likely to be listed within the period of this plan. There is a small probability of it being present in the Clifton Court Forebay area.
67. Stinkbells *Fritillaria agrestis*	-/-/4	-	+	-	+	No	This widespread species occurs on gentle hill slopes of the Transverse Range and northward in the outer and inner Coast Ranges to Monterrey and Yolo Counties. It also occurs in the foothills of the Sierra Nevada from Tulare County to Placer County. Therefore, this species does not occur within the Plan Area.
68. Fragrant fritillary *Fritillaria liliacea*	-/-/1B	-	+	-	+	No	This species is broadly distributed throughout California on sites with clay soils and is not likely to be listed within the period of this plan. Additionally, occurrences in the Plan Area are in upland habitats near vernal pools that will not be impacted and there are no documented occurrences within impacts areas.
69. Adobe-lily *Fritillaria pluriflora*	-/-/1B	-	+	-	+	No	This species is broadly distributed on gently sloping hillsides with clay soils from Yolo County to Glenn County in the inner Coast Range and in clay soils in the uplands surrounding vernal pool complexes in Butte and Tehama Counties. There is a 1910 reported occurrence in Solano County which CNDDB attributes to an incorrect identification. Therefore, this species does not occur within the Plan Area.
70. Purdy's fritillary *Fritillaria purdyi*	-/-/4	-	-	-	+	No	This species is found in the inner and outer Coast Ranges from Napa county north to Humboldt County and possibly in the foothills of the Sierra Nevada in Butte County but it does not occur within the Plan Area.
71. Phlox-leaf serpentine bedstraw *Galium andrewsii* ssp. *gatense*	-/-/4	-	-	-	+	No	This subspecies occurs at high elevations. Most recent occurrences have been recorded in San Benito and Stanislaus counties. Other occurrences have been recorded in Santa Cruz, Contra Costa, Santa Clara, Monterey, San Luis Obispo, Fresno, and San Bernardino counties. It does not occur within the Plan Area.
72. Boggs Lake hedge-hyssop *Gratiola heterosepala*	-/E/1B	+	+	+ (H)	+	Yes	Meets all four criteria. Boggs Lake hedge-hyssop in vernal pools and in marshy area on the margins of reservoirs and lakes; also found in man-made habitats such as borrow pits and cattle ponds (FWS Vernal Pool Recovery Plan 2006; San Joaquin HCP 2000). Covered in the San Joaquin, South Sacramento, and Solano HCPs. Occurs in areas near Cache Slough that are proposed for habitat restoration and, while no occurrences have been reported, may occur in the Stone Lakes area but not in impacted areas. The ISA Report recommends that this species be retained for consideration of coverage.
73. Nodding harmonia *Harmonia nutans*	-/-/4	-	-	-	+	No	This species occurs on hillsides and at high elevations of the North Coast range in Lake, Sonoma, and Napa counties and does not occur within the Plan Area.
74. Diablo helianthella *Helianthella castanea*	-/-/1B	-	-	-	+	No	This species generally occurs on hillsides and at high elevations in San Francisco Bay counties. Most recorded occurrences have been in Contra Costa and Alameda counties. Occurrences have also been recorded in San Francisco, San Mateo, and Marin counties. This species does not occur within the Plan Area.
75. Hogwallow Starfish *Hesperevax caulescens*	-/-/4	-	+	-	+	No	This species is widely distributed throughout California. There are recorded occurrences from Tehama County to San Diego County. It is present within the Plan Area in large playa pools at CDFG Tule Ranch Preserve but that area will not be impacted. Because it is widely distributed throughout California (herbaria specimens) it is unlikely to be listed within the period of this plan.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	Status[A] (Federal/State/ CNPS)	Selection Criteria For Coverage[B]				Consider for Coverage?	Coverage Comments
		Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information		
76. Brewer's western flax *Hesperolinon breweri*	-/-/1B	-	+	-	+	No	Distribution of this species is limited to Napa, Contra Costa, and Solano counties but it does not occur within impacts areas. Additionally, it occurs in the inner Coast Range north and south of the Delta in areas that are not likely to be impacted by development so its listing potential is very low.
77. Rose-mallow *Hibiscus lasiocarpus*	-/-/2	-	+	+ (H, AD, ID, O)	+	No	This species is broadly distributed throughout the Delta and Sacramento Valley in riparian areas, springs, and seeps and is not likely to be listed within the period of this plan.
78. Santa Cruz tarplant *Holocarpha macradenia*	E/T/1B	+	-	-	+	No	The distribution of this species is limited to several coastal counties: Marin, Santa Cruz, Monterey, Alameda, and Contra Costa but it does not occur within the Plan Area.
79. Coast iris *Iris longipetala*	-/-/4	-	-	-	+	No	This species has been observed in the outer Coast Range from Humboldt County to Monterey County, and in the inner Coast Range from Contra Costa County to Santa Clara County but it does not occur within the Plan Area.
80. Carquinez goldenbush *Isocoma arguta*	-/-/1B	+	+	+ (H)	+	Yes	Meets all four criteria. Carquinez goldenbush is present within impact areas of Suisun Marsh and Cache Slough. This shrub species in endemic to the alkaline and saline areas around the Montezuma Hills and sometimes grows along the transition between saline tidal marshes and uplands. Because of its extremely narrow distribution and small population sizes it is likely to be listed within the period of the plan. It is also likely to be impacted by sea level rise.
81. Northern California black walnut *Juglans californica* var. *hindsii*	-/-/1B	-	+	+ (H, AD, ID)	+	No	This variety is widespread in the Central Valley and Delta and is not likely to be listed within the plan period.
82. Ahart's dwarf rush *Juncus leiospermus* var. *ahartii*	-/-/1B	+	-	-	+	No	The distribution of this variety is limited to vernal pools in northern California. It has been recorded from Tehama, Butte, Yuba, Placer, Calaveras, and Sacramento counties but does not occur within the Plan Area.
83. Contra Costa goldfields *Lasthenia conjugens*	E/-/1B	+	+	-	+	No	This species occurs in counties along the California coast from Mendocino County to Santa Barbara County but does not occur within the plan and impacts areas.
84. Ferris' goldfields *Lasthenia ferrisiae*	-/-/4	-	+	+ (AD)	+	No	This species is widely distributed throughout California from Colusa and Butte counties in the north, to San Luis Obispo, Kern and Ventura counties in the south; and from Contra Costa and Alameda counties in the west to Merced, Fresno, and Tulare counties in the east. It does occur within the planning and impacts areas in the Clifton Court Forebay, but it is not likely to be listed during the plan period.
85. Delta tule pea *Lathyrus jepsonii* var. *jepsonii*	-/-/1B	+	+	+ (H, AD, ID, O)	+	Yes	Meets all four criteria. Delta tule pea grows in tidally influenced freshwater and brackish marshes, commonly along slough edges and levees (Solano HCP 2007; San Joaquin HCP 2000). It is covered in the Solano and San Joaquin HCPs. It is found in valley riparian, tidal perennial aquatic, tidal freshwater emergent wetland, and grasslands throughout central Plan Area. There are numerous occurrences throughout the lowland Legal Delta. It will likely be impacted by BDCP actions while possibly benefitting from habitat restoration, and may be listed within the period of this plan.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	*Status[A] (Federal/State/ CNPS)*	Selection Criteria For Coverage[B]				*Consider for Coverage?*	*Coverage Comments*
		Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information		
86. Legenere *Legenere limosa*	-/-/1B	+	+	?	+	Yes	Current covered activity and habitat restoration concepts may avoid impacts. Habitat is usually deep well defined vernal pools within grasslands (Solano HCP 2007; SJ HCP 2000). Covered in the SJ HCP and proposed for coverage in the Solano HCP. Found within Plan Area in grasslands along western border; found east and west outside of Plan Area.
87. Heckard's peppergrass *Lepidium latipes* var. *heckardii*	-/-/1B	+	+	?	+	Yes	Heckard's peppergrass grows on alkaline flats and in alkaline grasslands along the edges of vernal pools (Solano HCP 2007). It is proposed for coverage in the Solano HCP. The historical occurrence along Haas Slough was last observed by Jepson in 1891 (Consortium of California Herbaria 2008). Aerial imagery indicates that the Haas Slough occurrence is likely to have been extirpated by the spread of intensive agriculture along both sides of the slough. Present within the Plan Area in large playa pools at the DFG Tule Ranch Preserve and in vernal pools and swales at Jepson Prairie and Gridley Ranch Preserves, but those areas are in upland habitat that will not be affected. Current covered activity and habitat restoration concepts may affect species.
88. Bristly leptosiphon *Leptosiphon acicularis*	-/-/4	-	-	-	+	No	This species is generally found on hillsides and at high elevations. Most recent occurrences have been recorded in Mendocino, Sonoma, Lake, Napa, and Butte counties. Humboldt and Marin counties have recorded occurrences that pre-date 1950, and Alameda County's most recent recorded occurrence was in 1900. Single occurrences have been recorded in Colusa, Santa Cruz, San Benito, and San Diego counties. This species does not occur within the Plan Area.
89. Serpentine leptosiphon *Leptosiphon ambiguus*	-/-/4	-	-	-	+	No	This species occurs on hillsides and at high elevations. Most recorded occurrences are in central California from Contra Costa, Alameda, San Mateo, and Santa Clara counties in the west to Stanislaus and Merced counties in the east. There are single occurrences recorded for each of the following counties: Fresno, Plumas, Santa Cruz, and Tehama. This species does not occur within the Plan Area.
90. Large-flowered leptosiphon *Leptosiphon grandiflorus*	-/-/4	-	-	-	+	No	Most recent recorded occurrences of this species have been reported from Los Angeles, Marin, and Monterey counties. Other occurrences have been reported from Santa Clara, Santa Barbara, and Madera counties. This species does not occur within the Plan Area.
91. Spring lessingia *Lessingia tenuis*	-/-/4	-	-	-	+	No	This species is generally found at high elevations in central and southern California counties. Recorded occurrences are widely distributed from Alameda and Stanislaus counties south to Santa Barbara and Ventura counties. It does not occur within the Plan Area.
92. Mason's lilaeopsis *Lilaeopsis masonii*	-/R/1B	+	+	+ (H, ID, O)	+	Yes	Meets all four criteria. Mason's lilaeopsis grows in regularly flooded tidal zones, on mud banks and flats, and along eroding creek banks, sloughs, and rivers. It is also found in freshwater marshes, brackish marshes, and riparian scrub vegetation types that are tidally influenced. It is covered in the San Joaquin HCP and proposed for coverage in the Solano HCP. It is broadly distributed throughout the Delta and in the Napa River and will likely benefit from habitat restoration.
93. Delta mudwort *Limosella subulata*	-/-/2	+	+	+ (H, ID, O)	+	Yes	Meets all four criteria. Habitat consists of muddy or sandy intertidal flats in estuarine areas, surrounded by brackish or freshwater marsh or riparian scrub (SJ HCP 2000; Solano HCP 2007). Covered in the San Joaquin HCP and proposed for coverage in the Solano HCP. Generally found throughout the central Plan Area within valley riparian, tidal perennial aquatic, tidal freshwater emergent wetland, and grassland SAIC veg. types. A later assessment found that all of the numerous known occurrences are in the Legal Delta lowland areas.
94. Hoover's lomatium *Lomatium hooveri*	-/-/4	-	-	-	+	No	This species occurs at high elevations in Colusa, Lake, Glenn and Napa counties and does not occur within the Plan Area.
95. Napa lomatium *Lomatium repostum*	-/-/4	-	-	-	+	No	This species is distributed on hillsides and at high elevations in Lake, Napa, Solano and Sonoma counties and does not occur within the Plan Area.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	Status[A] (Federal/State/ CNPS)	Selection Criteria For Coverage[B] Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information	Consider for Coverage?	Coverage Comments
96. Showy madia *Madia radiata*	-/-/1B	+	+	-	+	No	This species occurs on hillsides and at high elevations. Recent recorded occurrences have been in southern central California in the counties of San Benito, Monterey, San Luis Obispo, Fresno, and Kern. There have also been recorded occurrences in Kings, Contra Costa, San Joaquin, and Stanislaus counties but this species does not occur within the plan and impacts areas.
97. Hall's bush-mallow *Malacothamnus hallii*	-/-/1B	-	-	-	+	No	Most of the recent recorded occurrences of this species have been on hillsides in Contra Costa and Santa Clara counties, but occurrences have also been recorded in Stanislaus, Merced, San Mateo, and Mendocino counties. This species does not occur within the Plan Area.
98. Heller's bush-mallow *Malacothamnus helleri*	-/-/4	-	-	-	+	No	This species has been observed on hillsides in Colusa and Napa counties and does not occur within the Plan Area.
99. Sylvan microseris *Microseris sylvatica*	-/-/4	-	-	-	+	No	This species is widely distributed on hillsides throughout California. It has been observed as far north as Tehama County, as far west as Napa County, as far south as Los Angeles County, and as far east as Inyo County. However, it does not occur within the Plan Area.
100. Sierra monardella *Monardella candicans*	-/-/4	-	-	-	+	No	This species is widely distributed - primarily on hillsides of the Sierra Nevada. It has been observed as far north as Placer County and as far south as San Bernardino County. There is also an undated record of this species in St. Helena in Napa County. This species does not occur within the Plan Area.
101. Green monardella *Monardella viridis* ssp. *viridis*	-/-/4	-	-	-	+	No	This subspecies has been observed on hillsides of the North Coast Range in Sonoma, Lake and Napa counties. It has also been recorded as occurring in the San Gabriel Mountains region in San Bernardino County. This species does not occur within the Plan Area.
102. Little mousetail *Myosurus minimus* ssp. *apus*	-/-/3	-	+	+ (H)	+	No	This subspecies is found in southern California with occurrences recorded only in San Diego and Riverside counties.
103. Cotula Navarretia *Navarretia cotulifolia*	-/-/4	-	+	+ (H)	+	No	This species is widely distributed throughout central and northern California. Its range extends from Lake and Glenn counties in the north to Sonoma and Marin counties in the west to San Benito County in the south and Sutter County in the east.
104. Hoary navarretia *Navarretia eriocephala*	-/-/4	-	+	-	+	No	This species occurs throughout central California from Glenn, Lake and Yuba counties in the north to Stanislaus and Tuolumne counties in the south. It does occur in the Plan Area in the Jepson Prairie area, but not within the impacts areas.
105. Jepson's navarretia *Navarretia jepsonii*	-/-/4	-	-	-	+	No	This species has been observed on hillsides in northern and central California counties Tehama, Glenn, Colusa, Lake, Napa, Sonoma, and Placer but it does not occur within the Plan Area.
106. Baker's navarretia *Navarretia leucocephala* ssp. *bakeri*	-/-/1B	+	+	-	+	No	This subspecies has been observed in vernal pool and swales in northern California counties from Mendocino and Tehama in the north to Marin, Napa, and Solano in the south. It is present within the Plan Area in large playa pools at CDFG Tule Ranch Preserve and in vernal pools and swales at Jepson Prairie and Gridley Ranch Preserves, but those areas are in upland habitat that will not be impacted.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	*Status[A] (Federal/State/ CNPS)*	*Selection Criteria For Coverage[B]*				*Consider for Coverage?*	*Coverage Comments*
		Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information		
107. Pincushion navarretia *Navarretia myersii* ssp. *myersii*	-/-/1B	+	-	-	+	No	This subspecies has been observed in vernal pools in Sacramento, Placer, Amador, Calaveras, and Merced counties but it does not occur within the Plan Area.
108. Adobe navarretia *Navarretia nigelliformis* ssp. *nigelliformis*	-/-/4	-	-	-	+	No	This subspecies is widespread throughout central California from Butte County in the north to Kern County in the south, but there have been no recorded occurrences within the counties included in the Plan Area.
109. Prostrate vernal pool navarretia *Navarretia prostrata*	-/-/1B	-	-	-	+	No	This species is broadly distributed in southern and central California. The northernmost counties in which it has been observed are Alameda and Merced. It does not occur within the Plan Area.
110. Colusa grass *Neostapfia colusana*	T/E/1B	+	+	-	+	No	This species is present within the Plan Area in large playa pools at the Jepson Prairie Preserve but that area is upland habitat that will not be impacted.
111. Antioch Dunes evening primrose *Oenothera deltoides* ssp. *howellii*	E/E/1B	+	+	-	+	Yes	Though it does not meet all four criteria, due to this species' rarity and dependence on limited specialized habitat that is found in the Plan Area, it is proposed for coverage under the BDCP. This subspecies only occurs in the Antioch Dunes and does not occur within impacts areas. It is proposed for coverage because it is a listed species associated with the inland dune scrub natural community.
112. San Joaquin Valley Orcutt grass *Orcuttia inaequalis*	T/E/1B	+	-	-	+	No	With the exception of a single population near Travis Air Force Base in Solano County, this species is distributed in large vernal pools on the east side of the San Joaquin Valley and it does not occur within the Plan Area.
113. Hairy Orcutt grass *Orcuttia pilosa*	E/E/1B	+	-	-	+	No	This species occurs in large vernal pools and playas on the eastern margin of the Central Valley north and south of the Delta and does not occur within the Plan Area.
114. Slender Orcutt grass *Orcuttia tenuis*	T/E/1B	+	-	-	+	No	This species occurs in vernal pools and vernally wet areas in Lake County, the eastern side of the Sacramento Valley, and the Modoc Plateau and does not occur within Plan Area.
115. Sacramento Orcutt grass *Orcuttia viscida*	E/E/1B	+	-	-	+	No	This species occurs in hard-pan vernal pools on the eastern edge of Sacramento County and does not occur within the Plan Area.
116. Gairdner's Yampah *Perideridia gairdneri* ssp. *gairdneri*	-/-/4	-	-	-	+	No	This subspecies is widely distributed throughout California. It has been observed as far north as Humboldt and Siskiyou counties and as far south as Kern and Orange counties but it does not occur within the Plan Area.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	Status[A] (Federal/State/ CNPS)	Selection Criteria For Coverage[B]				Consider for Coverage?	Coverage Comments
		Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information		
117. Mt. Diablo phacelia *Phacelia phacelioides*	-/-/1B	-	-	-	+	No	This species occurs at high elevations of the inner Coast Range and does not occur within the Plan Area.
118. Michael's rein orchid *Piperia michaelii*	-/-/4	U	-	-	+	No	This species is widely distributed throughout California. It has been observed in coastal counties from Humboldt to Los Angeles and in inland counties from Butte to Tulare. However, it does not occur within the Plan Area.
119. Hairless popcorn-flower *Plagiobothrys glaber*	-/-/1A	U	-	-	+	No	Herbarium collections of this species are mostly very old and its current status is unknown. The collections are from heavy alkaline clays in the south San Francisco Bay area and from scattered alkaline seeps in the inner Coast Range from the Livermore Valley to San Benito County. Therefore, this species does not occur within the Plan Area.
120. Bearded popcorn-flower *Plagiobothrys hystriculus*	-/-/1B	+	+	-	+	No	This species is present within the Plan Area in vernal pools and swales at Jepson Prairie and Gridley Ranch Preserves, but those areas are in upland habitat that will not be impacted. It is endemic to a small area of Solano County from Gridley Ranch to the Montezuma Hills.
121. Marin knotweed *Polygonum marinense*	-/-/3	-	-	+ (H)	+	No	This species is present in the Suisun Marsh, but it is a widespread species in central California salt marshes in Marin, Sonoma, Napa, and Solano counties.
122. Eel-grass pondweed *Potamogeton zosteriformis*	-/-/2	-	+	+ (H, ID, O)	+	No	This species is not likely to be listed within the plan period as it is widely distributed in northern California (Consortium of California Herbaria 2008).
123. Delta woolly-marbles *Psilocarphus brevissimus* var. *multiflorus*	-/-/4	-	+	-	+	No	This variety is widespread in vernal pools found in central California counties from Butte and Glenn counties in the north to Santa Clara and Stanislaus counties in the south. It is also likely to be present in vernal pools in the Jepson Prairie area, but that upland area will not be impacted.
124. Lobb's Aquatic Buttercup *Ranunculus lobbii*	-/-/4	-	U	U	+	No	This species is widespread in vernal pools found from Mendocino and Lake counties in the north to Monterey County in the south. It is not present in the Jepson Prairie area but may be present at the Tule Ranch Preserve, but that upland area will not be impacted.
125. Victor's gooseberry *Ribes victoris*	-/-/4	-	-	-	+	No	This species is found on hillsides of the Coastal Ranges of northern and central California and it does not occur within the Plan Area.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	Status[A] (Federal/State/ CNPS)	Selection Criteria For Coverage[B]				Consider for Coverage?	Coverage Comments
		Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information		
126. Sanford's arrowhead *Sagittaria sanfordii*	-/-/1B	-	+	+ (H, AD, ID, O)	+	No	This species is broadly distributed in the Central Valley (CNDDB, Consortium of California Herbaria 2008) and is unlikely to be listed during the plan period.
127. Rock sanicle *Sanicula saxatilis*	-/SR/1B	-	-	-	+	No	This species occurs at high elevations of the inner Coast Range does not occur within the Plan Area.
128. Marsh skullcap *Scutellaria galericulata*	-/-/2	-	+	+ (H, AD, ID, O)	+	No	This species is broadly distributed in wet soils in central and northern California from Siskiyou and Modoc counties in the north to Inyo County in the south.
129. Side-flowering skullcap *Scutellaria lateriflora*	-/-/2	U	+	+ (H, AD, ID, O)	U	Yes	Though it does not meet all four criteria, due to this species' rarity and dependence on limited specialized habitat that is found in the Plan Area, it is proposed for coverage under the BDCP. There are only three reported occurrences of this species: one herbarium collection from Santa Clara that was recently determined to be this species; an 1882 collection from Bouldin Island, and; a 1999 collection at Delta Meadows River Park, (Consortium of California Herbaria 2008).
130. Rayless Ragwort *Senecio aphanactis*	-/-/2	-	-	-	+	No	This species is widely distributed on hillsides of California coastal ranges from the inner Coast Ranges in Solano County to the Peninsular Ranges in San Diego County and does not occur within the Plan Area.
131. Most beautiful jewel-flower *Streptanthus albidus* ssp. *peramoenus*	-/-/1B	-	-	-	+	No	This subspecies occurs on rocky serpentine slopes of the coast range from Contra Costa County to San Luis Obispo County, and does not occur within the Plan Area.
132. Mt. Diablo jewel-flower *Streptanthus hispidus*	-/-/1B	-	-	-	+	No	This species is found at high elevations of Mount Diablo in Contra Costa County does not occur within the Plan Area.
133. Suisun Marsh aster *Symphyotrichum lentum*	-/-/1B	+	+	+ (H, AD, ID, O)	+	Yes	Meets all four criteria. Suisun Marsh aster grows in brackish and freshwater marshes and along the banks of sloughs and watercourses. It has been observed growing with common reed, cattails, bulrushes, and blackberry (Solano HCP 2007). It is covered in the Solano and San Joaquin HCPs. It is found in valley riparian, tidal perennial aquatic, tidal freshwater emergent wetland, managed seasonal wetland, grassland, agricultural, and developed. There are numerous occurrences in the Legal Delta, particularly near the Sacramento River, San Joaquin River, and tributaries and in the vicinity of Pittsburg, Antioch, and Big Break going eastward. Broadly distributed throughout the Delta and in the Napa River, will likely benefit from habitat restoration.
134. Wright's trichocoronis *Trichocoronis wrightii*	-/-/2	-	+	+ (H, AD)	+	No	Both the Jepson Manual and the Flora of North America state that this species is not native to California, but is instead native to Texas and Mexico.
135. Showy indian clover *Trifolium amoenum*	E/-/1B	+	-	-	+	No	This species is known from two extant occurrences near Tomales Bay and Bodega Bay and a few historical occurrences near Fairfield. It does not occur within the Plan Area.

Appendix C. Evaluation of Special-Status Fish, Wildlife, and Plants Known or Likely to Occur in the Plan Area for Coverage under the BDCP (continued)

Scientific Name/ Common Name	Status[A] (Federal/State/ CNPS)	Selection Criteria For Coverage[B]				Consider for Coverage?	Coverage Comments
		Listing Potential	Occurrence in the Plan Area	Potential to Adversely Affect[C]	Sufficient Information		
136. Saline Clover *Trifolium depauperatum* var. *hydrophilum*	-/-/1B	-	+	U (H, AD)	+	No	This variety is widely distributed in central California coastal counties, and it is not likely to be listed during the duration of the plan (CNDDB, Consortium of California Herbaria 2008). Known from the Plan Area at CDFG Tule Ranch, could be in the impacts area of the Suisun Marsh and Cache Slough but surveys have not found it in the Jepson Prairie area. Could also be in the vicinity of the Clifton Court Forebay impacts area.
137. Coastal triquitrella *Triquetrella californica*	-/-/1B	-	-	-	+	No	This species is widely distributed from Laguna Mountain in San Diego County to the Coast Range of central California to the North Coast but does not occur within the Plan Area.
138. Dark-mouthed triteleia *Triteleia lugens*	-/-/4	-	-	-	+	No	This species occurs at high elevations. Recent occurrences have been recorded in the Coastal Range from Napa to Monterey. Other occurrences have been recorded in the Sierra Nevada in Plumas, El Dorado, and Mariposa counties; and several occurrences have been recorded Lake, Fresno, and Los Angeles counties. It does not occur within the Plan Area.
139. Caper-fruited tropidocarpum *Tropidocarpum capparideum*	-/-/1B	+	+	+ (AD)	+	Yes	Meets all four criteria. Caper-fruited tropidocarpum grows on alkaline flats and low alkaline hills within valley and foothill grassland (San Joaquin HCP 2000; CNDDB 2008). It is covered in the San Joaquin HCP. Historical occurrences are within Plan Area at the Clifton Court Forebay but no current occurrences are documented from that area. The ISA Report recommends that this species be eliminated from consideration for coverage. However, this species is very rare and appears to have a long-lived seed bank that may be present in the Clifton Court Forebay impacts areas.
140. Greene's tuctoria *Tuctoria greenei*	E/R/1B	+	-	-	+	No	This species occurs in large playa type vernal pools on the east side of the Sacramento Valley. None of these occurrences are within Plan Area.
141. Solano grass *Tuctoria mucronata*	E/E/1B	+	-	-	+	No	This species is not present within Plan Area. The Olcott Lake population has been extirpated and the existing populations in Solano and Yolo Counties are outside of the project and impacts areas.
142. Oval-leaved viburnum *Viburnum ellipticum*	-/-/2	-	-	-	+	No	This species is widely distributed from the North Coast-Klamath Region to the inner Coast Range and Sierra Nevada but does not occur within the Plan Area.

[A] Status Explanations

Federal
- E = listed as endangered under the federal Endangered Species Act (ESA)
- T = listed as threatened under the federal ESA
- C = candidate for listing under the federal ESA
- BCC = U.S. Fish and Wildlife Service bird of conservation concern
- NSC = National Marine Fisheries Service species of concern
- – = no status

State
- E = listed as endangered under the California ESA
- T = listed as threatened
- C = Candidate for listing under CESA
- SSC = California species of special concern
- FP = fully protected under the California Fish and Game Code
- R = listed as rare under the California Native Plant Protection Act
- – = no status

California Native Plant Society (CNPS)
- 1A = presumed extinct in California
- 1B = rare or endangered in California and elsewhere
- 2 = rare and endangered in California, more common elsewhere
- 3 = species lacking sufficient information to determine status
- 4 = limited distribution, low threats at this time
- – = no status

[B] Criteria met or not
- + = Species meets the selection criterion
- – = Species does not meet the selection criterion
- U = Uncertain whether species meets selection criterion. More investigation required.

[C] BDCP Actions (covered activities and conservation measures) potentially adversely affecting the species
- H = habitat restoration actions
- ID = in-Delta conveyance facilities
- AD = around-Delta conveyance facilities
- O = water operations

Appendix F

DRERIP Evaluation Results

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Appendix F-1

DRERIP Evaluations of BDCP Draft Conservation Measures Summary Report

DRERIP Evaluations of BDCP Draft Conservation Measures

Summary Report

FINAL

Prepared by:

THE ESSEX PARTNERSHIP

July 5, 2009

(Revised September 18, 2009[1])

[1] *Revisions were made to outcome P4 for Suisun Marsh (HRCM9) as reflected in Appendix D. These revisions do not affect the body of the Final Summary Report.*

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1. INTRODUCTION

This report describes the application of the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) Scientific Evaluation Process to evaluate draft conservation measures being considered for inclusion in the Bay Delta Conservation Plan (BDCP). The report summarizes the DRERIP process, how it was applied, who was involved, and the key findings. This application of the DRERIP process to proposed BDCP conservation measures is intended to provide technical input to the BDCP planning process and to provide insights into potential refinement of draft conservation measures.

The DRERIP evaluation process, as described in more detail below, involved evaluating each proposed BDCP conservation measure independently to identify the effectiveness of each on its own merits. Some measures related to water operations such as the Hood Bypass Criteria were provided to the evaluation team as a single measure with a given set of assumptions regarding Delta Cross Channel operations and south Delta diversions, because they are integral components of the dual conveyance strategy being pursued by the BDCP. Ultimately, the BDCP will include an overall Conservation Strategy comprised of a suite of conservation measures, many of which bear on each other (see *An Overview of the Draft Conservation Strategy for the Bay Delta Conservation Plan* dated January 12, 2009). Such a suite of measures may provide benefits greater than the sum of the individual measures. To begin to address this issue, a Synthesis Team was convened following the initial DRERIP evaluations to consider potential synergies and conflicts between various measures and to develop recommendations for possible modifications to the draft conservation measures. Due to time limitations, however, the Synthesis Team did <u>not</u> utilize the DRERIP evaluation procedure to evaluate the outcomes of modified conservation measures or the potential impact of combinations of conservation measures.

All evaluation results presented herein are relative to existing, baseline conditions in the Delta (i.e. will the measure result in a change, either positive or negative, making conditions better or worse than they currently are). The existing regulatory baseline was assumed to be D-1641.

Following this introduction, Section 2 provides general background information on the DRERIP evaluation process. Section 3 provides a summary of how the process was specifically applied to proposed BDCP conservation measures and Section 4 provides a summary of findings from the evaluations of individual conservation measures. Section 5 presents results and recommendations from the Synthesis Team.

2. DRERIP EVALUATION PROCESS

The following sections provide a brief summary of how the DRERIP evaluation process is structured including information on scoring procedures and scoring criteria.

2.1 Background and Purpose

The DRERIP Scientific Evaluation Process was developed to aid planning and decision making for ecosystem restoration projects in the Delta. The process entails engaging teams of experts to work through a structured, step-by-step scientific examination of the potential positive and negative outcomes resulting from proposed restoration actions. Detailed instructions describing each of the steps used in the evaluation process, as well as definitions for key terms, is provided in Appendix A.

The process relies on a series of ecosystem and species' life history conceptual models developed specifically for the Delta. These conceptual models describe the current scientific understanding of how the Delta ecosystem works and are designed to serve as a foundation for the evaluation process. The conceptual models are useful because they summarize existing scientific knowledge in a comprehensive manner for a given species or aspect of the ecosystem. Additional sources of information, for example recent published literature not embraced by the models can also be utilized, resulting in evaluations based on up-to-date information. In a few limited cases, the evaluation team conducted new analyses to assess potential outcomes. In these cases, the analysis is provided as an appendix to the evaluation worksheet. These additional analyses have not been peer reviewed.

The DRERIP process focuses strictly on ecological issues. It is not designed, or intended to address other factors that may ultimately influence decisions, such as cost or socio-economic considerations. The process also does not address issues of feasibility or priority setting. Most of the BDCP conservation measures evaluated were previously screened relative to basic feasibility factors.

The DRERIP process is designed to evaluate restoration actions at any level provided, with the evaluations results being more specific as the action itself is described in more specific terms. It can look at single actions and groups of actions; the more complex the restoration action, the more effort required to conduct the evaluation and potentially less certainty in the findings. DRERIP was not designed to conduct new technical analyses of restoration actions (e.g., numerical hydrodynamic modeling) but instead to draw upon the existing knowledge base as contained in peer-reviewed conceptual models and other information where needed and available.

The scope of evaluations for BDCP were focused on individual BDCP conservation measures (which in many cases are very large in nature) and not on considering multiple conservation measures together. The Synthesis Team examined these possible synergies and provided recommendations to further refine the conservation measures, where appropriate, to improve their overall benefits to covered fish species. Readers should be cautious in attempting to estimate cumulative or synergistic impacts of different actions; the scores are not necessarily additive or multiplicative. Several low magnitude actions may or may not correspond to a "medium" overall outcome. Also, some conservation measures may interact negatively with other conservation measures (e.g. if habitat restoration produces changes in tidal prism or hydrodynamics that are counter to those required for positive outcomes of another conservation measure).

2.2 Magnitude and Certainty Scores

After identifying likely outcomes for each conservation measure, the evaluation team assigned scores to each outcome reflecting the expected magnitude of the outcome (positive and negative) and the level of certainty regarding that magnitude. Magnitude and certainty scores were assigned to both positive and negative outcomes based on current scientific information. Definitions and the criteria used for assigning magnitude and certainty scores are shown in Table 1 and 2 below.

Table 1 - Criteria for Scoring the Magnitude of Ecological Outcomes

Magnitude *–the size or level of the outcome, either positive or negative, in terms of population or habitat effects on a given species. Magnitude is not the same as the scale of the action; however, higher magnitude scores require consideration of scale.*
4 - High: expected sustained major population level effect, e.g., the outcome addresses a key limiting factor, or contributes substantially to a species population's natural productivity, abundance, spatial distribution and/or diversity (both genetic and life history diversity) or has a landscape scale habitat effect, including habitat quality, spatial configuration and/or dynamics. Requires a large-scale Action.
3 - Medium: expected sustained minor population effect or effect on large area (regional) or multiple patches of habitat. Requires at least a medium-scale Action.
2 - Low: expected sustained effect limited to small fraction of population, addresses productivity and diversity in a minor way, or limited spatial (local) or temporal habitat effects.
1 - Minimal: Conceptual model indicates little effect.

Table 2 - Criteria for Scoring Certainty of Ecological Outcomes

Certainty *-– the likelihood that a given Restoration Action will achieve a certain Outcome. Certainty considers both the predictability and understanding of linkages in the pathway from the action to the outcome. Generally, high importance-low predictability linkages drive the scoring; it is important to ensure that certainty is not unduly weighted by a comparatively low-importance, albeit low-predictability linkage.*
4 - High: Understanding is high (based on peer-reviewed studies from within system and scientific reasoning supported by most experts within system) and nature of outcome is largely unconstrained by variability (i.e., predictable) in ecosystem dynamics, other external factors, or is expected to confer benefits under conditions or times when model indicates greatest importance.
3 - Medium: Understanding is high but nature of outcome is dependent on other highly variable ecosystem processes or uncertain external factors or understanding is medium (based on peer-reviewed studies from outside the system and corroborated by non peer-reviewed studies within the system) and nature of outcome is largely unconstrained by variability in ecosystem dynamics or other external factors
2 - Low: Understanding is medium and nature of outcome is greatly dependent on highly variable ecosystem processes or other external factors or understanding is low (based on non peer-reviewed research within system or elsewhere) and nature of outcome is largely unconstrained by variability in ecosystem dynamics or other external factors
1 - Minimal: Understanding is lacking (scientific basis unknown or not widely accepted), or understanding is low and nature of outcome is greatly dependent on highly variable ecosystem processes or other external factors

These definitions indicate how challenging it is for an individual action to achieve a magnitude score of 4 (population level effect) in a complex ecosystem with many stressors. Similarly, because many of the outcomes are influenced by highly variable (and thus unpredictable) ecosystem dynamics, only rarely will an individual action achieve high or even medium certainty scores. A measure with a "low" magnitude score can still be implemented – and the cumulative effects of many such actions may result in a greater level of effect at the population level scale.

For some species, particularly salmonids and sturgeon that spend a relatively short portion of their life history in the Delta, it is rare for Delta-specific actions to have population level effects. The benefits of measures in the Delta can easily be overwhelmed by conditions upstream and/or downstream (i.e., ocean), which may be driving the population in more significant ways. Given this fact, magnitude scores of "3" or "4" are not common for salmonids with Delta restoration alone.

Beyond individual magnitude and certainty scores, it is important to review combinations of magnitude and certainty (i.e., different combinations suggest different things). For example, a medium benefit with low certainty (combined score of "3, 2") means that the team concluded that the outcome would have a minor population level effect and that the certainty that this magnitude would be achieved (as opposed to a lower magnitude) was low.

Both positive and negative outcomes are scored, and it's important to look at the positive scores in combination with the negative scores to provide an overall evaluation of the action. Together, these outcomes could result in a theoretical no-net-gain, or even a net negative effect. Many of these trade-offs are potentially quite complex and very difficult to predict in terms of likely net biological response, the mechanisms underlying those responses, and our ability to mitigate risk factors in design and implementation.

3. EVALUATION OF BDCP CONSERVATION MEASURES

The following sections describe how the DRERIP Scientific Evaluation Process was applied to proposed BDCP measures.

A total of 32 draft BDCP conservation measures were identified for evaluation. These measures were selected by the BDCP planning team from the draft conservation measures described in Handouts #3, 4, and 5 from the October 31, 2008 BDCP Steering Committee meeting. These measures were reviewed and refined in December 2008 for the purposes of conducting the DRERIP evaluations. Refinements included stipulating details such as target restoration acreages and bypass flows. A listing of the measures evaluated as well as descriptions of those measures as provided to the evaluation team are contained in Appendix C. This refinement for the purposes of evaluation occurred prior to the release of the BDCP Overview document entitled *An Overview of the Draft Conservation Strategy for the Bay Delta Conservation Plan* dated January 12, 2009. As a result, there are some minor differences in the descriptions and assumptions between the measures evaluated and those described in the Overview document.

A team of 50 experts was convened to evaluate several draft proposed BDCP conservation measures. Team members were selected based on their expertise relative to the specific ecological issues associated with the draft conservation measures, as well as their familiarity with the Delta, the DRERIP conceptual models, and the DRERIP evaluation process. Team members were trained on how to conduct the evaluations and were tasked with reviewing particular conceptual models prior to the evaluations. The team was further divided into five subteams with each team assigned specific conservation measures on related topics. Each subteam was headed by a Chair familiar with the topic and was assigned a 'coach; familiar with the DRERIP process. A listing of evaluation team members is provided in Appendix D.

A series of workshops were held where team members discussed the draft measures and worked through the pre-established evaluation steps for each action. Workshops were followed by team conference calls and email deliberations over a three-month period from January to April 2009, including review and refinement of findings. The results of each team's evaluations were recorded in standardized worksheets which were reviewed and edited by the teams. Due to the intensity and volume of work, not all evaluations were completed to the same level of detail and not all worksheets were reviewed by all team members.

4. SUMMARY OF FINDINGS

The following presents a brief summary of findings from the evaluation of individual draft proposed BDCP conservation measures. Summary findings are presented for each subteam. All findings are for the specific conservation measures as given to the teams in January 2009 (see Appendix C). Findings regarding interrelationships between conservation measures are discussed in Section 5 of this report.

Completed evaluation worksheets for each measure, including the rationales behind the findings, can be viewed at http://baydeltaconservationplan.com/BDCPPages/BDCPInfoBackgroundDOcsDRERIP.aspx . The detailed worksheets include the specifics regarding individual measures and expected species outcomes. The numerous and complex ecological interactions and trade-offs between the various measures do not lend themselves well to simple summary results. For example, there can be a temptation to gauge a measure's merits by simply reviewing the magnitude scores for positive outcomes. Readers should note that: (1) magnitude scores for positive outcomes represent the highest possible outcome; (2) certainty scores indicate the degree of certainty experts have about attaining an outcome as high as that indicated by the magnitude score; and (3) negative outcomes associated with the conservation measures deserve attention as well. The worksheets prepared by each evaluation subteam describe in detail the potential benefits and pitfalls associated with each conservation measure.

Not all evaluations were completed with equal degrees of analysis due to time and budget constraints. In several instances, general conclusions from one evaluation were applied to other evaluations, with varying levels of measure-specific refinements. Details of measure-specific differences were not always explored fully due to limited information and uncertainties about the population level effects of these differences. Evaluations that fall into this category are noted in their worksheets.

Each evaluation worksheet contains a list of data gaps and future research needs. These lists warrant further consideration by BDCP.

Appendix D provides a series of tables listing the magnitude and certainty scores for each measure and the expected outcomes (positive and negative) by species.

4.1 Floodplain and Riparian Habitat Restoration Measures

Nine specific floodplain and riparian habitat restoration measures were evaluated including restoring former floodplains along the San Joaquin River (HRCM1, 2) and in the South Delta (HRCM3), creating channel margin habitat along Steamboat and Sutter sloughs (HRCM12) and the San Joaquin River (HRCM13), and creating riparian habitat in association with other actions (HRCM11, 14). The Floodplain and Riparian Habitat team also evaluated measures to modify and reoperate the Fremont Weir and Yolo Bypass (Core Element No.1, WOCM2) and to create a new bypass adjacent to the Sacramento River Deep Water Ship Channel (WOCM3). Multiple scenarios were considered for several of the actions involving different restoration acreages and different inundation regimes.

Fremont Weir and Yolo Bypass (Core Element No.1; WOCM2)

- Modifications to the Fremont Weir and reoperation of the Yolo bypass to provide higher frequency and duration of inundation is expected to have high magnitude benefits for several covered species with a high degree of certainty.
- Benefits are attributable to increased spawning and rearing habitat as well as expected reductions in stranding and associated illegal harvest.
- Results suggest that Option 1 (spill discharge of 4,000 cfs for 45 days) would provide greater benefits for covered species than Option 2 (spill discharge of 2,000 cfs for 30 days) due to the greater extent and duration of flooding.
- Potential negative outcomes to covered species were few, and appear to be manageable through more detailed design and effective monitoring. The potential for mercury methylation and associated environmental toxicity is expected to be of low magnitude for covered fish species, but the certainty of that outcome is low because there is very limited data on mercury toxicity to fish in the Delta.
- Results for creation of a new floodplain bypass adjacent to the Sacramento Deep Water Ship channel (WOCM3) were similar to those for reoperation of the Yolo bypass.

San Joaquin River and South Delta (HRCM1, 2, and 3)

- Floodplain restoration measures along the San Joaquin River would be expected to provide minimal to low benefits (with a medium to high degree of certainty) due to infrequent floodplain inundation associated with the current San Joaquin River flow regime, which is a limiting factor.
- Expected benefits of floodplain restoration in the south Delta (along Old River at Fabian Tract) are also minimal to low due to the relatively small scale of the action (800 to 1600 acres). However, there could be minor population level benefits for splittail associated with this measure if the Old River were isolated such that it did not experience the effects of south Delta pumping.

Channel Margin and Riparian Habitat (HRCM 11, 12, 13 and 14)

- Proposed improvements to "channel margin habitat" would be expected to have largely minimal to low benefits for covered species due to the relatively small scale of the actions, the lack of any change in the currently impaired flood hydrology, and the fact that channels would not be allowed to evolve and erode providing limited instream structure such as woody debris.
- The team recommended providing a clearer definition of "channel margin" habitat.

4.2 Tidal Restoration Measures

The effects of reintroducing tidal flows into six Restoration Opportunity Areas (ROA) in the Delta were evaluated, including the Yolo/Cache Slough Complex ROA (Core Element No. 6; HRCM4), the Cosumnes/Mokelumne ROA (HRCM5), the West Delta ROA (Core Element No. 7; HRCM6), the South Delta ROA (HRCM7), the East Delta ROA (HRCM8), and the Suisun Marsh ROA (Core Element No. 8; HRCM9). Restoration of these areas would involve varying degrees of tidal marsh and shallow subtidal restoration as described in more detail in Appendix C. Multiple scenarios were considered for several of the ROAs reflecting different amounts of restored habitat. The evaluation team focused its greatest efforts on HRCM4 (Yolo/Cache) and HRCM9 (Suisun); HRCM6 (West Delta) received the next level of effort; and the remaining measures were evaluated with far less detail.

In general, evaluation results vary considerably depending on the species in question and the geographic location of the restoration. The magnitude of the benefits tend to be greater for delta smelt (which spends its entire life history in the delta preferring cooler, turbid waters) than they are for migratory fish, such as salmon and sturgeon which spend a relatively small portion of their life cycle in the Delta. The likelihood that restored tidal areas would export zooplankton and insects to provide food for covered species in other areas of the Delta is a function of the size of the restoration area, its relative mix of marsh and open water, its connectivity to the estuary, the amount of riverine influence on the area, and the degree to which production is consumed within the ROA. The evaluation team had difficulty evaluating this outcome and in the end presented alternate conclusions. These different viewpoints reflect a core need to gain better understanding, which can be accomplished most effectively through implementing restoration efforts and evaluating their outcomes on this issue.

Negative outcomes of concern include the potential for restored areas to be colonized by *Egeria* providing habitat that increases predation risk, and the potential for methylation of mercury.

Yolo/Cache Slough ROA (Core Element No. 6; HRCM4)

- Many of the benefits of this restoration depend upon relocation of major urban and agricultural water supply diversions within the Cache Slough area, especially the North Bay Aqueduct intake and a handful of the large agricultural intakes.
- Expected medium magnitude benefits (minor population level effect) for delta smelt, splittail, and Sacramento fall-run Chinook salmon, but with low certainty. While the measure would increase the amount of habitat area for delta smelt in the north Delta, it would not expand the range of the species in the Delta, a critical concern for delta smelt conservation.
- Expected minimal to low population benefits for longfin smelt, sturgeon, winter and spring-run Chinook salmon, and steelhead with low certainty. The evaluation recognized that the near total absence of tidal marshes in the Delta and thus the near total absence of local data to understand how these species may use or be affected by restored tidal habitats contribute to the low certainty score.
- The measure has the potential to produce a considerable quantity of organic carbon to support the aquatic food web; uncertainty exists regarding the extent to which the primary production component might be reduced if invasive clams colonize restored areas. Uncertainty also exists about the magnitude of secondary production being transported to locations where covered fish species could gain the most benefit.
- The establishment of *Corbicula* could limit or eliminate the benefits of the action by consuming increases in primary productivity created by the restored marsh and subtidal areas. Uncertainty is high regarding whether this loss of primary production could affect secondary production – zooplankton and insects – that serve as the primary prey items for covered fish species.
- Other invasives, namely *Egeria* and centrarchids, could have a medium magnitude negative effect on covered species, but the certainty of this effect is low.

- The potential for mercury methylation is expected to be of low magnitude with medium certainty; the associated environmental toxicity for covered fish species is expected to be of low magnitude, but the certainty of this toxicity outcome is low because there is very limited data on mercury toxicity to fish.
- The negative outcomes for human health and piscivorous wildlife associated with the potential for habitat restoration to increase MeHg concentrations in fish received low magnitude and medium certainty scores and need to be seriously considered.
- Increased mercury methylation could potentially be a significant issue for birds and humans.
- Linkage to Yolo Bypass improvements identified as raising the benefits of this measure though the magnitudes were not assessed.

Cosumnes/Mokelumne ROA (HRCM5)

- This evaluation was not subject to the full development and review by the evaluation team so its findings are preliminary and subject to revision were further analysis to be conducted.
- Expected medium magnitude benefits (minor population level effect) for splittail with medium certainty.
- Expected minimal to low benefits for delta smelt, longfin smelt, sturgeon, steelhead, and salmonids (all runs) with minimal to low certainty.
- The measure would likely provide low magnitude local increases in productivity, but may not provide a significant net increase in zooplankton or insects to other areas of the Delta. See productivity discussion for HRCM4 above.
- Potential for negative outcomes, including establishment of *Egeria* and centrarchids are similar to that described above for the Yolo/Cache ROA.

West Delta ROA (Core Element No. 7; HRCM6)

- This evaluation was not subject to the full development and review by the evaluation team so its findings are preliminary and subject to revision were further analysis to be conducted.
- Results indicate that the effects of *Egeria* establishment and associated predation are potential medium to high magnitude negative outcomes, but certainty is low. This measure has a greater likelihood for this negative outcome due to its composition of many, relatively small restorations alongside large water bodies vs. the larger restorations of other ROAs.
- The West Delta ROA is particularly limited by the fact that it consists of numerous, small, disconnected parcels.

South Delta ROA (HRCM7)

- This evaluation was not subject to the full development and review by the evaluation team so its findings are preliminary and subject to revision were further analysis to be conducted.
- Expected minimal to low benefits for all covered species with minimal to low certainty.
- Similar to the West Delta ROA, results indicate that the effects of *Egeria* establishment and associated predation are potential medium to high magnitude negative outcomes, but certainty is low.
- The potential for this measure to adversely contribute to low dissolved oxygen (DO) conditions in the Delta was also identified as a concern with a medium magnitude, but low certainty. Increased residence times associated with limited circulation combined with greater biological productivity contributing to increased water column Biological Oxygen Demand (BOD) could lead to low DO conditions.

- Benefits considered minimal at best under current conveyance and export configuration.
- Potential for negative outcomes is similar to that described above for the Yolo/Cache ROA.

<u>East Delta ROA (HRCM8)</u>

- This evaluation was not subject to the full development and review by the evaluation team so its findings are preliminary and subject to revision were further analysis to be conducted.
- Benefits for covered fish species are expected to be low with minimal to low certainty.
- Potential for negative outcomes is similar to that described above for the Yolo/Cache ROA.
- Evaluation noted potential for greater magnitude of negative outcomes due to the relative isolation of this ROA and the poor quality habitats linking it to other suitable habitat areas.

<u>Suisun Marsh ROA (Core Element No. 8; HRCM9)</u>

- Expected medium magnitude benefits (minor population level effect) of providing habitats for splittail, delta smelt, and fall and spring-run Chinook salmon, but certainty is minimal to low.
- Expected medium magnitude benefits for contributing desired productivity contributions, with low to medium certainty; benefits highly dependent on where within Suisun Marsh the restoration efforts are located.
- Expected to reduce periodic low dissolved oxygen conditions that originate with the existing managed wetlands.
- May reduce overall methyl mercury production and exposure that originate with the existing managed wetlands (medium magnitude, low to medium certainty).
- Potential for establishment of *Egeria* is zero, but potential for establishment of *Corbula*, which could constrain the desired productivity benefits, is high with a low certainty. Predator establishment potential is minimal to low, with low certainty.

4.3 Water Operations Measures

The team evaluated two potential water operations conservation measures, a new diversion point in the north Delta with Hood Bypass Criteria and other Measures (Core Elements No. 2, 3, 4, and 5; WOCM1) and new Interim Tidal Gates in the south Delta (Core Element No. 9; WOCM8) - commonly referred to as 2-Gates. Evaluation of the new north Delta diversion and associated other measures included reductions in south Delta pumping (dual conveyance), changes to Delta Cross-channel gate operations, and two alternative Hood bypass flow criteria. Modifications and operational changes to the Yolo Bypass (WOCM2) were evaluated as part of the floodplains evaluation. The Interim Tidal Gates measure included installing operable tidal gates in Old River on the eastern side of Bacon Island, and in Connection Slough on the western side of Bacon Island. The implications of the Interim Tidal Gates measure were only evaluated for delta smelt and longfin smelt.

The evaluation of WOCM1 did <u>not</u> include any assessment of entrainment or impingement related to fish screens on the new North Delta Diversion(s). The team assumed that the fish screens would be 100% efficient.

Results of the evaluation point to complex trade-offs between potential positive outcomes in the south Delta associated with reduced export pumping resulting in modified Old and Middle River (OMR) flows and potential negative outcomes in the north Delta associated with the new diversion. Negative outcomes are also expected in the south Delta related to exacerbation of existing low dissolved oxygen conditions and other water quality impacts, including the potential for greater residence times (i.e., less flushing) and less dilution of San Joaquin River inflows.

<u>New North Delta Diversion with Hood Bypass Criteria and other Measures (Core Elements No. 2, 3, 4, and 5; WOCM1)</u>

- Reduced diversions at the South Delta facilities, and associated reductions in entrainment are expected to result in:
  - medium magnitude benefits with medium certainty for delta smelt adults and juveniles;
  - medium magnitude benefits for longfin smelt juveniles and low magnitude benefits for longfin smelt adults with medium certainty; and
  - low magnitude benefits for splittail, Sacramento River salmon runs, and steelhead with medium certainty.
- The potential benefits of reduced diversions at the South Delta facilities are expected to be minimal for San Joaquin fall-run Chinook salmon (*Stanislaus, Merced, and Tuolumne rivers)* because exports remain high during the period SJR fall run Chinook are migrating through the south Delta and the action does not address SJR flows which are needed to facilitate escapement.
- New diversions on the Sacramento River would have negative effects due to increased predation, both at the diversion facilities themselves and downstream due to modified hydrodynamics and fish travel time. The magnitude of the negative impact due to increased predation ranged from low to high depending of species, and will depend on the design of the diversion structures and associated screens (particularly their location and orientation to the river bank), and the change in flow conditions downstream.
- Potential impacts of large diversions of Sacramento River water on foodweb dynamics are highly uncertain. Removal of organic carbon and organisms from the system could adversely impact productivity downstream. However, increased residence time associated with reduced flows could increase primary productivity (additional conservation measures could also potentially influence productivity downstream, namely Yolo Bypass inundation and tidal marsh restoration). Increased primary productivity may not yield suitable secondary productivity utilized by covered fish species because the primary productivity may be intercepted by other organisms, including invasive clams, or it may be of an undesirable form (e.g., Microcystis).
- Evaluation results indicate that operation of a new North Delta Diversion would have medium to high magnitude negative impacts on covered species due to potential declines in water quality in the South Delta, including increased frequency and duration of low dissolved oxygen events.
- There is a medium to high level of certainty that there would be medium level negative impacts to Mokelumne and Cosumnes fall run Chinook.

<u>Interim Tidal Gates (Core Element No. 9; WOCM8)</u>

- The construction of operable tidal gates in Old River and Connection Slough along the east and west sides of Bacon Island is expected to provide medium to high magnitude benefits for adult delta smelt and low to medium benefits for juvenile delta smelt, with low to medium certainty for both outcomes.

- The potential for negative outcomes for delta and longfin smelt associated with increased predation at the new gate structures and increased entrainment at the pumps are expected to be low, with a low certainty.
- Potential implications of the 2-Gates measure on other covered species, including salmonids were not evaluated.

4.4 Hatcheries and Harvest Measures

Six "Other Stressor" conservation measures related to hatcheries and harvest regulations were evaluated including increased sport harvest of non-native predatory fishes (OSCM14), enhanced enforcement in the Delta (OSCM16), modified splittail harvest regulations (OSCM17), implementing a Mark-Select program to reduce the harvest of wild Chinook salmon (OSCM19), establishing artificial propagation programs for delta smelt and longfin smelt (OSCM20), and modifying or eliminating non-project diversions in the Delta (OSCM21).

Increased Sport Harvest of Non-Native Predatory Fishes (OSCM14)

- Expected medium benefits for delta and longfin smelt, but low certainty. Potential benefits for other covered species are minimal to low with low certainty.
- The likelihood and magnitude of positive effects on covered species are not well-understood due to uncertainty regarding (1) the magnitude and frequency of competition between juvenile striped bass and delta and longfin smelt, (2) how fishermen will respond to changes in sport fishing regulations, and (3) the magnitude of the impact of bass predation on any one species. Research in these areas will increase our understanding of the benefits provided to covered species by this measure.
- Negative outcomes identified for this conservation measure are: (1) increased by-catch of non-target species (minimal magnitude, low certainty), (2) release of other predator populations from predation pressure (low magnitude, low certainty), (3) release of other competitor populations from predation pressure (medium magnitude, medium certainty), and (4) unintended changes to the bass populations (i.e., may shift average size of bass populations) (low magnitude, low certainty).

Enhanced Enforcement in the Delta (OSCM16)

- Expected medium benefits for green and white sturgeon, low to medium benefits for Chinook salmon, and low benefits for steelhead – all with low certainty.
- Uncertainty regarding the impact of poaching on population sizes of covered fishes, relative to other threats, makes it difficult to determine the potential benefits of implementing this measure.
- There is a possibility that lack of information regarding where poaching is most important may result in greater effort to enforce fishing regulations in less important areas and a shift of poaching to areas of greater importance to the population.

Modified Splittail Harvest Regulations (OSCM17)

- Two positive outcomes were identified by the evaluation team: (1) increased population abundance of splittail, and (2) improved foodweb energy transfer in wet years. Both are expected to result in medium benefit with low certainty.

- It is difficult to evaluate the potential benefits of this measure due to uncertainty regarding the size of the current splittail fishery, and magnitude of foodweb energy transfer caused by movement of splittail into and out of inundated floodplains.
- The primary negative outcome identified was the potential for redirection of fishing effort toward other sensitive species as splittail harvest regulations are put in place (low magnitude, medium certainty).

Mark-Select Program for Chinook salmon (OSCM19)

- Based on experiences in other states with mark-select fisheries, the evaluation team stated that the effectiveness of such a program largely depends on implementation and monitoring, and that it would be difficult, if not impossible, to limit all commercial and recreational harvest to marked fish.
- Expected medium magnitude benefits for integrated (natural and hatchery produced) Chinook salmon population with medium certainty. The evaluations found that natural Chinook populations may not necessarily increase abundance as other stressors may exert a greater influence on the population.
- Potential negative outcomes include: (1) complication of management and data for conservation hatcheries and agency sampling programs; and (2) increased bycatch and non-harvest mortality of covered salmonids. These outcomes are based largely on uncertainty regarding the magnitude of non-catch mortality and approaches for managing conservation stocks.

Artificial Propagation of Delta and Longfin Smelt (OSCM20)

- Expected medium magnitude benefits for delta smelt and longfin smelt with minimal to low certainty.
- Negative outcomes include: (1) potential genetic consequences for hatchery and wild populations; (2) negative ecological interactions with wild fish (e.g., competition, displacement); (3) genetic bottlenecks resulting from mining of wild population to support broodstock needs leading to reduced capacity of species to adapt to changing environmental conditions; and (4) mortality associated with catching broodstock.
- The potential for mortality associated with collection of broodstock is considered to be low (with medium certainty) because effective collection techniques have been established for delta smelt. Longfin smelt are expected to be less sensitive to handling stress and physical injury than delta smelt (magnitude low, certainty low).
- It will be difficult to determine how many hatchery fish are needed to boost spawning in the wild. Adaptively managing the numbers of hatchery fish introduced will be necessary. Numbers should be adjusted if reproductive rates do not increase.
- The negative outcome results are based largely on uncertainty regarding the genetic implications of hatchery propagation for wild and hatchery delta and longfin smelt. The genetic diversity of hatchery fish is of concern because these fish are to be introduced into the wild, are expected to interbreed with wild fish, and will undergo domestication without integrating new wild broodstock into the propagation activity. Information is particularly limited for longfin smelt, for which hatchery propagation has not been conducted to date.

<u>Reducing Non-project Diversions (OSCM21)</u>

- The positive outcomes identified include: (1) reduced entrainment mortality by non-project diversions; and (2) increased food availability. Benefits are expected to be of minimal magnitude, with minimal certainty for both outcomes due to uncertainty regarding the entrainment mortality caused by non-project diversions and how these diversions affect planktonic food availability.
- No negative outcomes for covered species were identified for this measure.

4.5 Water Quality and Invasive Species Measures

Six "Other Stressor" conservation measures related to water quality and invasive species were evaluated including, measures to: reduce the concentrations of ammonia discharged into the Sacramento River (OSCM1); reduce the loads of endocrine disrupting compounds (EDCs) (OSCM2); reduce the load of methylmercury (OSCM3); reduce loads of pesticides and herbicides (OSCM4); reduce loads of toxic contaminants in stormwater and urban runoff (OSCM5); and remove water hyacinth (*Eichornia crassipes*) and Brazilian waterweed (*Egeria densa*) from select areas of the Delta (OSCM13).

Results of the evaluation indicate that the majority of the water quality and invasive species measures would be expected to deliver positive benefits to covered species, with the exception of OSMC13 (SAV and FAV), for which significant negative outcomes were identified that could potentially deliver net losses for covered species. Negative outcomes were also identified for OSCM1 (Ammonia), OSCM4 (Pesticides) and OSCM5 (Urban runoff). In general, reducing the amounts of chemicals in Delta waterways are expected to be a good thing for covered fish species, even if the specific benefits are difficult to quantify.

<u>Ammonia Loadings Reductions (OSCM1)</u>

- Expected to have medium magnitude benefits for delta smelt and longfin smelt, but the certainty of these benefits is minimal. Benefits for other species are minimal to low magnitude with a range of certainty depending on the species and the specific outcome (see Appendix D).
- Negative outcomes identified include: (1) possible removal of important nutrients from the system by tertiary treatment of WWTP effluent (magnitude minimal, certainty high); (2) microcystis blooms could result from increased nitrate (from nitrification of ammonium) (magnitude low, certainty low); and (3) enhanced phytoplankton production from reduction of ammonium (by nitrification) could increase clam biomass and uptake of selenium, impairing reproduction in benthic-foraging fishes (magnitude medium, certainty high).
- The negative outcomes anticipated in the evaluation are based largely on uncertainty regarding the need to identify more sources of ammonia and the unsettled state of the science regarding food web relationships of phytoplankton, diatoms, microcystis, zooplankton, and clams, and how they and their relationships are affected by excess ammonium in the system, water residence time, salinity, temperature, and flow.
- Integrated research should be undertaken to develop a numerical model of ammonia/ammonium affects on the Delta food web and covered species so that the multiple factors influencing production can be manipulated/isolated from other factors, and the respective roles of each factor can be determined for the different portions of the estuary.

Endocrine Disrupting Compounds (EDCs) Loadings Reductions (OSCM2)

- Reducing EDCs is expected to result in benefits for all covered fish species. The magnitude of these benefits range from low to medium, while certainty is minimal to medium, depending on the outcome.
- There were no negative outcomes identified by the evaluation team for this conservation measure. However, to effectively target reductions in EDCs, the main sources need to be identified and quantified.
- WWTPs contribute to the EDC problem. However, EDCs can also come from pyrethroids and other agricultural runoff, particularly dairies, which represent potentially large, untreated loadings. Therefore, the relative contributions of wastewater treatment plants to those of other potential EDC sources such as hatcheries, pesticide sources (which include both agricultural and urban use), and dairies need to be determined.
- Secondarily, EDC monitoring based on biological responses is needed to identify hotspots and sources as well as temporal and special distribution of EDCs within the system.

Methyl Mercury Loadings Reductions (OSCM3)

- The expected benefits for covered fish species of reducing methyl mercury loadings and resulting bioavailability are minimal to low, with low certainty. The benefits to wildlife and humans, however, are expected to be of medium magnitude with medium certainty.
- There were no negative outcomes for covered species identified by the evaluation team for this conservation measure.
- As more seasonal wetlands are created in the Delta and as the Delta's hydrology changes due to the dual conveyance system or climate change, monitoring of MeHg concentrations in water and fish becomes more important. Species-specific studies on sub-lethal population-level effects (e.g. feeding efficiency, growth, or spawning success) of MeHg in covered fish species are also necessary.
- Monitoring studies would contribute to the development of a numerical MeHg transport and fate model, with a food web component, that combines source information, water transport and residence times, photodemethylation and particle settling to predict methyl mercury concentrations in water, sediment, and biota at various locations in the Delta under different hydrologic conditions.
- From a sociological perspective, better estimates of the number of people at risk for MeHg toxicity due to recreational or subsistence fishing should be made to refine or expand fish consumption advisories and to develop educational strategies for teaching the affected public how to reduce the risk.

Pesticide and Herbicide Loadings (OSCM4)

- Reducing pesticide and herbicide loadings in Delta waterways would be expected to have benefits (medium to high magnitude, medium certainty) for several covered fish species, including delta smelt, green and white sturgeon, spring-run Chinook salmon, and winter-run Chinook salmon.
- The negative outcome identified for this conservation measure was loss of freshwater input to the system and loss of habitat for freshwater phytoplankton and zooplankton if tailwater recovery systems are used as a BMP to reduce pesticide-contaminated runoff (medium magnitude, minimal certainty). This outcome, if confirmed, could be managed by specifying appropriate BMPs to avoid loss of freshwater input.

- There are currently no data on the use of small creeks by covered species or their phytoplankton and zooplankton prey. Such data could be developed to evaluate: 1) the relative importance of the freshwater input of small creeks to the system; 2) the use of small creeks as nursery areas by ecologically important phytoplankton and zooplankton species; and 3) where to avoid freshwater reductions.

Urban Runoff (OSCM5)

- Reducing urban runoff is expected to have benefits (medium magnitude, low to medium certainty) for several covered fish species, including steelhead, spring-run Chinook salmon, winter-run Chinook salmon, fall-run Chinook salmon, delta smelt, longfin smelt, and green and white sturgeon,.
- Negative outcomes identified include: (1) human health impacts from use of ponded stormwater by breeding mosquitoes; and (2) contamination of groundwater by infiltration of impounded surface water. Both of these outcomes could be managed to reduce the likelihood of occurrence.
- Urban runoff containment and treatment methods (both existing and potential future methods) should be assessed with respect to mosquito control and groundwater infiltration. Monitoring should include collection of data to determine how and when small subgroups of the covered species and their zooplankton prey use urban creeks, and how individual sources of runoff affect receiving waters.

Submerged and Floating Aquatic Vegetation (SAV and FAV) (OSCM13)

- Reducing non-native SAV and FAV in specific areas of the Delta is expected to have positive benefits for Chinook salmon and steelhead rearing in the Delta (magnitude medium, certainty medium).
- Negative outcomes identified include: (1) reduction in zooplankton from herbicide toxicity (magnitude low, certainty low); (2) reduction in phytoplankton from herbicide toxicity (magnitude medium, certainty minimal); (3) increased detritus including particulate organic carbon (POC) (magnitude low, certainty low); (4) increased microcystis blooms due to reduced competition for nutrients from phytoplankton and microcystis resistance to herbicides (magnitude low, certainty medium); (5) toxic effects on juvenile sturgeon from fluridone and 2,4-D used at approved application rates (magnitude low, certainty medium); and (6) endocrine disrupting effects of 2,4-D on fish (magnitude low, certainty low).
- A large part of the uncertainty regarding this conservation measure is due to unknown factors in the relationship between phytoplankton and microcystis and how they are affected by herbicides. In addition, more information is needed on the interactive effects of flow and temperature on microcystis blooms.
- The potential toxic effects on sturgeon are based on studies from outside the system that looked specifically at aquatic herbicides. Sturgeon were more sensitive than salmon to these chemicals in controlled laboratory tests. However, the use of proposed weed control areas in the Delta and actual water concentrations resulting from the CDBW program are unknown.
- Most of the uncertainties could be addressed by controlled, small-scale pilot studies with detailed before-and-after monitoring.

5. SYNTHESIS TEAM RECOMMENDATIONS

Following the individual evaluations, a Synthesis Team was formed to examine potential synergies and conflicts between the various draft conservation measures. The team was comprised of the five DRERIP evaluation subteam chairs and select members of the evaluation subteams. Members of the Synthesis Team (see Table 5.1) were assigned to review the evaluation worksheets and identify potential refinements to the draft conservation measures, including additional information or analyses that would be useful in reducing uncertainties. The Team also looked at areas where measures could work with or against each other and tried to identify refinements that would enhance potential synergies and reduce potential conflicts among actions. The Team did not attempt a comprehensive assessment of cumulative impacts or a scoring of the ultimate net effect of the all the measures combined. Synthesis Team findings, as presented below, were based on a series of meetings and discussions among team members culminating in a two-day workshop where the team developed final recommendations.

Table 5.1 – Synthesis Team

Name	Affiliation	Evaluation Team(s) Role
Dave Harlow	SWC	Tidal reintroduction, chair
Stuart Siegel	Wetland and Water Resources	Tidal reintroduction, coach
Chuck Hanson	Hanson Environmental	Tidal reintroduction
Amy Richey	Mosaic/SLDMWA	Tidal reintroduction
Campbell Ingram	TNC	Floodplains, chair
Denise Reed	UNO	Floodplains, coach
Jim Haas	USFWS	Water quality and invasives, chair
David Fullerton	MWD	Water quality and invasives, member
Brad Cavallo	CFS/SWC	Hatcheries and harvest, chair
John Cain	NHI	Water operations, chair
Joshua Israel	EDF	Water operations, Hatcheries and harvest
Rosalie del Rosario	NMFS	Water operations, Floodplains
Matt Norbriga	DFG	Water operations
Armin Munevar	CH2M Hill	Hydrodynamic modeling results
Carl Wilcox	DFG	NA
Michael Hoover	USFWS	NA

5.1 General Synthesis Team Conclusions

Collectively, the synthesis team concluded that a number of the conservation measures have the potential for additional synergistic effects that can raise or lower the worth of some individual conservation measures when implemented concurrently with other actions. The complexity of various trade-offs between expected positive and negative effects make it difficult to predict the biological responses to multiple measures in combination. The Synthesis Team recommended that refinements could be made to the proposed modification of the Fremont Weir and Yolo Bypass inundation, North Delta diversions with bypass criteria, and Cache slough restoration to optimize ecological benefits and water supply goals. They also identified the need for better information and modeling of the survival and growth of covered species and predators to establish baseline conditions against which benefits can be assessed as these BDCP conservation measures are further developed and implemented. The Synthesis Team further recommends that BDCP proceed with large scale implementation of tidal reintroductions in Cache Slough, Suisun Marsh and Dutch Slough based on the existence of favorable landscape characteristics for restoration in the areas and expected benefits to multiple covered fish species.

The Synthesis Team identified seven general conclusions that apply broadly to the evaluations and that form the foundation for the Team's recommendations.

1. Refinements should be made to add specificity to the proposed modifications to the Fremont Weir and Yolo Bypass inundation (WOCM2), North Delta Diversions with Hood bypass criteria and other measures (WOCM1), and Cache Slough restoration (HRCM4) to reduce potential conflicts between ecosystem and water supply goals, and better optimize ecological benefits.

2. Better information on the survival and growth of covered species and predators using the Yolo Bypass, Cache Slough and Sacramento River (above, within, and below the section where new diversions are proposed) is needed to establish baseline conditions against which covered species benefits resulting from implementing the conservation measures can be determined and documented.

3. Potential benefits to San Joaquin River fish are limited by San Joaquin River flows and source water quality. The potential benefits of proposed BDCP measures, including reduced south Delta pumping and habitat restoration for San Joaquin River fishes, is minimal without concurrently addressing other limiting factors.

4. Tidal restoration measures could be more clearly defined, to clarify the desired future conditions, including the intent to provide tidal marsh and tidally influenced open water habitats with hydrodynamic and water quality characteristics suitable to native fishes and not suitable for extensive growth of *Egeria densa* and with conditions that promote desirable secondary production and its availability to target covered fish species within and beyond the restoration areas. Unpublished research data (Wilcox, pers. comm.) on the ecological characteristics and fish use in the Cache Slough/Liberty Island area suggest it could serve as a model for future tidal restoration.

5. The potential benefits of habitat restoration measures (tidal reintroduction and floodplain restoration) are highly dependent on location, scale, landscape setting, and design that considers site specific characteristics (e.g., elevations, tidal exchange, substrate, sediment supply, turbidity, quality and frequency of available habitat, geomorphology, wind-wave regime, and connectivity to adjacent aquatic and upland environments).

6. The uncertainties surrounding benefits of tidal restoration for habitat and productivity can be reduced primarily through two main strategies: (1) implementation of large-scale pilot projects designed to address these questions and with associated science-based monitoring, and (2) collection of further data from existing restorations to maximize their "lessons learned" value for subsequent project designs.

7. Other stressor measures should be refined and strategically paired with habitat restoration and conveyance conservation measures to enhance benefits for covered species; some also have value as stand-alone measures.

5.2 Specific Observations and Recommendations

Results from the DRERIP evaluations point to complex ecological trade-offs between implementation of multiple conservation measures, particularly measures that influence hydrodynamic conditions in the Delta such as modifying the Fremont Weir, operating new diversions in the north Delta, reintroducing tidal flows to large areas, and reducing pumping in the south Delta. There are likely opportunities to optimize benefits and manage risks for covered species better through more refined modeling analyses and a closer examination of the interrelationships between measures.

The following sections describe specific observations regarding trade-offs, synergies between various draft conservation measures, and recommendations regarding potential adjustments to the draft conservation measures. It should be noted that the DRERIP evaluations were defined by dual conveyance Scenarios 1 and 2, which assumed 2-10% greater export levels over the Reference Scenario (D1641 with existing infrastructure). Neither the Synthesis Team nor the evaluation team were tasked with considering lowered export levels to improve biological outcomes; no such Conservation Measure was provided for evaluation.

Floodplain Inundation Benefits and Predation Losses - Results of the DRERIP evaluations indicate that increased flooding of the Yolo bypass would enhance conditions for splittail and salmon. However, operation of a New North Delta Diversion could have negative population level effects on splittail and salmon due to increased predation (see WOCM1, Outcome N2). Predation losses could off-set the positive benefits of increased Yolo inundation. This may be particularly true in dry years when both the predation effects associated with the new diversion could be higher (as all salmon must pass the new diversion point) and the Yolo Bypass may not be available, or may not flood for a sufficient duration to allow adequate splittail spawning or salmon access to off-set predation losses. Under certain flow conditions, Particle Tracking Model(PTM) results indicate that fewer particles (i.e., representing salmon smolts) exit the Delta.

High uncertainty about salmon survival necessitates better hydrodynamic modeling capabilities (with salmon models of the diversion structures and important junctions). DSM2 modeling to date of reintroducing large tidal flows into the Yolo/Cache Slough area shows a big impact on phase shift, tidal range, net flow, and flow magnitudes of tides which in turn affect conditions at the North Delta Diversions and thus operating scenarios for Fremont Weir. These changes will affect residence times, salmon migration, availability of streambank habitat, and predation losses in the Sacramento River and its distributaries, particularly Georgiana, Steamboat and Sutter sloughs.

Recommendations:

1. Institute pre-implementation acoustic studies to establish baseline survival data and growth for covered species and predators using the Yolo Bypass, Cache Slough, and Sacramento

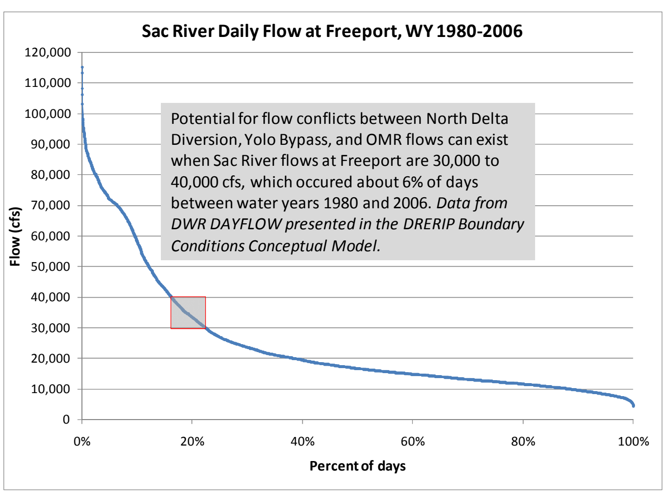
River. Use the Delta Passage Model as a working hypothesis to look at how fish respond to various dual conveyance and habitat restoration scenarios.

- Couple with CALSIM to develop relationships for baseline alternative.
- Review CWT/acoustic study design from past study to inform study design for evaluating alternative combinations of conservation measures. Past study designs are not sufficient to develop a necessary pre-project baseline for BDCP.
- Test sensitive model outputs with refined study design to field validate survival estimates.
- Consider similar studies for San Joaquin River and Cosumnes/Mokelumne.
- Develop explicit Hood Bypass survival data.

2. Develop modeling capability to assess salmon survival, using a diversity of potential diversion designs as necessary with:
   - 3D hydrodynamic model in the diversion reach, including fish behavior;
   - 2D hydrodynamic model at the tributaries influenced by the diversion;
   - Field validations;
   - Comparisons of with and without diversions, and with and without diversion structures;
   - Fish screen effectiveness (i.e., what happens if a screen does not meet its expected efficiencies).

3. Conduct more sophisticated 2D modeling in order to better understand the potential implications of changing hydrodynamics, on factors such as tidal phase, tidal amplitude, net tidal flow, and tidal flow magnitudes, under different scenarios of flooded island inundation on covered species (including the influence of Cache Slough restoration on hydrodynamics in Steamboat and Sutter sloughs). DSM2 was not designed to do this type of modeling.

Yolo Bypass Inundation, Hood bypass criteria, and South Delta Entrainment -Modeling results indicate that when flows at Freeport are between 30,000 to 40,000 cfs (see figure below) there is a potential conflict between inundating Yolo Bypass and Hood bypass flow and OMR flow. This potential conflict was not evaluated by either the DRERIP Water Operations subteam or the DRERIP Floodplains subteam.



Recommendations:

4. Conduct sensitivity analyses using finer scale modeling tools (e.g., daily time step modeling) and refined operational criteria to examine the effects different combinations of Hood bypass flow, Yolo inundation, and south Delta export pumping on OMR flows, residence time, and the fate of SJR waters. Scenarios should include examining the potential benefits of higher Hood bypass flows, as well as modified Yolo inundation regimes (including modified timing and inflow volumes).

5. Better optimize potential ecological benefits of WOCM1 and 2 through modified Hood bypass flow criteria and more refined Yolo Bypass operations (see recommendation below) to reduce negative OMR flows and associated entrainment, particularly for periods when Sacramento River flows are between 30k and 40k cfs. Consider incorporating OMR flow criteria as an explicit element of WOCM1.

6. Develop more specific operational criteria for Yolo inundation based on daily time-step modeling to optimize potential benefits. Take advantage of additional information being developed by DWR (e.g., improved bathymetry data) and utilize BDCP hydrologic modeling of Yolo Bypass to estimate increased production of adult splittail in the Yolo bypass and weigh that against increased predation in dry years.

7. Consider more naturalistic floodplain pulse flows into the Yolo Bypass that could involve an early pulse to achieve inundation and more fish onto the floodplain, followed by occasional inputs of smaller volumes of water to retain depths, and subsequent higher volume pulse flows that would move fish and material downstream. The CM presents the Yolo Bypass more as a higher-flow side channel to the Sacramento River than a pulse-flow floodplain system.

8. Consider flooding the Yolo Bypass only when sufficient flows exist to support a sustained level of inundation (i.e., avoid risk of stranding from attraction flows that cannot be followed by sufficient inundation flows).

<u>North Delta Diversions and South Delta Water Quality</u> - Changes in Delta hydrodynamics resulting from operational modifications (new diversions in the north Delta coupled with modified diversions in the south Delta), particularly in the summer and potentially in combination with proposed south Delta restoration measures, are expected to result in increased South Delta residence times, which, when combined with the influence of greater levels of nitrate- and phytoplankton-rich San Joaquin River water in the south and central Delta, could exacerbate the frequency and severity of low dissolved oxygen conditions. Reduced estuary flows and turbidity combined with the existing high nutrient levels, warming temperatures, greater relative contributions from the San Joaquin River, and constricted tidal flows could produce many "classic" eutrophication symptoms in the Delta. Reduced exports in the south Delta could also result in increased concentrations of Selenium (Se) and other chemical stressors in the Delta.

Recommendations:

9. Develop a comprehensive water quality – biological response modeling capability to inform decisions about flow needs given particular water temperature and nutrient load scenarios. Modeling should include examining nutrient uptake potential for marsh and floodplain vegetation which could increase bioavailability or provide alternate exposure pathways affecting different receptors.

10. Consider in-Delta and upstream source control measures to reduce nutrient and contaminant loading, including the effects of ongoing efforts to reduce Se loading into the San Joaquin River.

11. Refine and articulate Other Stressor conservation measures to target specific issues in the southern and central Delta, so they are coupled strategically with proposed habitat restoration measures. .

Limitations for San Joaquin River Fishes - Results of the DRERIP evaluations indicate that the benefits of reduced south Delta pumping and floodplains habitat restoration along the San Joaquin River (SJR) and in the south Delta are limited by SJR flows through the Delta (i.e., not just inflow but through-flow as well), source water quality, and limited tidal exchange capacity of existing waterways, particularly for San Joaquin fishes. Under current operations, little San Joaquin River water makes it to Chipps Island when juvenile salmon and steelhead are out-migrating, except under rare flood flow conditions. Proposed BDCP conservation measures do not appear to improve these conditions measurably.

12. Run fingerprinting analyses for San Joaquin River water without south Delta exports to determine if conditions for out-migrating juvenile San Joaquin River fishes could be improved by getting more San Joaquin water into the west Delta.

13. Consider the use of a Vernalis to south Delta export ratio as an additional operational criterion.

Adjustments to San Joaquin River Floodplain Restoration, Levee Setbacks, and Channel Margin Habitat Measures - Similar to the limitations for San Joaquin River fishes noted above, the benefits of floodplain restoration measures in the south Delta are limited by San Joaquin River flows and the expected low frequency of inundation. The DRERIP evaluations were based on simplified assumptions regarding levee setbacks (i.e., 500 feet on each side of the river). More specific designs that work with the existing flow regime and seek to incorporate important site specific features such as backwater areas, more habitat diversity, greater channel migration capacity, and more overbank flooding could increase the potential benefits of these measures. The current configuration of largely rip-raped, trapezoidal channels in the Delta provides little habitat for covered species and contributes to a high degree of predation.

Recommendations:

14. Evaluate the likely outcomes of San Joaquin River Floodplain Restoration, Levee Setbacks, and Channel Margin Habitat measures under several scenarios of future increased SJR flows to identify the benefits such restoration could provide if flows were increased under other authorities.

15. Where there are currently narrow corridors, consider levee setbacks for wider floodplain with natural meanders, backwaters, and channel margin habitat.

16. Revise the existing BDCP definition of channel margin habitat (see evaluation worksheets for HRCM 12 and13).

17. Integrate ecological design into future flood control projects. Incorporate modified channel geometry to provide habitat for splittail and other covered species, including allowing for channels to meander providing more microhabitats with emergent vegetation, woody debris, and more structural heterogeneity.

Yolo Bypass Inundation and Cache Slough Productivity

The potential benefits of coupled Yolo Bypass improvements and tidal restoration in Cache Slough, especially desired productivity benefits, are influenced greatly by flows (inputs) and urban and agricultural diversions (losses), or the net flows. First and foremost, relocation of the major diversions (North Bay Aqueduct and the major agricultural intakes) is essential to realize many of these benefits and in particular to allow the advective transport capacity of Yolo Bypass outflows to increase transport and mixing. Second, there is potential to improve the hydrologic connectivity of the southern end of the Yolo Bypass and the Cache Slough area in a manner that takes better advantage of the base flows from Putah and Cache creeks, reported to be on the order of 100-200 cfs, in providing contributions to advective transport. The magnitude of these contributions to advective transport has not been evaluated quantitatively. Through physical modifications at the southern end of the bypass it may be possible to enhance the benefits of increased seasonal flooding of the Yolo Bypass. These adaptations to the conservation measure should be articulated as part of a possible adaptive management program including Cache Slough.

Recommendations:

18. Develop plans for relocating the major water supply intakes away from the Cache Slough area.

19. Identify and articulate specific physical landscape modifications (focused on tributaries at the bottom end of the Yolo Bypass and Cache Slough restoration) to improve distribution of Yolo Bypass base outflow into the Cache Slough area to enhance the movement of insects and zooplankton to the northwest Delta. Descriptions regarding the type, location, and nature of the modifications should be developed based on more specific operational criteria and analysis for Yolo Bypass flooding (see Recommendation #6 above).

Tidal Reintroductions and Restoration Design

While restoration of tidal marsh and open water habitat in the Cache Slough and Suisun Marsh areas are expected to benefit covered species, particularly delta smelt, there is uncertainty and disagreement on the potential population level effects of the proposed measures for rearing juvenile salmonids. Unpublished data (Wilcox, pers. comm.) regarding salmon use of the Cache Slough/Liberty Island area are available, but need to be compiled and summarized.

The value of tidal reintroductions for covered fish species will be strongly influenced by location, landscape setting, and site specific design considerations such as elevation, tidal exchange, substrate, sediment supply, turbidity, geomorphology, wind-wave regime, and connectivity to aquatic and upland environments. Careful siting and design can influence the likelihood of species benefits as well as the potential adverse effects of non-native invasives such as *Egeria* and associated predation risk.

The relationships between geomorphic elements of a tidal reintroduction (vegetated tidal marsh, channels, and open water), tidal flow regimes and connectivity to pelagic environments, and the potential for adverse effects from invasive species establishment affect the benefits that may be achieved for covered fish species. Key uncertainties include relative benefits of vegetated tidal marsh vs. open water (and thus how to address subsided properties), importance of productivity contributions from vegetated tidal marsh directly or indirectly to covered species, conditions that promote vs. discourage *Egeria* establishment (see page 25), extent to which invasive clams may divert considerable quantities of new primary production, magnitude of suitable productivity (zooplankton and insects) exported from restoration areas, and density of channels in Delta historical tidal marshes and ability of natural processes to establish channels in restored marshes.

Recommendations:

20. Compile, analyze, and summarize existing fish utilization data from existing restored and reference sites in the Delta and Suisun Marsh to identify “lessons learned” applicable to proposed restorations.

21. Proceed with large scale tidal reintroduction in Cache Slough, Suisun Marsh and Dutch Slough based on existing information and maximize adaptive management in the design and monitoring in recognition that proto-habitat types and additional research are both needed to address uncertainties and make future decisions.

22. Describe baseline survival and growth of salmon runs so that post-restoration monitoring and analysis can demonstrate to what extent tidal marsh contributes to salmonid survival.

23. Develop a focused suite of restoration design principles for the Delta and Suisun, building on existing work where available, that reflects the variability in landscape context, unique setting of each restoration site, and lessons learned from successful and unsuccessful projects. These principles should not be overly prescriptive nor contain any single “template” so as to avoid over-engineering or over-simplification. They should also direct incorporation of adaptive management design features to address the uncertainties identified here to the extent possible at each site. Principles should specifically address approaches for areas below the elevation of potential colonization by emergent vegetation: e.g. whether to incorporate as open water, grading/sculpting, reverse subsidence by planting before tidal reintroduction, or retain as leveed.

24. Pursue tidal restoration of small parcels in the West Delta ROA only if they are expected to result in net benefits for covered species. Focus on aggregation of smaller parcels so as to create larger, contiguous restoration areas wherever possible.

Egeria Control - *Egeria* changes habitat toward conditions more suitable for largemouth bass and other centrarchids fishes than for native fishes and increases predation success on covered fish species. However, the presence of some Egeria may not eliminate covered fish species benefits, as evidenced at Sherman Lake which has extensive *Egeria* within small tidal channel networks, but does not extend into Delta smelt's pelagic habitat in the open-water like it does in Franks Tract. There are three categories of *Egeria* control methods each with varying efficacy and undesirable consequences:

1) Through various design considerations including tidal flushing, wind fetch and turbidity, competitive exclusion via establishment of other vegetation such as tules in the area of tidal reintroduction. Promoting higher energy open water should reduce *Egeria* but also limits tidal marsh formation.
2) Mechanical removal after establishment. Has practicality limitations given *Egeria*'s ability to reestablish quickly and to reestablish from cut pieces.
3) Chemical treatment after establishment. Though has had reasonable effectiveness where used (e.g., Frank's Tract, Big Break), the chemicals used pose direct and indirect risks to covered species that limit desirability.

Recommendations:

25. Explicitly design tidal, floodplain, and channel margin restoration measures to control the establishment of *Egeria* and to reduce predator success. Existing areas in the Delta should be used as models both successful and unsuccessful: Liberty Island, Little Holland Tract, Frank's Tract, Mildred Island, Big Break, Sherman Lake, and Donlon Island.

26. Focus post-establishment *Egeria* control measures on locations and habitats that are known to be, or could become important for covered fish and where physical design approaches are insufficient.

27. Prioritize tidal reintroduction locations where control through design has the best chances for success.

Managing MeHg Release from Restored Tidal Areas and Floodplains - DRERIP evaluations indicate that there is a potential for Mercury methylation in high marsh and floodplain areas due to ongoing input of mercury and patterns of wetting and drying. While not a direct threat to covered fish species, elevated mercury levels in fish could adversely affect wildlife that prey on fish, as well as humans that harvest them.

28. Monitor MeHg concentrations in water, fish and wildlife as more seasonal wetlands are created in the Yolo Bypass and elsewhere and the hydrology of the Delta is changed with construction of a dual conveyance system

29. Conduct species-specific studies on sub-lethal population-level effects (e.g. feeding efficiency, growth, or spawning success) of MeHg in birds and wildlife species.

30. Develop a numerical MeHg transport and fate model, with a food web component, that combines source information, water transport and residence times, photodemethylation and particle settling to predict methyl mercury concentrations in water, sediment, and biota at various locations in the Delta under different hydrologic conditions.

31. Establish better estimates of the number of people at risk for MeHg toxicity due to hunting and recreational or subsistence fishing to refine or expand fish and wildlife consumption advisories and develop educational strategies for teaching the affected public how to reduce the risk.

32. Focus efforts on controlling ongoing mercury loading into the Delta and Suisun Marsh so as to reduce mercury supply over the long term available for methylation. Plan tidal and floodplain inundations to minimize frequent wetting and drying of areas containing mercury.

Appendix A:
DRERIP Scientific Evaluation Process Instructions

Appendix A
DRERIP Scientific Evaluation Process Instructions

The following instructions were developed for the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP). For the purpose of evaluating draft Bay Delta Conservation Plan (BDCP) conservation measures, evaluation teams were asked to stop after Step 9. Overall worth and risk scores were not developed, and the DRERIP Decision Tree was not applied.

Step 1: Is the action written in such a way that it can be evaluated?

The action should be clearly written and contain basic components (action, approach, and outcome) as outlined in the Guidelines for Writing and Parsing Actions (*7/16/07*). An action can include multiple outcomes, but should list only one approach.

Step 2: Is the cause and effect relationship between the action, approach, and outcome supported by the conceptual models, or other source material?

Review General Outcomes table to identify conceptual models that include the general type of outcome identified in the action. Use these models and any other relevant source materials to assess if the relationship inferred by the action has been documented. If it is determined that the cause and effect relationship is not supported, document why and provide suggestions for how the actions might be re-cast to better achieve the desired outcome based on information in the conceptual models and other available scientific information. These suggestions can be used by action developers to improve the action for the next round of screening.

Step 3: Identify Scale of Action

Identify the scale of the Action 'scope' based on the following criteria. The purpose of establishing Action scale is to assist with determining the magnitude of effect on the ecosystem. Large, medium and small should be considered relative to the Delta and the temporal dynamics of processes being manipulated.

Large: Broad spatial extent, significant duration and/or frequency, and/or major reversal compared to existing conditions. Landscape scale.

Medium: Moderate spatial extent, moderate duration and/or frequency, and/or moderate change compared to existing conditions. Regional scale.

Small: Small acreage, short duration or only occasionally, and/or small change compared to existing conditions. Local scale.

Step 4: Describe Relation to Existing Conditions

Review the Boundary Conditions paper to assess whether or not the action has the potential to change system dynamics (either within the Delta or as inputs to the Delta) beyond the existing range conditions (i.e. change in inflows to the Delta, modified hydrodynamic conditions, or salinity regimes) such that the current understanding of how the system works may no longer hold? Consider how the changes may affect the ability to evaluate the action using existing models and information.

Step 5: Identify Positive and Negative Outcome(s) to be Evaluated

Using the standardized lists of outcomes and stressors from the Outcomes Table, identify as many positive and negative outcomes as possible (including the intended outcome). Outcomes should not be evaluated at this step, just simply listed. Outcomes not captured in models but identified based on other available information should be included, with notes describing the information used to identify the outcomes.

Identify positive and negative outcomes focusing only on covered species, but ensuring that all covered species anticipated to be affected are addressed, i.e., if the action is intended to benefit salmon, still look at effects on smelt.

Step 6: Score Magnitude and Certainty of Potential Positive Ecological Outcome(s)

Using the conceptual models and other relevant source materials, identify and score the expected magnitude and certainty of the identified positive ecological outcomes. Record the magnitude and certainty for each positive outcome. ***Use one table per positive outcome.*** Add additional tables as needed to reflect additional outcomes.

Step 7: Score Magnitude and Certainty of Potential Negative Ecological Outcome(s)

Using the conceptual models and other relevant source materials identify and score the expected magnitude and certainty of each negative ecological outcome. Record the magnitude and certainty in the tables below. ***Use one table per outcome***. Add additional tables as needed to reflect additional outcomes.

Step 8: Identify any Important Gaps in Information and/or Understanding

Using the levels of understanding described in the conceptual models, and/or other additional information sources used, identify important data or research needs, that could enhance future evaluation of this or similar actions.

Step 9: Assess Reversibility and Opportunity for Learning

Assess reversibility and opportunity to learn using the criteria below.

Reversibility

Yes/Easy Outcome could likely be reversed as, or more quickly and cheaply than implementing the action.

No/Hard Reversing outcomes would require more time or more money than implementing the action; outcomes may not be completely reversible.

Opportunity for Learning

High Expect to advance our understanding of critical uncertainties as identified in Conceptual Models in a quantifiable manner

Low Impractical or excessive time or resources likely required to achieve such understanding.

Definitions and Scoring Criteria

The following definitions and criteria are provided to aid the Scientific Evaluation process. Some of the definitions pertain to terms used in the conceptual models, such as understanding and predictability. Other definitions relate directly to completion of the Scientific Evaluation worksheet.

Scientific Evaluation Terms

The terms ***scale, magnitude, and certainty*** are Scientific Evaluation terms used to characterize the cumulate "path" or "chain" found between a Restoration Action being evaluated and each Outcome being considered within Scientific Evaluation. Such a path or chain is not the same as the linkages in the conceptual models that describe the cause-effect relationships between a single driver and a single outcome (see conceptual model terms below).

The terms ***reversibility, and opportunity for learning*** are Scientific Evaluation terms designed to aid in making decisions regarding implementation of proposed actions.

Scale - Scale addresses temporal and spatial considerations, quantity and/or degree of change contained within the Action.

Magnitude – Magnitude assesses the size or level of the outcome, either positive or negative, in terms of population or habitat effects on a given species. Magnitude is not the same as the scale of the action, however, higher magnitude scores require consideration of scale.

Certainty - Certainty describes the likelihood that a given Restoration Action will achieve a certain Outcome. Certainty considers both the predictability and understanding of linkages in the DLO pathway from the action to the outcome. Generally, high importance-low predictability linkages drive the scoring; it is important to ensure that certainty is not unduly weighted by a comparatively low-importance, albeit low-predictability linkage.

Reversibility - The ease and predictability with which the outcome(s) of a Restoration Action or a group of Restoration Actions can be undone and/or reversed. For example, if the Action changes the ecosystem structure, can the original form be re-established? Have such outcomes been un-done in the past? A change to a flow regime is relatively easy to reverse; successful introduction of a new species is relatively difficult to reverse.

Opportunity for learning - Opportunity for learning is the likelihood that a Restoration Action or a group of Restoration Actions will increase the level of understanding with regard to the species, process, condition, region or system that is in question or of concern, assuming that appropriate monitoring and evaluation is conducted.

Conceptual Model Terms

The terms ***importance, predictability, and understanding*** are used in the conceptual models to characterize individual linkages (depicted as arrows in the models) between a driver and an outcome. The terms pertain to specific processes or mechanisms within a given model (e.g. how important is the supply of organic matter to mercury methylation?). The graphical forms of the conceptual models apply line color, thickness, and style to represent these three terms.

> ***Importance*** - The degree to which a linkage controls the outcome *relative to* other drivers and linkages affecting that same outcome. Models are designed to encompass all identifiable drivers, linkages and outcomes but this concept recognizes that some are more important than others in determining how the system works. If a driver is potentially more important under particular environmental conditions, the graphic should display the maximum level of importance of this driver with the narrative describing the range of spatial and temporal conditions associated with this driver.
>
> ***Predictability*** - The degree to which the performance or the nature of the outcome can be predicted from the driver. Predictability seeks to capture the variability in the driver-outcome relationship. Predictability can encompass temporal or spatial variability in conditions of a driver (e.g., suspended sediment concentration or grain size), variability in the processes that link the driver to the outcome (e.g., sediment deposition or erosion rate as influenced by flow velocity), or our level of understanding about the cause-effect relationship (e.g., magnitude of sediment accretion inside vs. outside beds of submerged aquatic vegetation). Any of these forms of variability can lead to difficulty in predicting change in an outcome based on changes in a driver.
>
> ***Understanding* –** A description of the known, established, and/or generally agreed upon scientific understanding of the cause-effect relationship between a single driver and a single outcome. Understanding may be limited due to lack of knowledge and information or due to disagreements in the interpretation of existing data and information; or because the basis for assessing the understanding of a linkage or outcome is based on studies done elsewhere and/or on different organisms, or conflicting results have been reported. Understanding should reflect the degree to which the model that is used to represent the system does, in fact, represent the system.

Scientific Evaluation Scoring Criteria

The following tables should be used to inform ***magnitude and certainty*** scores for Scientific Evaluation. These entail looking holistically at the cumulative value (positive or negative) of an action.

Table 1 - Criteria for Scoring Magnitude of Ecological Outcomes (positive or negative)

4 - High: expected sustained major population level effect, e.g., the outcome addresses a key limiting factor, or contributes substantially to a species population's natural productivity, abundance, spatial distribution and/or diversity (both genetic and life history diversity) or has a landscape scale habitat effect, including habitat quality, spatial configuration and/or dynamics. Requires a large-scale Action.
3 - Medium: expected sustained minor population effect or effect on large area (regional) or multiple patches of habitat. Requires at least a medium-scale Action.
2 - Low: expected sustained effect limited to small fraction of population, addresses productivity and diversity in a minor way, or limited spatial (local) or temporal habitat effects.
1 - Minimal: Conceptual model indicates little effect.

Table 2 - Criteria for Scoring Certainty of Ecological Outcomes (positive or negative)

4 - High: Understanding is high (based on peer-reviewed studies from within system and scientific reasoning supported by most experts within system) and nature of outcome is largely unconstrained by variability (i.e., predictable) in ecosystem dynamics, other external factors, or is expected to confer benefits under conditions or times when model indicates greatest importance.
3 - Medium: Understanding is high but nature of outcome is dependent on other highly variable ecosystem processes or uncertain external factors or understanding is medium (based on peer-reviewed studies from outside the system and corroborated by non peer-reviewed studies within the system) and nature of outcome is largely unconstrained by variability in ecosystem dynamics or other external factors
2 - Low: Understanding is medium and nature of outcome is greatly dependent on highly variable ecosystem processes or other external factors or understanding is low (based on non peer-reviewed research within system or elsewhere) and nature of outcome is largely unconstrained by variability in ecosystem dynamics or other external factors
1 - Minimual: Understanding is lacking (scientific basis unknown or not widely accepted), or understanding is low and nature of outcome is greatly dependent on highly variable ecosystem processes or other external factors

Appendix B:
List of Evaluation Team Members

Appendix B: List of Evaluation Team Members

Tidal Restoration Subteam

Name	Affiliation
Dave Harlow	SWC
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Floodplains and Riparian Habitat Subteam

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Appendix B: List of Evaluation Team Members

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Steven Detwiler	USFWS
John Burke	USBR
Tracy Hinojosa	DWR
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Appendix C:
Conservation Measures Evaluated

Tidal Restoration Conservation Measures

HRCM4: Yolo/Cache Slough Complex ROA Tidal Marsh & Shallow Subtidal Restoration - Restore between 5,000 and 11,000 acres to tidal action and vegetated tidal marsh and shallow sub tidal habitat in the Yolo Bypass/Cache Slough Complex ROA (in addition to Liberty Island and Little Holland Tract). *(Evaluate both 5,000 and 11,000 acres).*

HRCM5: Cosumnes/Mokelumne ROA Tidal Marsh & Shallow Subtidal Restoration
Restore 1,150 acres of vegetated tidal marsh and 300 acres of shallow subtidal habitat within the Cosumnes/Mokelumne ROA.

HRCM6: West Delta ROA Tidal Marsh & Shallow Subtidal Restoration
Restore 3,900 acres of vegetated tidal marsh and 900 acres of shallow subtidal habitat in the West Delta ROA.

HRCM7: South Delta ROA Tidal Marsh & Shallow Subtidal Restoration
Restore 3,650 acres of vegetated tidal marsh and 950 acres of shallow subtidal habitats on portions of Union, Upper Roberts, and Middle Roberts Islands in the South Delta ROA.

HRCM8: East Delta ROA Tidal Marsh & Shallow Subtidal Restoration
Restore 1,300 acres to tidal action and vegetated tidal marsh and 300 acres of shallow subtidal habitats on portions of Canal Tract, Terminus Tract, and Bract Tract in the East Delta ROA.

HRCM9: Suisun Marsh ROA Tidal Marsh & Shallow Subtidal Restoration
Re-establish 9,000 acres of brackish intertidal marsh and shallow subtidal aquatic within the Suisun Marsh.

Floodplains and Riparian Habitat Restoration Measures

HRCM1: San Joaquin ROA Floodplain Restoration (upstream of Mossdale)
Restore floodplain habitat along 7 to 14 miles of the San Joaquin River from Vernalis to Mossdale.

HRCM2: San Joaquin ROA Floodplain Restoration (downstream of Mossdale)
Restore floodplain habitat along 6 to 12 miles of the San Joaquin River from Mossdale to French Camp Slough.

HRCM3: South Delta ROA Floodplain
Restore between 800 and 1,600 acres of floodplain habitat (including aquatic, intertidal marsh, floodplain and riparian features) along Old River at Fabian Tract. (Evaluate both 800 and 1,600 acres).

HRCM11: BDCP-Constructed Levees
Establish native riparian woody vegetation and emergent vegetation along a 5 mile segment of levee constructed along the Sacramento River in the West Delta (somewhere between Isleton and Ryde), and along a 5 mile segment of levee along Old River near Bacon Island.

HRCM12: Channel Margin Habitat in Sutter and Steamboat Sloughs
Enhance channel margin habitats along between 12 and 36 miles of Steamboat and Sutter Sloughs to improve habitat conditions for covered fish species. *(Evaluate both 12 and 36 miles of habitat enhancement).*

HRCM13: Channel Margin Habitat in the San Joaquin River ROA
Enhance channel margin habitats along between 14 and 28 miles of the San Joaquin River in the San Joaquin River ROA to improve habitat conditions for covered fish species.

HRCM14: Riparian/scrub Habitat Restoration as a Component of Other Restoration Actions –

Water Operation Conservation Measures

WOCM1: New North Delta Diversions with Hood Bypass Criteria and other Measures
Construct new diversion facilities in the North Delta along the Sacramento River between Walnut Grove and Freeport with a capacity to divert up to 15,000 cfs. The new diversions would be operated to divert large amounts of water during wet periods and less in dry periods. No diversion would be allowed unless flows downstream of the diversion points exceed minimum flow requirements known as the Hood Bypass Flow Criteria.

WOCM2: Modify And Reoperate The Yolo Bypass And Fremont Weir
Option #1 Period of Potential Operation: December 1-May 15
Desired Duration of Inundation: 45 days
Target Spill Discharge into Bypass: 4000 cfs
Predicted area of inundation: 22,982 acres
Predicted mean depth of inundated area: 2.2 feet
Predicted travel time: 6.5 days
Spill Frequency of Fremont Weir (assuming 4000 cfs and 45 day duration with a spill intermission of no more than 7 days): 48% of years (38 of 79), compared to 6% of years (5 out of 79) at existing weir height.

Option #2 Period of Potential Operation: January 1-April 15
Desired Duration of Inundation: 30 days
Target Spill Discharge into Bypass: 2000 cfs
Predicted area of inundation: 17,421 acres
Predicted mean depth of inundated area: 2.3 feet
Predicted travel time: 9.3 days

Spill Frequency of Fremont Weir (assuming 2000 cfs and 30 day duration with a spill intermission of no more than 7 days): 54% of years (43 of 79), compared to 6% of years (5 out of 79) at existing weir height.

WOCM3: Deep Water Ship Channel Bypass Floodplain
Create a new flood bypass that provides up to 3800 acres (at 3000 cfs) of inundated floodplain habitat adjacent to and east of the Sacramento Deep Water Ship Channel (DWSC) and that inundates in ~50% of years from December 1 to May 15 for 45 consecutive days with a spill intermission of no more than 7 days.

WOCM8: Interim Tidal Gates (2-Gates)
Construct and operate two tidal gates:

1. one installed in Old River on the eastern side of Bacon Island,
2. the second gate would be installed in Connection Slough on the western side of Bacon Island.

Water Quality and Invasives Other Stressor Measures

OSCM1: Reduction Of Ammonia Discharges
Implement advanced treatment processes at Sac Regional County Sanitation District (SRCSD) Wastewater Treatment Plant to reduce the concentrations and load of ammonia in effluent discharged into the Sacramento River to levels that do not directly or indirectly harm covered fish species.

OSCM2: Reduction Of The Load Of Endocrine Disrupting Compounds
Implement advanced treatment processes at wastewater treatment plants in the Delta to reduce the loads of endocrine disrupting compounds (EDCs) discharged into the Delta to levels that do not harm covered fish species.

OSCM3: Reduce The Load Of Methylmercury
Implement measures to reduce the load of methylmercury entering the Delta from upstream and in-Delta sources by 50 percent.

OSCM4: Reduce The Load Of Pesticides And Herbicides
Implement measures to reduce loads of pesticides and herbicides entering Delta waterways to levels that are not toxic to covered fish species.

OSCM5: Reduce The Loads Of Toxic Contaminants In Stormwater And Urban Runoff
Develop and implement stormwater management plans and additional measures to reduce loads of toxic contaminants in stormwater and urban runoff entering Delta waterways to levels below which they are toxic to covered fish species.

OSCM7: Improve Dissolved Oxygen Levels In The Stockton Deep Water Ship Channel

OSCM8: Improve Managed Seasonal Wetlands Discharge

OSCM 12: Reduce The Risk For Establishment Of Zebra Mussel And Quagga Mussel In Delta Waterways –

OSCM 13: Remove Non-Native Sav And Fav
Remove water hyacinth (*Eichornia crassipes*) and Brazilian waterweed (*Egeria densa*) from 1,000 water acres of ecologically important Delta waterways each year.

Harvest and Hatcheries Other Stressor Measures

OSCM 14: Increase Harvest Of Non-Native Predatory Fish
Modify sport fishing regulations to reduce the abundance, size, and, therefore, reproductive capacity of black bass (largemouth, smallmouth, and spotted bass) and striped bass in the Sacramento-San Joaquin Delta (the Delta).

OSCM16: Enhanced Delta Enforcement
Increase enforcement of existing fishing regulations to reduce illegal harvest of catchable covered salmonids and sturgeon in the Delta and tributary rivers, including summer holding habitat for spring-run and sturgeon.

OSCM17: Splittail Harvest Regulations
Modify fishing regulations to reduce the effects of harvest on Sacramento splittail.

OSCM19: Mark-Select Chinook Salmon Fishery
Mark all Central Valley Chinook salmon produced in hatcheries with a visible mark (e.g., adipose fin clip), and limit all commercial and recreational harvest of Chinook salmon to those with visible marks.

OSCM20: Artificial Propagation Of Smelt
Establish artificial propagation programs for delta smelt and longfin smelt.

OSCM21: Non-Project Diversions
Modify or eliminate non-project diversions in the Delta to reduce the entrainment of covered fish species.

Appendix D:
Summary of Evaluation Scores and Tables

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P6	All	Increased establishment of woody riparian vegetation to export LWD	2	3
P7a/b	Chinook salmon-San Joaquin	Increase establishment of woody riparian vegetation to provide shaded channel habitat	2	3
P8a	Delta smelt	Increased downstream turbidity improves habitat quality for delta smelt and longfin smelt	2	3-4
P5g	Delta smelt	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	2	3
P5a	Fall-run Chinook Salmon	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	2	3-4
P4a	Fall-run Chinook Salmon	Increase production of food for rearing Chinook salmon, steelhead, green/white sturgeon, splittail from inundation and riparian vegetation (local)	2	3-4
P3a	Fall-run Chinook Salmon	Create rearing habitat for Chinook salmon, green/white sturgeon, splittail and steelhead. Consider loss to entrainment.	2	3-4
P1a	Fall-run Chinook Salmon	Improve connectivity of seasonally inundated floodplain habitat for juvenile fish (Splittail, G/W sturgeon, Chinook salmon and steelhead)	2	3-4
P5e	Green Sturgeon	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	1	2
P4e	Green Sturgeon	Increase production of food for rearing Chinook salmon, steelhead, green/white sturgeon, splittail from inundation and riparian vegetation (local)	1	2
P3e	Green Sturgeon	Create rearing habitat for Chinook salmon, green/white sturgeon, splittail and steelhead. Consider loss to entrainment.	1	2
P1e	Green Sturgeon	Improve connectivity of seasonally inundated floodplain habitat for juvenile fish (Splittail, G/W sturgeon, Chinook salmon and steelhead)	1	2
P8b	Longfin smelt	Increased downstream turbidity improves habitat quality for delta smelt and longfin smelt	2	3
P5f	Longfin smelt	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	2	3

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes (contd.)				
P5c	Splittail	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	3	3-4
P4c	Splittail	Increase production of food for rearing Chinook salmon, steelhead, green/white sturgeon, splittail from inundation and riparian vegetation (local)	3	3-4
P3c	Splittail	Create rearing habitat for Chinook salmon, green/white sturgeon, splittail and steelhead. Consider loss to entrainment.	3	3-4
P2a	Splittail	Create additional splittail spawning habitat on floodplain	3	3-4
P1c	Splittail	Improve connectivity of seasonally inundated floodplain habitat for juvenile fish (Splittail, G/W sturgeon, Chinook salmon and steelhead)	3	3-4
P5b	Steelhead	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	2	2
P4b	Steelhead	Increase production of food for rearing Chinook salmon, steelhead, green/white sturgeon, splittail from inundation and riparian vegetation (local)	2	2
P3b	Steelhead	Create rearing habitat for Chinook salmon, green/white sturgeon, splittail and steelhead. Consider loss to entrainment.	2	2
P1b	Steelhead	Improve connectivity of seasonally inundated floodplain habitat for juvenile fish (Splittail, G/W sturgeon, Chinook salmon and steelhead)	2	2-3
P5d	White Sturgeon	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	1	1
P4d	White Sturgeon	Increase production of food for rearing Chinook salmon, steelhead, green/white sturgeon, splittail from inundation and riparian vegetation (local)	1	1
P3d	White Sturgeon	Create rearing habitat for Chinook salmon, green/white sturgeon, splittail and steelhead. Consider loss to entrainment.	1-2	1
P1d	White Sturgeon	Improve connectivity of seasonally inundated floodplain habitat for juvenile fish (Splittail, G/W sturgeon, Chinook salmon and steelhead)	1-2	1

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Negative Outcomes				
N6a	All	Increased exposure risk to contaminants (including Selinium) due to longer residence time in this area	2	3
N3a	All	Increased frequency and magnitude of low DO in SDWSC due to an increase in algae/POM and impact on Chinook salmon, steelhead, and green and white sturgeon passage.	1	4
N2a	All	Increased resuspension/mobilization and export of toxic compounds with impact on covered species (consider time course of effect)	1	2
N1a	All	Increased MeHg and impact on covered species (direct or indirect)	1	3
N5a	Chinook salmon	Increased habitat for non-native predators/competitors to native fishes (Chinook salmon, steelhead, green and white sturgeon, and splittail)	2	4
N4	Delta smelt & Longfin smelt	Decreased downstream turbidity decreases habitat quality for longfin smelt and delta smelt	1	4
N5c	Green & White Sturgeon	Increased habitat for non-native predators/competitors to native fishes (Chinook salmon, steelhead, green and white sturgeon, and splittail)	1	2
N5d	Splittail	Increased habitat for non-native predators/competitors to native fishes (Chinook salmon, steelhead, green and white sturgeon, and splittail)	2	4
N5b	Steelhead	Increased habitat for non-native predators/competitors to native fishes (Chinook salmon, steelhead, green and white sturgeon, and splittail)	2	4

Outcome Code	Covered Spp.	Description	Scenario 1 Magnitude	Scenario 1 Certainty
Positive Outcomes				
P7	All	Increased establishment of woody riparian vegetation to provide shaded channel habitat	3	2
P6	All	Increased establishment of woody riparian vegetation to export LWD	2	3
P8a	Delta smelt	Increased downstream turbidity to improve habitat quality for longfin smelt and delta smelt	2	3-4
P5g	Delta smelt	Increased availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for splittail, green and white sturgeon, Chinook salmon, steelhead (off site), longfin smelt, and delta smelt	2	3
P5a	Fall-run Chinook Salmon	Increased availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for splittail, green and white sturgeon, Chinook salmon, steelhead (off site), longfin smelt, and delta smelt	2	3-4
P4a	Fall-run Chinook Salmon	Increased production of food for rearing splittail, green and white sturgeon, Chinook salmon and steelhead from inundation and riparian vegetation (local)	2	3-4
P3a	Fall-run Chinook Salmon	Additional rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment)	2	3-4
P1a	Fall-run Chinook Salmon	Improved connectivity of seasonally inundated floodplain habitat for juvenile splittail, green and white sturgeon, Chinook salmon and steelhead	2	3-4
P5e	Green Sturgeon	Increased availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for splittail, green and white sturgeon, Chinook salmon, steelhead (off site), longfin smelt, and delta smelt	1	2
P4e	Green Sturgeon	Increased production of food for rearing splittail, green and white sturgeon, Chinook salmon and steelhead from inundation and riparian vegetation (local)	1	2
P3e	Green Sturgeon	Additional rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment)	1	2
P1e	Green Sturgeon	Improved connectivity of seasonally inundated floodplain habitat for juvenile splittail, green and white sturgeon, Chinook salmon and steelhead	1	2

Outcome Code	Covered Spp.	Description	Scenario 1 Magnitude	Scenario 1 Certainty
Positive Outcomes (contd.)				
P8b	Longfin smelt	Increased downstream turbidity to improve habitat quality for longfin smelt and delta smelt	2	3
P5f	Longfin smelt	Increased availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for splittail, green and white sturgeon, Chinook salmon, steelhead (off site), longfin smelt, and delta smelt	2	3
P5c	Splittail	Increased availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for splittail, green and white sturgeon, Chinook salmon, steelhead (off site), longfin smelt, and delta smelt	3	3-4
P4c	Splittail	Increased production of food for rearing splittail, green and white sturgeon, Chinook salmon and steelhead from inundation and riparian vegetation (local)	3	3-4
P3c	Splittail	Additional rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment)	3	3-4
P2	Splittail	Additional splittail spawning habitat on floodplain	3	3-4
P1c	Splittail	Improved connectivity of seasonally inundated floodplain habitat for juvenile splittail, green and white sturgeon, Chinook salmon and steelhead	3	3-4
P5b	Steelhead	Increased availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for splittail, green and white sturgeon, Chinook salmon, steelhead (off site), longfin smelt, and delta smelt	2	2
P4b	Steelhead	Increased production of food for rearing splittail, green and white sturgeon, Chinook salmon and steelhead from inundation and riparian vegetation (local)	2	2
P3b	Steelhead	Additional rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment)	2	2-3
P1b	Steelhead	Improved connectivity of seasonally inundated floodplain habitat for juvenile splittail, green and white sturgeon, Chinook salmon and steelhead	2	2

Outcome Code	Covered Spp.	Description	Scenario 1 Magnitude	Scenario 1 Certainty
Positive Outcomes (contd.)				
P5d	White Sturgeon	Increased availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for splittail, green and white sturgeon, Chinook salmon, steelhead (off site), longfin smelt, and delta smelt	1	1
P4d	White Sturgeon	Increased production of food for rearing splittail, green and white sturgeon, Chinook salmon and steelhead from inundation and riparian vegetation (local)	1	1
P3d	White Sturgeon	Additional rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment)	1-2	1
P1d	White Sturgeon	Improved connectivity of seasonally inundated floodplain habitat for juvenile splittail, green and white sturgeon, Chinook salmon and steelhead	1-2	1

Outcome Code	Covered Spp.	Description	Scenario 1 Magnitude	Scenario 1 Certainty
Negative Outcomes				
N6	All	Increased exposure risk to contaminants (including Selinium) due to longer residence time in this area	2	3
N2	All	Increased resuspension/mobilization and export of toxic compounds with impact on covered species (consider time course of effect)	1	2
N1	All	Increased MeHg and impact on covered species (direct or indirect)	1	3
N5a	Chinook salmon	Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail	2	4
N4	Delta smelt & Longfin smelt	Decreased downstream turbidity decreases habitat quality for longfin smelt and delta smelt	1	4
N5c	Green & White Sturgeon	Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail	1	2
N3	green and white sturgeon, Chinook salmon and steelhead	Increased frequency and magnitude of low DO in SDWSC due to an increase in algae/POM and impact on Chinook salmon, steelhead, and green and white sturgeon passage.	1	4
N5d	Splittail	Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail	2	4
N5b	Steelhead	Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail	2	4

			Scenario 1		Scenario 2	
Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
Positive Outcomes						
P7	All	Increase establishment of woody riparian vegetation to provide shaded channel habitat	2	3	2	3
P6	All	Increase establishment of woody riparian vegetation to export LWD	2	3	3	3
P8a	Delta smelt	Increased downstream turbidity improves habitat quality for delta smelt and longfin smelt	2	3-4		
P5g	Delta smelt	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	2	3		
P5a	Fall-run Chinook Salmon	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	2	3-4		
P4a	Fall-run Chinook Salmon	Increase production of food for rearing Chinook salmon, steelhead, green and white sturgeon, and splittail from inundation and riparian vegetation (local)	2	3-4		
P3a	Fall-run Chinook Salmon	Create rearing habitat for Chinook salmon, green and white sturgeon, splittail and steelhead (consider loss to entrainment)	2	3-4		
P1a	Fall-run Chinook Salmon	Improve connectivity of seasonally inundated floodplain habitat for juvenile fish (splittail, green and white sturgeon, Chinook salmon and steelhead).	2	3-4		

			Scenario 1		Scenario 2	
Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
Positive Outcomes (contd.)						
P5e	Green Sturgeon	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	1	2		
P4e	Green Sturgeon	Increase production of food for rearing Chinook salmon, steelhead, green and white sturgeon, and splittail from inundation and riparian vegetation (local)	1	2		
P3e	Green Sturgeon	Create rearing habitat for Chinook salmon, green and white sturgeon, splittail and steelhead (consider loss to entrainment)	1	2		
P1e	Green Sturgeon	Improve connectivity of seasonally inundated floodplain habitat for juvenile fish (splittail, green and white sturgeon, Chinook salmon and steelhead).	1	2		
P8b	Longfin smelt	Increased downstream turbidity improves habitat quality for delta smelt and longfin smelt	2	3		
P5f	Longfin smelt	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	2	3		
P5c	Splittail	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	3	3-4		
P4c	Splittail	Increase production of food for rearing Chinook salmon, steelhead, green and white sturgeon, and splittail from inundation and riparian vegetation (local)	3	3-4		
P3c	Splittail	Create rearing habitat for Chinook salmon, green and white sturgeon, splittail and steelhead (consider loss to entrainment)	3	3-4		
P2	Splittail	Create additional spawning habitat for splittail on floodplain	3	3-4		
P1c	Splittail	Improve connectivity of seasonally inundated floodplain habitat for juvenile fish (splittail, green and white sturgeon, Chinook salmon and steelhead).	3	3-4		

			Scenario 1		Scenario 2	
Outcome Code	**Covered Spp.**	**Description**	**Magnitude**	**Certainty**	**Magnitude**	**Certainty**
Positive Outcomes (contd.)						
P5b	Steelhead	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	2	2		
P4b	Steelhead	Increase production of food for rearing Chinook salmon, steelhead, green and white sturgeon, and splittail from inundation and riparian vegetation (local)	2	2		
P3b	Steelhead	Create rearing habitat for Chinook salmon, green and white sturgeon, splittail and steelhead (consider loss to entrainment)	2	2-3		
P1b	Steelhead	Improve connectivity of seasonally inundated floodplain habitat for juvenile fish (splittail, green and white sturgeon, Chinook salmon and steelhead).	2	2-3		
P5d	White Sturgeon	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	1	1		
P4d	White Sturgeon	Increase production of food for rearing Chinook salmon, steelhead, green and white sturgeon, and splittail from inundation and riparian vegetation (local)	1	1		
P3d	White Sturgeon	Create rearing habitat for Chinook salmon, green and white sturgeon, splittail and steelhead (consider loss to entrainment)	1-2	1		
P1d	White Sturgeon	Improve connectivity of seasonally inundated floodplain habitat for juvenile fish (splittail, green and white sturgeon, Chinook salmon and steelhead).	1-2	1		

			Scenario 1		Scenario 2	
Outcome Code	**Covered Spp.**	**Description**	**Magnitude**	**Certainty**	**Magnitude**	**Certainty**
		Negative Outcomes				
N5	All	Increased exposure risk to contaminants (inc. Se) due to longer residence time in this area	1	3		
N2a	All	Increased resuspension/mobilization and export of toxic compounds with impact on covered species (consider time course of effect)	1	4		
N1	All	Increased MeHg and impact on covered species (direct or indirect)	1	3		
N4a	Chinook salmon	Increased habitat for non-native predators/competitors to native fishes (Chinook salmon, steelhead, green and white sturgeon, and splittail)	2	4		
N3a	Delta smelt & Longfin smelt	Decreased downstream turbidity decreases habitat quality for delta smelt and longfin smelt	1	4		
N4c	Green & White Sturgeon	Increased habitat for non-native predators/competitors to native fishes (Chinook salmon, steelhead, green and white sturgeon, and splittail)	1	2		
N4d	Splittail	Increased habitat for non-native predators/competitors to native fishes (Chinook salmon, steelhead, green and white sturgeon, and splittail)	2	4		
N4b	Steelhead	Increased habitat for non-native predators/competitors to native fishes (Chinook salmon, steelhead, green and white sturgeon, and splittail)	2	4		

Scenario 1 Restore 800 acres of floodplain habitat (including aquatic, intertidal marsh, floodplain and riparian features) along Old River at Fabian Tract (see map).

Scenario 2 Restore 1600 acres of floodplain habitat (including aquatic, intertidal marsh, floodplain and riparian features) along Old River at Fabian Tract (see map).

Outcome Code	Covered Spp.	Description	Viewpoint 1 Magnitude	Viewpoint 1 Certainty	Viewpoint 2 Magnitude	Viewpoint 2 Certainty
Positive Outcomes						
P3	All	Food resources produced on the restored marsh will be exported and contribute to foood availability downstream of Rio Vista	1-2	1		
P4b	chinook salmon	Provide local cool water refugia for delta smelt and rearing salmonids	2	1		
P4a	delta smelt	Provide local cool water refugia for delta smelt and rearing salmonids	2	1		
P1a	delta smelt	Increase rearing habitat and local food production	3	2		
P1c3	Fall-run Chinook salmon, Sac.	Increase rearing habitat and local food production	3-4	3	1-2	1
P2	Green & White Sturgeon	Increase food production for local consumption by green and white sturgeon (added by evaluation team).	2	1		
P1c4	Late Fall-run Chinook Salmon, Sac.	Increase rearing habitat and local food production	1	1		
P1b	Longfin smelt	Increase rearing habitat and local food production	1	2		
P1d	splittail	Increase rearing habitat and local food production	3	2		
P1c2	Spring-run Chinook Salmon	Increase rearing habitat and local food production	2	2		
P1c5	steelhead	Increase rearing habitat and local food production	1	1		
P1c1	Winter-run Chinook Salmon	Increase rearing habitat and local food production	2	1		

Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
Negative Outcomes						
N3a	All	Contaminate Resuspension Hg	1	2		
N2b1	All	Local toxicity from residual pesticides and herbicides: e.g. pyrethroids:	1-2	1		
N2a1	All	Potential for mercury methylation and local bioaccumulation	1	2		
N1d	All	Establishment of Inland silversides that will prey or compete or alter habitat conditions for covered fish.	2	2		
N1c	All	Establishment of centrarchids that will prey or compete or alter habitat conditions for covered fish.	3	2		
N1b	All	Establishment of undesirable clams species that will compete with or alter habitat conditions for covered fish.	1	2		
N1a	All	Establishment of undesirable SAV will alter habitat conditions for covered fish.	3	2		
N4a	delta smelt	Increased velocities in larger channels could scour spawning habitat for Delta smelt and/or habitat for other covered species.	4	1		
N2a3	Human health	Potential for mercury methylation and local bioaccumulation	2	3		
N4b	Longfin smelt	Increased velocities in larger channels could scour spawning habitat for Delta smelt and/or habitat for other covered species.	2-3	1		
N2b2	Wildlife	Local toxicity from residual pesticides and herbicides: e.g. pyrethroids:	1-2	1		
N2a2	Wildlife	Potential for mercury methylation and local bioaccumulation	2	2-3		

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			Viewpoint 1		Viewpoint 2	
Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
		Positive Outcomes				
P2a	All	INCREASE THE AVAILABILITY AND PRODUCTION OF FOOD IN THE EAST AND CENTRAL DELTA BY EXPORTING ORGANIC MATERIAL FROM THE MARSH PLAIN AND PHYTOPLANKTON, ZOOPLANKTON, AND OTHER ORGANISMS PRODUCED IN INTERTIDAL CHANNELS INTO THE DELTA.	3-4	3	1-2	1
P3b	Chinook Salmon	LOCALLY PROVIDE AREAS OF COOL WATER REFUGIA (FEB-JUN) FOR DELTA SMELT AND SALMON.	2	1		
P3a	Delta smelt	LOCALLY PROVIDE AREAS OF COOL WATER REFUGIA (FEB-JUN) FOR DELTA SMELT AND SALMON.	2	1		
P1a	Delta smelt	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	1	1		
P1c	Fall-run Chinook salmon	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	1	2		
P1d	Splittail	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	3	3		
P1b	steelhead	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	1	2		

Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
Negative Outcomes						
N4a	All	Resuspension and export of mercury and methylmercury to downstream areas	1	2		
N3b	All	Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids	1-2	1		
N3b	All	Contaminate Resuspension - Residual pesticides and herbicides	1	1		
N3a	All	Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids	1-2	1		
N2a	All	POTENTIAL FOR MERCURY METHYLATION AND LOCAL BIOACCUMULATION TO AFFECT WILDLIFE: N2-A - TARGET SPECIES, N2-B, NON-TARGET WILDLIFE SPECIES, N2-C, HUMAN HEALTH.	1	2		
N1b	All	Establishment of undesirable species (such as Centrachids) that will prey or compete or alter habitat conditions for covered fish.	4	2		
N1a	All	Establishment of undesirable species (such as egeria,) that will prey or compete or alter habitat conditions for covered fish.	3	2		
N1c	All	Establishment of undesirable species (such as Corbicula) that will prey or compete or alter habitat conditions for covered fish.	1	2		
N1d	Delta smelt	Establishment of undesirable species (such as Inland Silversides) that will prey or compete or alter habitat conditions for covered fish.	2	2		
N2c	Human health	POTENTIAL FOR MERCURY METHYLATION AND LOCAL BIOACCUMULATION TO AFFECT WILDLIFE: N2-A - TARGET SPECIES, N2-B, NON-TARGET WILDLIFE SPECIES, N2-C, HUMAN HEALTH.	2	3		
N2b	Wildlife	Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A - Target species, N2-B, Non-target wildlife species, N2-C, Human health.	3	2-3		

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			Viewpoint 1		Viewpoint 2	
Outcome Code	**Covered Spp.**	**Description**	**Magnitude**	**Certainty**	**Magnitude**	**Certainty**
		Positive Outcomes				
P3a	All	INCREASE THE AVAILABILITY AND PRODUCTION OF FOOD IN THE WESTERN DELTA AND SUISUN BAY BY EXPORTING, VIA TIDAL FLOW, ORGANIC MATERIAL FROM THE MARSH PLAIN AND ORGANIC CARBON, PHYTOPLANKTON, ZOOPLANKTON, AND OTHER ORGANISMS FROM INTERTIDAL CHANNELS INTO THE DELTA	3-4	3	1-2	1
P4b	Chinook Salmon	LOCALLY PROVIDE AREAS OF COOL WATER REFUGIA FOR DELTA SMELT AND SALMONIDS.	2	1		
P4a	Delta smelt	LOCALLY PROVIDE AREAS OF COOL WATER REFUGIA FOR DELTA SMELT AND SALMONIDS.	2	1		
P1b	Fall-run Chinook Salmon	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	2		
P2b	Green Sturgeon	Provide a continuous corridor of habitat & food productivity linking current & future restored habitat in the Cache Slough Complex with habitat in Suisun Marsh & Bay	2	1		
P2a	Splittail	Provide a continuous corridor of habitat & food productivity linking current & future restored habitat in the Cache Slough Complex with habitat in Suisun Marsh & Bay	3	3		
P1a	Spring-run Chinook Salmon	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	2		
P2c	White Sturgeon	Provide a continuous corridor of habitat & food productivity linking current & future restored habitat in the Cache Slough Complex with habitat in Suisun Marsh & Bay	2	1		

Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
Negative Outcomes						
N4a	All	Resuspension and export of mercury and methylmercury to downstream areas	1	2		
N3a	All	Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids	1-2	1		
N2a	All	POTENTIAL FOR MERCURY METHYLATION AND LOCAL BIOACCUMULATION TO AFFECT WILDLIFE: N2-A - TARGET SPECIES, N2-B, NON-TARGET WILDLIFE SPECIES, N2-C, HUMAN HEALTH.	1	2		
N1c	All	ESTABLISHMENT OF UNDESIRABLE SPECIES (SUCH AS Corbicula) THAT WILL PREY OR COMPETE OR ALTER HABITAT CONDITIONS FOR COVERED FISH	4	2		
N1b	All	ESTABLISHMENT OF UNDESIRABLE SPECIES (SUCH AS Centrachids) THAT WILL PREY OR COMPETE OR ALTER HABITAT CONDITIONS FOR COVERED FISH	4	2		
N5a	All	Movement of fish and food resources to areas in central Delta with high predation	2-3	1		
N1a	All	ESTABLISHMENT OF UNDESIRABLE SPECIES (SUCH AS EGERIA,) THAT WILL PREY OR COMPETE OR ALTER HABITAT CONDITIONS FOR COVERED FISH	3	2		
N1d	Delta smelt	ESTABLISHMENT OF UNDESIRABLE SPECIES (SUCH AS Inland Silversides) THAT WILL PREY OR COMPETE OR ALTER HABITAT CONDITIONS FOR COVERED FISH	2	2		
N2c	Humans	POTENTIAL FOR MERCURY METHYLATION AND LOCAL BIOACCUMULATION TO AFFECT WILDLIFE: N2-A - TARGET SPECIES, N2-B, NON-TARGET WILDLIFE SPECIES, N2-C, HUMAN HEALTH.	2	3		
N3b	Others	Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids	1-2	1		
N2b	Wildlife	Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A - Target species, N2-B, Non-target wildlife species, N2-C, Human health.	3	2-3		

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			Viewpoint 1		Viewpoint 2	
Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
Positive Outcomes						
P2a	All	INCREASE THE AVAILABILITY AND PRODUCTION OF FOOD IN THE DELTA AND SUISUN BAY BY EXPORT FROM THE SOUTH DELTA OF ORGANIC MATERIAL VIA TIDAL FLOW FROM THE NEW MARSH PLAIN AND ORGANIC CARBON, PHYTOPLANKTON, ZOOPLANKTON, AND OTHER ORGANISMS PRODUCED IN NEW INTERTIDAL CHANNELS.	3-4	3	1-2	1
P3a	Delta smelt	Locally provide areas of cool water refugia for Delta smelt and Salmonids	2	1		
P1a	Delta smelt	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	1	2		
P1b	Fall-run Chinook Salmon	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	2		
P1d	Green sturgeon	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	2		
P1c	Splittail	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	3		
P1e	White sturgeon	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	1		

Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
Negative Outcomes						
N4a	All	Resuspension and export of mercury and methylmercury to downstream areas	1	2		
N3a	All	Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids	1-2	1		
N2a	All	POTENTIAL FOR MERCURY METHYLATION AND LOCAL BIOACCUMULATION TO AFFECT TARGET SPECIES	1	2		
N1b	All	Establishment of undesirable species (such as Centrachids,) that will prey or compete or alter habitat conditions for covered fish	4	2		
N1a	All	Establishment of undesirable species (such as egeria,) that will prey or compete or alter habitat conditions for covered fish	3	2		
N6a	All	Production of organic matter that will contribute to low dissolved oxygen (DO) conditions	3	2		
N5a	All	Creation of a population sink due to longer residence times with associated increased exposure to predators and entrainment.	2	4		
N1c	All	Establishment of undesirable species (such as Corbicula,) that will prey or compete or alter habitat conditions for covered fish	1	2		
N1d	Delta smelt	Establishment of undesirable species (such as Inland Silversides,) that will prey or compete or alter habitat conditions for covered fish	2	2		
N2c	Human health	POTENTIAL FOR MERCURY METHYLATION AND LOCAL BIOACCUMULATION TO AFFECT WILDLIFE: N2-A - TARGET SPECIES, N2-B, NON-TARGET WILDLIFE SPECIES, N2-C, HUMAN HEALTH.	2	3		
N3b	Others	Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids	1-2	1		
N2b	Wildlife	Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A - Target species, N2-B, Non-target wildlife species, N2-C, Human health.	3	2-3		

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			Viewpoint 1		Viewpoint 2	
Outcome Code	**Covered Spp.**	**Description**	**Magnitude**	**Certainty**	**Magnitude**	**Certainty**
Positive Outcomes						
P2a	All	Increase the availability and production of food in the east and central Delta by exporting organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta.	3-4	3	1-2	1
P3a	Delta Smelt	Locally provide areas of cool water refugia for delta smelt	2	1		
P1a	Fall-run Chinook salmon- San Joaquin River or eastside	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	2		
P1c	Green Sturgeon	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	2		
P1b	Splittail	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	3		
P1d	White Sturgeon	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	1		

Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
Negative Outcomes						
N4a	All	Resuspension and export of mercury and methylmercury to downstream areas	1	2		
N3a	All	Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids	1-2	1		
N2a	All	Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A - Target species, N2-B, Non-target wildlife species, N2-C, Human health.	1	2		
N1b	All	Establishment of undesirable species (such as Centrachids) that will prey or compete or alter habitat conditions for covered fish.	4	3		
N1a	All	Establishment of undesirable species (such as egeria,) that will prey or compete or alter habitat conditions for covered fish.	3	2		
N7a	Chinook salmon- San Joaquin	Restoration site creates a population sink for covered fish species (Provides rearing habitat that becomes a one-way trip	1	3		
N1c	All	Establishment of undesirable species (such as Corbicula) that will prey or compete or alter habitat conditions for covered fish.	4	2		
N7c	Delta smelt	Restoration site creates a population sink for covered fish species (Provides rearing habitat that becomes a one-way trip	2	3		
N1d	Delta smelt	Establishment of undesirable species (such as Inland Silversides) that will prey or compete or alter habitat conditions for covered fish.	2	2		
N2c	Human health	Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A - Target species, N2-B, Non-target wildlife species, N2-C, Human health.	2	3		
N3b	Others	Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids	1-2	1		
N7b	Steelhead	Restoration site creates a population sink for covered fish species (Provides rearing habitat that becomes a one-way trip	1	3		
N2b	Wildlife	Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A - Target species, N2-B, Non-target wildlife species, N2-C, Human health.	3	2-3		

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			Viewpoint 1		Viewpoint 2	
Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
		Positive Outcomes				
P4a	Fall-run Chinook Salmon	Reduce periodic low dissolved oxygen events and associated Mercury Methylation events associated with the discharge of waters from lands managed as seasonal freshwater wetlands that would be restored as brackish intertidal marsh.	1	2		
P4b	Spring-run Chinook salmon	Reduce periodic low dissolved oxygen events and associated Mercury Methylation events associated with the discharge of waters from lands managed as seasonal freshwater wetlands that would be restored as brackish intertidal marsh.	0	4		
P4c	Winter-run Chinook salmon	Reduce periodic low dissolved oxygen events and associated Mercury Methylation events associated with the discharge of waters from lands managed as seasonal freshwater wetlands that would be restored as brackish intertidal marsh.	1	2		
P4d	Late Fall-run Chinook Salmon	Reduce periodic low dissolved oxygen events and associated Mercury Methylation events associated with the discharge of waters from lands managed as seasonal freshwater wetlands that would be restored as brackish intertidal marsh.	1	2		
P4e	Steelhead	Reduce periodic low dissolved oxygen events and associated Mercury Methylation events associated with the discharge of waters from lands managed as seasonal freshwater wetlands that would be restored as brackish intertidal marsh.	2	2		
P4f	Longfin smelt	Reduce periodic low dissolved oxygen events and associated Mercury Methylation events associated with the discharge of waters from lands managed as seasonal freshwater wetlands that would be restored as brackish intertidal marsh.	2	2		
P4g	Delta Smelt	Reduce periodic low dissolved oxygen events and associated Mercury Methylation events associated with the discharge of waters from lands managed as seasonal freshwater wetlands that would be restored as brackish intertidal marsh.	1	2		

Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
P4h	Splittail	Reduce periodic low dissolved oxygen events and associated Mercury Methylation events associated with the discharge of waters from lands managed as seasonal freshwater wetlands that would be restored as brackish intertidal marsh.	2	3		
P4i	Green Sturgeon	Reduce periodic low dissolved oxygen events and associated Mercury Methylation events associated with the discharge of waters from lands managed as seasonal freshwater wetlands that would be restored as brackish intertidal marsh.	2	1		
P4j	White Sturgeon	Reduce periodic low dissolved oxygen events and associated Mercury Methylation events associated with the discharge of waters from lands managed as seasonal freshwater wetlands that would be restored as brackish intertidal marsh.	3	1		
P2a	All	Increase the availability & production of food in Suisun Bay by exporting organic material via tidal flow from the marsh plain & phytoplankton, zooplankton, & other organisms produced in intertidal channels into the Bay.	3-4	3	1-2	1
P3a	Delta Smelt	Locally provide areas of cool water refugia for Delta smelt and Salmonids	2	1		
P1a	Delta Smelt	Increase rearing habitat area for covered fish species.	3	1		
P3b2	Fall-run Chinook Salmon	Locally provide areas of cool water refugia for Delta smelt and Salmonids	2	1		
P1c3	Fall-run Chinook Salmon	Increase rearing habitat area for covered fish species.	3	1		
P1e	Green Sturgeon	Increase rearing habitat area for covered fish species.	2	2		
P1c4	Late Fall-run Chinook Salmon	Increase rearing habitat area for covered fish species.	1	1		
OP2	Late Fall-run Chinook Salmon	Locally provide areas of cool water refugia for late fall-run Salmonids	0			
P1b	Longfin smelt	Increase rearing habitat area for covered fish species.	1	1		
P1d	Splittail	Increase rearing habitat area for covered fish species.	3	2		
P3b1	Spring-run Chinook salmon	Locally provide areas of cool water refugia for Delta smelt and Salmonids	2	1		
P1c2	Spring-run Chinook Salmon	Increase rearing habitat area for covered fish species.	3	1		
P3b3	Steelhead	Locally provide areas of cool water refugia for Delta smelt and Salmonids	2	1		
P1f	White Sturgeon	Increase rearing habitat area for covered fish species.	2	2		
P1c1	Winter-run Chinook Salmon	Increase rearing habitat area for covered fish species.	1	1		

Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
Negative Outcomes						
N2a	All	Potential for mercury methylation and local bioaccumulation: N2-A-Covered species, N2-B, Non-covered wildlife species, N2-C, human health.	1	2		
N1b	All	Establishment of undesirable species (such as Centrachids) that will prey or compete or alter habitat conditions for covered fish.	1	4		
N1a	All	Establishment of undesirable species (such as Egeria) that will prey or compete or alter habitat conditions for covered fish.	1	4		
N1c	All	Establishment of undesirable species (such as Corbicula) that will prey or compete or alter habitat conditions for covered fish.	4	2		
N1d	Delta smelt	Establishment of undesirable species (such as Inland Silversides) that will prey or compete or alter habitat conditions for covered fish.	2	2		
N2c	Human health	Potential for mercury methylation and local bioaccumulation: N2-A-Covered species, N2-B, Non-covered wildlife species, N2-C, human health.	2	3		
N2b	Wildlife	Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A - Target species, N2-B, Non-target wildlife species, N2-C, Human health.	3	2-3		

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Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P6	All	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (offsite), longfin smelt, and delta smelt (consider loss to entrainment on Bacon Island option)	1	3
P2	All	Increased establishment of instream structure through export of LWD to benefit covered species	1	1
P5d	Chinook salmon	Increased production and export of terrestrial invertebrates into the aquatic ecosystem for rearing splittail, green and white sturgeon, Chinook salmon and steelhead	2	3-4
P4e	Chinook salmon	Increase rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment for Old River)	2-3	2-3
P5b	Green & White Sturgeon	Increased production and export of terrestrial invertebrates into the aquatic ecosystem for rearing splittail, green and white sturgeon, Chinook salmon and steelhead	1	2
P4b	Green Sturgeon	Increase rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment for Old River)	2	1
P5a	Splittail	Increased production and export of terrestrial invertebrates into the aquatic ecosystem for rearing splittail, green and white sturgeon, Chinook salmon and steelhead	3	3
P4a	Splittail	Increase rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment for Old River)	2	3-4
P3	splittail	Increase splittail spawning habitat on narrow floodplain margin	2	3-4
P5c	Steelhead	Increased production and export of terrestrial invertebrates into the aquatic ecosystem for rearing splittail, green and white sturgeon, Chinook salmon and steelhead	2	3
P4d	Steelhead	Increase rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment for Old River)	3	2
P4c	White Sturgeon	Increase rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment for Old River)	2	1

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Negative Outcomes				
N2	All	Increased exposure risk to contaminants (including Selinium) due to longer residence time in this area (for Bacon Island option only)	1	3
N1a	Delta smelt	Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail, if flows through sloughs are not sufficient to prevent colonization by non natives	2	3
N1d	Green & White Sturgeon	Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail, if flows through sloughs are not sufficient to prevent colonization by non natives	1	2
N1b	Longfin smelt	Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail, if flows through sloughs are not sufficient to prevent colonization by non natives	3	2
N1c	Splittail	Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail, if flows through sloughs are not sufficient to prevent colonization by non natives	2	3
N1e	Steelhead & Chinook salmon	Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail, if flows through sloughs are not sufficient to prevent colonization by non natives	2-3	2

			Scenario 1		Scenario 2	
Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
Positive Outcomes						
P2	All	Increased establishment of instream structure through export of LWD to benefit covered species.	3	2		
P5e1	Chinook salmon	Increased production and export of terrestrial invertebrates into the aquatic ecosystem for rearing splittail, green and white sturgeon, Chinook salmon and steelhead	2	3-4	3	3-4
P4e	Chinook Salmon	Additional rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment)	3	3	3	3
P5b	Green Sturgeon	Increased production and export of terrestrial invertebrates into the aquatic ecosystem for rearing splittail, green and white sturgeon, Chinook salmon and steelhead	1	2	1	2
P4b	Green Sturgeon	Additional rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment)	2	1	2	1
P5a1	Splittail	Increased production and export of terrestrial invertebrates into the aquatic ecosystem for rearing splittail, green and white sturgeon, Chinook salmon and steelhead	2	3	3	3
P4a1	Splittail	Additional rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment)	2	3	3	3
P3a1	Splittail	Additional splittail spawning habitat on narrow floodplain margin (12 mi)	2	3	3	3
P5d	Steelhead	Increased production and export of terrestrial invertebrates into the aquatic ecosystem for rearing splittail, green and white sturgeon, Chinook salmon and steelhead	2	2		
P4d	Steelhead	Additional rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment)	2	2	2	2
P5c	White Sturgeon	Increased production and export of terrestrial invertebrates into the aquatic ecosystem for rearing splittail, green and white sturgeon, Chinook salmon and steelhead	1	2	1	2
P4c	White Sturgeon	Additional rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment)	2	1	2	1

			Scenario 1		Scenario 2	
Outcome Code	**Covered Spp.**	**Description**	**Magnitude**	**Certainty**	**Magnitude**	**Certainty**
		Negative Outcomes				
N2	All	Increased mortality of covered species due to increased exposure risk to contaminants due to longer residence time in this area	1	3		
N1c	Green & White Sturgeon	Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail, if flows through sloughs are not sufficient to prevent colonization by non natives (by creating more predator habitat)	1	2		
N1a	Longfin smelt	Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail, if flows through sloughs are not sufficient to prevent colonization by non natives (by creating more predator habitat)	2	2		
N1b	Splittail	Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail, if flows through sloughs are not sufficient to prevent colonization by non natives (by creating more predator habitat)	2	3		
N1d	Steelhead & Chinook salmon	Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail, if flows through sloughs are not sufficient to prevent colonization by non natives (by creating more predator habitat)	2-3	2		

Scenario 1 Enhance channel margin habitats along 12 miles (6 miles/side) of Steamboat and Sutter Sloughs to improve habitat conditions for covered fish species.

Scenario 2 Enhance channel margin habitats along 36 miles (18 miles/side) of Steamboat and Sutter Sloughs to improve habitat conditions for covered fish species.

			Scenario 1		Scenario 2	
Outcome Code	**Covered Spp.**	**Description**	**Magnitude**	**Certainty**	**Magnitude**	**Certainty**
		Positive Outcomes				
P3	All	Improved resting habitat for migrating adults (Chinook Salmon upstream, steelhead up and downstream, Green/White sturgeon)	1-3	1-2		
P4e	Chinook salmon	Increased food production and availability (fall of OM, terrestrial invertebrates) for Chinook salmon, steelhead, splittail and green and white sturgeon (consider loss to entrainment)	1	3	1	3
P1e	Chinook salmon	Increased establishment of woody riparian and emergent vegetation to provide high quality rearing habitat for covered species	2-3	2-3	2-3	2-3
P4b	Green Sturgeon	Increased food production and availability (fall of OM, terrestrial invertebrates) for Chinook salmon, steelhead, splittail and green and white sturgeon (consider loss to entrainment)	1	3	1	3
P1b	Green Sturgeon	Increased establishment of woody riparian and emergent vegetation to provide high quality rearing habitat for covered species	2	1	2	1
P2	Splittail	Increase availability of spawning habitat for splittail	3	3-4	3	3-4
P4a	Splittail	Increased food production and availability (fall of OM, terrestrial invertebrates) for Chinook salmon, steelhead, splittail and green and white sturgeon (consider loss to entrainment)	1	3	1	3
P1a1	Splittail	Increased establishment of woody riparian and emergent vegetation to provide high quality rearing habitat for covered species	1	3-4	2	3-4
P4d	Steelhead	Increased food production and availability (fall of OM, terrestrial invertebrates) for Chinook salmon, steelhead, splittail and green and white sturgeon (consider loss to entrainment)	1	2	1	2
P1d	Steelhead	Increased establishment of woody riparian and emergent vegetation to provide high quality rearing habitat for covered species	3	2	3	2
P4c	White Sturgeon	Increased food production and availability (fall of OM, terrestrial invertebrates) for Chinook salmon, steelhead, splittail and green and white sturgeon (consider loss to entrainment)	1	1	1	1
P1c	White Sturgeon	Increased establishment of woody riparian and emergent vegetation to provide high quality rearing habitat for covered species	2	1	2	1

			Scenario 1		Scenario 2	
Outcome Code	**Covered Spp.**	**Description**	**Magnitude**	**Certainty**	**Magnitude**	**Certainty**
		Negative Outcomes				
N2	All	Increased exposure risk to contaminants (including Selenium) to longer residence time in this area	1	4		
N1	All (note salmonids more sensitive to Selenium)	Increased exposure risk to contaminants (including Selenium) to longer residence time in this area	2	3		
N3c	Green & White Sturgeon	Increased habitat for non-native predators/competitors to native fishes (longfin smelt, splittail, green/white sturgeon, steelhead, Chinook salmon)	1	2		
N3a	Longfin smelt	Increased habitat for non-native predators/competitors to native fishes (longfin smelt, splittail, green/white sturgeon, steelhead, Chinook salmon)	2	2		
N3b	Splittail	Increased habitat for non-native predators/competitors to native fishes (longfin smelt, splittail, green/white sturgeon, steelhead, Chinook salmon)	3	2		
N3d	Steelhead & Chinook salmon	Increased habitat for non-native predators/competitors to native fishes (longfin smelt, splittail, green/white sturgeon, steelhead, Chinook salmon)	2-3	2		

Scenario 1 Enhance channel margin habitats along 14 miles of the San Joaquin River in the San Joaquin River ROA to improve habitat conditions for covered fish species.

Scenario 2 Enhance channel margin habitats along 28 miles of the San Joaquin River in the San Joaquin River ROA to improve habitat conditions for covered fish species.

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P4b	All	Reduction in ammonia would decrease blooms of nuisance species such as microcystis* or non-native zooplankton**	2	1
P4a	All	Reduction in ammonia would decrease blooms of nuisance species such as microcystis* or non-native zooplankton**	2	3
P3b	All	Effect of increasing diatom production on zooplankton abundance	2	2
P2b	All	Effect of increasing diatom production on zooplankton abundance	2	2
P6c	Chinook Salmon	Reduction in direct toxic effects on fish species	2	3
P3c	Chinook salmon	Effect of increasing zooplankton abundance on fish abundance	2	1
P2c	Chinook salmon	Effect of increasing zooplankton abundance on fish abundance	2	1
P1c	Chinook Salmon	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the freshwater portion of the estuary (Lower Sacramento River)	2	1
P6a	Delta smelt	Reduction in direct toxic effects on fish species	3	2
P3c	Delta smelt	Effect of increasing zooplankton abundance on fish abundance	2	2
P2c	Delta smelt	Effect of increasing zooplankton abundance on fish abundance	3	1
P1c	Delta smelt	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the freshwater portion of the estuary (Lower Sacramento River)	3	1
P1b	Delta smelt	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the freshwater portion of the estuary (Lower Sacramento River)	2	2
P3a	Delta smelt & Longfin smelt	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the brackish portion of the estuary (Suisun and Grizzly Bays)	2	2
P2a	Delta smelt & Longfin smelt	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in low-salinity portion of the estuary (confluence).	3	1

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes (contd.)				
P1c	Delta smelt & Longfin smelt	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the freshwater portion of the estuary (Lower Sacramento River)	3	1
P1a	Delta smelt & Longfin smelt	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the freshwater portion of the estuary (Lower Sacramento River)	3	1
P5a	Delta smelt, Longfin smelt, & Chinook salmon	Reduction in direct toxic effects on zooplankton species	2	3
P6d	Green & White Sturgeon	Reduction in direct toxic effects on fish species	1	3
P6b	Longfin smelt	Reduction in direct toxic effects on fish species	1	3
P3c	Longfin smelt	Effect of increasing zooplankton abundance on fish abundance	3	1
P2c	Longfin smelt	Effect of increasing zooplankton abundance on fish abundance	2	1
P1c	Longfin smelt	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the freshwater portion of the estuary (Lower Sacramento River)	2	2
P6e	Splittail	Reduction in direct toxic effects on fish species	1	3
P2c	Splittail & Sturgeon	Effect of increasing zooplankton abundance on fish abundance	1	4
P2	Splittail & Sturgeon	Effect of increasing zooplankton abundance on fish abundance	1	4
P1c	Splittail & Sturgeon	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the freshwater portion of the estuary (Lower Sacramento River)	1	4
P3c	Steelhead	Effect of increasing zooplankton abundance on fish abundance	2	1
P2c	Steelhead	Effect of increasing zooplankton abundance on fish abundance	2	1
P1c	Steelhead	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the freshwater portion of the estuary (Lower Sacramento River)	2	1

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Negative Outcomes				
N1	All	Removal of valuable nutrients as a function of WWTP outputs	1	4
N2	All	Nitrification will reduce ammonia, but increased nitrate could result in growth of undesirable algal blooms and macrophytes	2	2
N3	All	Increased phytoplankton productivity will increase clam biomass and uptake of selenium, impairing reproduction in benthic foraging fish species	3	4

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P4	All	Ancillary benefits – if you're removing EDCs you're also removing other harmful chemicals (e.g. methylmercury, personal care products, ammonia, antibacterial, pharmaceuticals, pesticides)	NA	NA
P3	All	Reduce effects of endocrine disrupting compounds to food web organisms/invertebrates	2	1
P2	All	Reduced endocrine issues (transgender, reproductive, etc.) caused by endocrine disruptors in delta and longfin smelt, white and green sturgeon, salmonids (all races), and splittail.	2-3	3
P1	All	Increased reproductive success of covered fish species	2	2

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P1	All	Reduced direct mortality due to consumption of mercury by splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon.	1	2
P2	All	Reduced sublethal effects (genetic, tissue/organ damage, development, reproductive, growth, and immune) of mercury on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon.	2	2
P3	Humans & birds	(Added) Reduce toxic concentrations of methyl mercury in forage and sportfish to protect wildlife and humans from chronic sublethal toxicity.	3	3

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P3a	All	Increased food abundance and quality for splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from reduced food web disruption	3	2
P2a	Delta smelt	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races).	4	3
P1a	delta smelt	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides.	3	3
P2i	Fall, late Fall-run Chinook salmon	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races).	3	3
P1i	Fall, late Fall-run Chinook salmon	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides.	2	3
P2d	Green Sturgeon	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races).	2	2
P1d	Green Sturgeon	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides.	2	2
P2b	Longfin smelt	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races).	2	2
P1b	Longfin smelt	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides.	2	2

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes (contd.)				
P2c	Splittail	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races).	3	2
P1c	Splittail	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides.	3	2
P2h	Spring-run Chinook salmon, Sac.	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races).	3	3
P1h	Spring-run Chinook salmon, Sac.	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides.	2	3
P2f	Steelhead	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races).	3	3
P1f	Steelhead	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides.	2	3
P2e	White Sturgeon	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races).	3	3
P1e	White Sturgeon	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides.	3	3
P2g	Winter-run Chinook salmon, Sac.	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races).	3	3
P1g	Winter-run Chinook salmon, Sac.	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides.	2	3

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Negative Outcomes				
N1	All	Possible drying up of some smaller creeks	3	1

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P3a	All	Increased food abundance for splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from reduced food web disruption and increased food quality and abundance for important invertebrate species.	2-3	2-3
P1	All	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from contaminants.	3	2
P2a	Delta smelt	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)	2	2
P2i	Fall-run Chinook salmon	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)	3	3
P2d	Green Sturgeon	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)	2	2
P2b	Longfin smelt	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)	2	2
P2c	Splittail	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)	2	2

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes (contd.)				
P2h	Spring-run Chinook salmon, Sac.	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)	3	3
P2f	Steelhead	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)	3	3
P2e	White Sturgeon	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)	2	2
P2g	Winter-run Chinook salmon, Sac.	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)	3	3

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Negative Outcomes				
N1	Human health	Ponded or contained stormwater could exacerbate mosquito control problems and associated human health issues.	1	3
N2	Human health	Ponded or contained stormwater could transfer of contaminants to groundwater by infiltration	1	3

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P4	Chinook salmon, steelhead, and splittail- juvenile	Reduce predation on juvenile salmon, steelhead, and splittail by reducing habitat for non-native predatory fish.	2	2
P5a	Chinook salmon	Increase rearing habitat for juvenile salmon (all races), steelhead, and splittail.	3	3
P6a	Delta smelt	Increased extent of spawning habitat for delta smelt and longfin smelt.	2	2
P3a	Delta smelt	Improve the extent of delta and longfin smelt rearing habitat by reducing local water temperatures.	1	2
P2	delta smelt	Reduce predation of delta smelt as a result of reduced turbidity	3	2
P1a	Delta smelt	Increase food consumption by delta and longfin smelt due to higher turbidity	1	4
P6b	Longfin smelt	Increased extent of spawning habitat for delta smelt and longfin smelt.	1	2
P3b	Longfin smelt	Improve the extent of delta and longfin smelt rearing habitat by reducing local water temperatures.	1	2
P1b	Longfin smelt	Increase food consumption by delta and longfin smelt due to higher turbidity	1	3
P5c	Splittail	Increase rearing habitat for juvenile salmon (all races), steelhead, and splittail.	2	3
P5b	Steelhead	Increase rearing habitat for juvenile salmon (all races), steelhead, and splittail.	3	3

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Negative Outcomes				
N6	All	Possible endocrine disruption in fish by 2,4-D	2	2
N4	All	Increased blooms of microcystis due to a reduction in competition for nutrients	2	3
N3	All	Increase in detritus POC – temporally and spatially limited	2	2
N2	All	Reduction in phytoplankton quantity or quality from effects of herbicide	3	1
N1	All	Reduction in zooplankton from effects of herbicide	2	2
N5	Green & White Sturgeon	Possible toxic effects to juvenile white and green sturgeon from Fluridone and 2,4-D used at approved application rates	2	3

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P3a	Chinook salmon	Reduced predation mortality by black bass	2	3
P1a	Chinook salmon	Reduced predation mortality by striped bass	2	3
P3c	Delta smelt	Reduced predation mortality by black bass	2	2
P1c	Delta smelt	Reduced predation mortality by striped bass	2	2
P4	Delta smelt & Longfin smelt	Increased knowledge about the efficacy of using fishing regulations to modify bass population size	2	2
P2	Delta smelt & Longfin smelt	Reduced competition for food with delta and longfin smelt by juvenile striped bass	3	2
P3f	Green Sturgeon	Reduced predation mortality by black bass	1	2
P1f	Green Sturgeon	Reduced predation mortality by striped bass	1	2

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes (contd.)				
P3d	Longfin smelt	Reduced predation mortality by black bass	2	2
P1d	Longfin smelt	Reduced predation mortality by striped bass	2	2
P3e	Splittail	Reduced predation mortality by black bass	1	2
P1e	Splittail	Reduced predation mortality by striped bass	2	2
P3b	Steelhead	Reduced predation mortality by black bass	2	2
P1b	Steelhead	Reduced predation mortality by striped bass	2	2
P3g	White Sturgeon	Reduced predation mortality by black bass	1	2
P1g	White Sturgeon	Reduced predation mortality by striped bass	1	2

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Negative Outcomes				
N4	All	Unintended changes to the striped and black bass populations (e.g., decrease abundance but increase average size)	2	2
N3	All	Release of other competitor populations from predation pressure	3	3
N2	All	Release of other predator populations from predation pressure	2	2
N1	All	Increased bycatch of non-target species	1	2

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P3	Chinook Salmon	Increased population sizes of Chinook salmon	2-3	2
P1	Green Sturgeon	Increased population sizes of green sturgeon	3	2
P4	Steelhead	Increased population sizes of steelhead	2	2
P2	White Sturgeon	Increased population sizes of white sturgeon	3	2
Negative Outcomes				
N1	Chinook salmon & Green & White Sturgeon	Information gap about where poaching is most important may result in effort being directed at less important areas and may shift poaching to areas with greater importance to the population	1	2

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P3	All	Would improve ability to gather information about species	2	3
P4	Splittail	Increased predation on Corbula	2	2
P2	Splittail	Improved foodweb energy transfer in wet years	3	2
P1	splittail	Increase population abundance of splittail	3	2
Negative Outcomes				
N1	Splittail	Potential for redirection of fishing effort to other sensitive species	2	2

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P1	Chinook Salmon	Increased population size of Central Valley Chinook salmon (all races)	4	3
P2	Chinook Salmon	Increased knowledge base regarding Central Valley Chinook salmon (population sizes, harvest rates, success of restoration programs, and other key biological parameters) for improved management	3	3
P3	Chinook Salmon	Reduce competition and introgression from hatchery fish with natural fish on spawning grounds	4	3
P4	Chinook Salmon	Can improve broodstock management at hatcheries (with tagging, much improved)	4	4
Negative Outcomes				
N1	Chinook Salmon	Complicates management and data acquisition for conservation hatcheries (e.g., Livingston-Stone) and associated agency sampling programs	4	4
N2	Chinook Salmon	Action may lead to increased harvest of hatchery fish, which may result in higher bycatch of covered salmonids	2	2
N3	Chinook Salmon	Action may lead to sociological pressure for increased hatchery production	?	?

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P2a	Delta smelt	Preserve genetic diversity	3	2
P1a	Delta smelt	Increased population sizes to self-sustaining levels in the wild	3	2
P3	Delta smelt & Longfin smelt	Improved knowledge base about threats to and management of the species stemming from ability to study the effects of various stressors on these species using hatchery reared specimens	4	4
P2b	Longfin smelt	Preserve genetic diversity	3	1
P1b	Longfin smelt	Increased population sizes to self-sustaining levels in the wild	3	1
Negative Outcomes				
N4a	Delta smelt	Mortality associated with catching broodstock (genetic material lost)	2	3
N1a	Delta smelt	Genetic consequences for hatchery and wild populations	3	2
N3	Delta smelt & Longfin smelt	Mining of wild population to support broodstock needs	3	3
N2	Delta smelt & Longfin smelt	Negative ecological interactions with wild fish (competition, displacement)	3	2
N4b	Longfin smelt	Mortality associated with catching broodstock (genetic material lost)	2	2
N1b	Longfin smelt	Genetic consequences for hatchery and wild populations	3	1

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P2f	Chinook Salmon	Increased Food Availability	1	1
P1f	Chinook salmon-Fry and juvenile	Reduce entrainment mortality by non-project diversions	1	1
P2a	Delta smelt	Increased Food Availability	1	1
P2c	Green Sturgeon	Increased Food Availability	1	1
P1c	Green Sturgeon-juvenile	Reduce entrainment mortality by non-project diversions	1	1
P1a	Larval and juvenile delta smelt	Reduce entrainment mortality by non-project diversions	2	2
P2b	Longfin smelt	Increased Food Availability	1	1
P1b	longfin smelt- Larval and juvenile	Reduce entrainment mortality by non-project diversions	1	1
P2e	Splittail	Increased Food Availability	1	1
P1e	Splittail- Juvenile	Reduce entrainment mortality by non-project diversions	1	1
P2g	Steelhead	Increased Food Availability	1	1
P1g	steelhead-Fry and juvenile	Reduce entrainment mortality by non-project diversions	1	1
P2d	White Sturgeon	Increased Food Availability	1	1
P1d	White Sturgeon-Juvenile	Reduce entrainment mortality by non-project diversions	1	1

Outcome Code	Covered Spp.	Description	Scenario 1 Magnitude	Scenario 1 Certainty	Scenario 2 Magnitude	Scenario 2 Certainty
Positive Outcomes						
P1a	Fall-run Chinook salmon- San Joaquin River	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	1	4	1	4
P1b	Spring-run Chinook salmon, Sac	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	2	3	3	3
P1c	Fall-run Chinook salmon, Sac.	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	2	3	3	3
P1d	Late Fall-run Chinook Salmon	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	2	3	3	3
P1e	Winter-run Chinook salmon	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	2	3	3	3
P1f	White Sturgeon	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	1	3	1	3
P1g	Green Sturgeon	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	1	3	1	3
P1h	Steelhead, Sacramento	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	2	3	3	3
P1i	Steelhead, San Joaquin	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	1	2	1	2

Outcome Code	Covered Spp.	Description	Scenario 1 Magnitude	Scenario 1 Certainty	Scenario 2 Magnitude	Scenario 2 Certainty
Positive Outcomes (contd.)						
P1j	Delta smelt-adult	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	3	3	3	3
P1k	Delta Smelt – Larval and Juvenile	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	3	3	3	3
P1L	Longfin Smelt - Adult	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	2	3	2	3
P1m	Longfin Smelt – Larval-Juvenile	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	3	3	3	3
P1n	Splittail	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	2	3	2	3
P2	All	Increased food availability for covered species due to higher productivity at lower trophic levels in the Delta associated with increased residence time	2	3	2	3

Outcome Code	Covered Spp.	Description	Scenario 1 Magnitude	Scenario 1 Certainty	Scenario 2 Magnitude	Scenario 2 Certainty
Negative Outcomes						
N1a	Sac Chinook & Steelhead	Increased predation on juvenile Sacramento salmon, steelhead, and sturgeon associated with local hydraulics at new North Delta water diversion structures	4	2	4	2
N1b	White sturgeon	Increased predation on juvenile Sacramento salmon, steelhead, and sturgeon associated with local hydraulics at new North Delta water diversion structures	2	2	2	2
N1c	Splittail- Juvenile	Increased predation on juvenile Sacramento salmon, steelhead, and sturgeon associated with local hydraulics at new North Delta water diversion structures	4	2	4	2
N3	Delta smelt	Increased mortality of juvenile delta smelt associated with new North Delta facilities and operations	2	3	2	2
N4a,b	Green & White Sturgeon	Increased mortality of covered species due to degradation of water quality which increases a stressor (on fish species of concern)	3	2	3	2
N4c	Chinook salmon- San Joaquin	Increased mortality of covered species due to degradation of water quality which increases a stressor (on fish species of concern)	4	2	4	2
N4d	Steelhead- San Joaquin	Increased mortality of covered species due to degradation of water quality which increases a stressor (on fish species of concern)	4	2	4	2
N4e	Splittail, Sac.	Increased mortality of covered species due to degradation of water quality which increases a stressor (on fish species of concern)	3	3	3	3

Outcome Code	Covered Spp.	Description	Scenario 1 Magnitude	Scenario 1 Certainty	Scenario 2 Magnitude	Scenario 2 Certainty
Negative Outcomes (contd.)						
N5	Delta smelt	Lower quality Delta smelt habitat due to reduced turbidity (i.e. loss of sediment due to fewer pulse flows on the Sacramento River).	2-3	1		
N6a,b	Chinook Salmon & steelhead- San Joaquin	Increased frequency, duration and extent of low DO at Stockton and blockage of salmon/steelhead migration on the San Joaquin River.	4	4		
N9	Chinook Salmon - Mokelumne River	Increased mortality of juvenile Mokelumne River Chinook salmon.	3	3-4		
N6c,d,e	Green & White Sturgeon, & Sacramento splittail	Increased frequency, duration and extent of low DO at Stockton and blockage of salmon/steelhead migration on the San Joaquin River.	1	2		
N7	All	Loss of Sacramento River food material for covered species into the Delta due to diversions of water and reduction in flow to the Delta.	2	1		
N8	All	Increased Microcystis biomass which will affect aquatic food webs and covered fish species due to the new North Delta Diversion.	3	2		
N9	All	Increased predationof juvenile Mokelumne River salmon due to modified Delta Cross Channel operations	3	3		

Scenario 1

Mid-Range Hood Bypass Criteria.

- December 1 through June 30 maintain a Sacramento River bypass flow of not less than 11,000 cfs;
- July 1 through August 30 maintain a Sacramento River bypass flow of not less than 5,000 cfs;
- September 1 through November 30 maintain a Sacramento River bypass flow of not less than 7,000 cfs for fall salmon attraction and migration;
- Require at least 55% of river flows above minimum bypass flows during February-April, 45% during January and May, and 35% during December and June

Scenario 2

Low (5,000 cfs) Hood Bypass Criteria

- Set minimum bypass flow of 5,000 cfs year round except as provided in the bullet below;
- Require at least 55% of river flows above 5,000 cfs during February-April, 45% during January and May, and 35% during December and June (see figure 3) to maintain the shape of the hydrograph.

Outcome Code	Covered Spp.	Description	Scenario 2a Magnitude	Scenario 2a Certainty	Scenario 2b Magnitude	Scenario 2b Certainty
Positive Outcomes						
P8a	Chinook salmon	Increase survival of out migrating juveniles (steelhead and Chinook salmon) by providing migration route with lower predation and entrainment (at North and South Delta diversions) risk	3-4	3	3-4	3
P6c	Chinook salmon	Reduce losses due to stranding, illegal harvest and blocked/delayed passage for Chinook salmon, steelhead, green/white sturgeon	4	3-4	4	3-4
P5f	Chinook Salmon	Increase frequency and magnitude of transport of OC and organisms from Cache Slough/Bypass tidal marshes to support Delta foodweb for delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon	2	2	2	2
P4f1	Chinook Salmon	Increase frequency and magnitude of export of DOM, POM and organisms from seasonal floodplain to provide food in Delta for delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon	2-3	2	2-3	2
P3d1 & 2	Chinook salmon	Increase production of food for rearing of Chinook salmon, green and white sturgeon, splittail, and steelhead, on the seasonal floodplain	4	3	3-4	3
P2d	Chinook salmon	Create additional juvenile rearing habitat for splittail, green and white sturgeon, steelhead and Chinook salmon	4	4	4	4
P7	delta smelt	Increase delivery of readily suspendable sediments to north Delta and improved delta smelt habitats	3	3	3	3
P5a	Delta Smelt	Increase frequency and magnitude of transport of OC and organisms from Cache Slough/Bypass tidal marshes to support Delta foodweb for delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon	3	2	3	2
P4a	Delta Smelt	Increase frequency and magnitude of export of DOM, POM and organisms from seasonal floodplain to provide food in Delta for delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon	3	3	3	3

Outcome Code	Covered Spp.	Description	Scenario 2a Magnitude	Scenario 2a Certainty	Scenario 2b Magnitude	Scenario 2b Certainty
Positive Outcomes (contd.)						
P2b	Green & White Sturgeon	Create additional juvenile rearing habitat for splittail, green and white sturgeon, steelhead and Chinook salmon	1	2	1	2
P6a	Green & White Sturgeon Scenarios 1 & 2	Reduce losses due to stranding, illegal harvest and blocked/delayed passage for Chinook salmon, steelhead, green/white sturgeon	4	4	4	4
P5d	Green & White Sturgeon Scenarios 1 & 2	Increase frequency and magnitude of transport of OC and organisms from Cache Slough/Bypass tidal marshes to support Delta foodweb for delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon	2	2	2	2
P4d	Green & White Sturgeon Scenarios 1 & 2	Increase frequency and magnitude of export of DOM, POM and organisms from seasonal floodplain to provide food in Delta for delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon	2	2	2	2
P3b	Green & White Sturgeon Scenarios 1 & 2	Increase production of food for rearing of Chinook salmon, green and white sturgeon, splittail, and steelhead, on the seasonal floodplain	1	2	1	2
P5b	Longfin Smelt	Increase frequency and magnitude of transport of OC and organisms from Cache Slough/Bypass tidal marshes to support Delta foodweb for delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon	3	2	3	2
P4b	Longfin Smelt	Increase frequency and magnitude of export of DOM, POM and organisms from seasonal floodplain to provide food in Delta for delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon	2-3	2	2-3	2

			Scenario 2a		Scenario 2b	
Outcome Code	**Covered Spp.**	**Description**	**Magnitude**	**Certainty**	**Magnitude**	**Certainty**
Positive Outcomes (contd.)						
P5c	Splittail	Increase frequency and magnitude of transport of OC and organisms from Cache Slough/Bypass tidal marshes to support Delta foodweb for delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon	2	2	2	2
P4c	Splittail	Increase frequency and magnitude of export of DOM, POM and organisms from seasonal floodplain to provide food in Delta for delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon	3	2	3	2
P3a	Splittail	Increase production of food for rearing of Chinook salmon, green and white sturgeon, splittail, and steelhead, on the seasonal floodplain	4	4	4	4
P2a1 & 2	Splittail	Create additional juvenile rearing habitat for splittail, green and white sturgeon, steelhead and Chinook salmon	4	4	3	4
P1a1 & 2	Splittail	Create additional spawning habitat for splittail	4	4	3	4
P8b	Steelhead	Increase survival of out migrating juveniles (steelhead and Chinook salmon) by providing migration route with lower predation and entrainment (at North and South Delta diversions) risk	3-4	2	3-4	2
P6b	Steelhead	Reduce losses due to stranding, illegal harvest and blocked/delayed passage for Chinook salmon, steelhead, green/white sturgeon	4	3	4	3
P5e	Steelhead	Increase frequency and magnitude of transport of OC and organisms from Cache Slough/Bypass tidal marshes to support Delta foodweb for delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon	2	2	2	2
P4e1	Steelhead	Increase frequency and magnitude of export of DOM, POM and organisms from seasonal floodplain to provide food in Delta for delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon	2-3	2	2-3	2
P3c1 & 2	Steelhead	Increase production of food for rearing of Chinook salmon, green and white sturgeon, splittail, and steelhead, on the seasonal floodplain	3	3	2	3
P2c	Steelhead	Create additional juvenile rearing habitat for splittail, green and white sturgeon, steelhead and Chinook salmon	4	2	4	2

Outcome Code	Covered Spp.	Description	Scenario 2a Magnitude	Scenario 2a Certainty	Scenario 2b Magnitude	Scenario 2b Certainty
Negative Outcomes						
N4	All	Reduced flows in Sacramento River and distributaries to support successful outmigration (scenarios 1 & 2).	2	3	2	3
N2	All	Increased resuspension/mobilization and export of toxic compounds w/impact on covered species (consider sensitivity to changes in land use - none stated in assumptions)	1-2	2		
N1	All	Increased MeHg and impact on covered species (on floodplain and downstream)	1-2	2		
N3d2	Chinook salmon-juvenile	Increased stranding of covered species (consider grading proposed in the approach)	2	4	2	4
N3d1	Chinook Salmon-Adults	Increased stranding of covered species (consider grading proposed in the approach)	1	4	1	4
N5a	Delta smelt	Increased habitat for predators/competitors to covered species	2	3		
N5d	Green & White Sturgeon	Increased habitat for predators/competitors to covered species	1	3		
N3b	Green & white Sturgeon-adult & juvenile	Increased stranding of covered species (consider grading proposed in the approach)	1	4	1	4
N5b	Longfin smelt	Increased habitat for predators/competitors to covered species	2	3		
N5c	Splittail	Increased habitat for predators/competitors to covered species	2	4		
N3a	Splittail- adult and juvenile	Increased stranding of covered species (consider grading proposed in the approach)	1	4	1	4

			Scenario 2a		Scenario 2b	
Outcome Code	**Covered Spp.**	**Description**	**Magnitude**	**Certainty**	**Magnitude**	**Certainty**
Negative Outcomes (contd.)						
N5e	Steelhead & Chinook salmon	Increased habitat for predators/competitors to covered species	2	4		
N3c1	Steelhead- Adults	Increased stranding of covered species (consider grading proposed in the approach)	1	4	1	4
N3c2	Steelhead- Juvenile	Increased stranding of covered species (consider grading proposed in the approach)	2	4	2	4

Scenario 2a

Period of Potential Operation: December 1-May 15
Desired Duration of Inundation: 45 days
Target Spill Discharge into Bypass: 4000 cfs
Predicted area of inundation: 22,982 acres
Predicted mean depth of inundated area: 2.2 feet
Predicted travel time: 6.5 days
Spill Frequency of Fremont Weir (assuming 4000 cfs and 45 day duration with a spill intermission of no more than 7 days): 48% of years (38 of 79), compared to 6% of years (5 out of 79) at existing weir height.

Scenario 2b

Period of Potential Operation: January 1-April 15
Desired Duration of Inundation: 30 days
Target Spill Discharge into Bypass: 2000 cfs
Predicted area of inundation: 17,421 acres
Predicted mean depth of inundated area: 2.3 feet
Predicted travel time: 9.3 days
Spill Frequency of Fremont Weir (assuming 2000 cfs and 30 day duration with a spill intermission of no more than 7 days): 54% of years (43 of 79), compared to 6% of years (5 out of 79) at existing weir height.

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P4f	Chinook salmon	Increase frequency and magnitude of export of DOM, POM and organisms from seasonal floodplain to provide food in Delta for delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon	2	2
P2d	Chinook salmon	Create additional juvenile rearing habitat for splittail, green and white sturgeon, steelhead and Chinook salmon	3-4	3-4
P8a	Chinook salmon	Increase survival of out migrating juveniles by providing mitigation route with lower predation and entrainment (at North and South Delta diversions) risk.	3-4	3
P7a	Delta smelt	Increase delivery of readily suspendable sediments to Prospect Is and improved DS habitats	3	2
P5a	Delta smelt	Increase transport of OC and organisms from Prospect/Miner Sl tidal marshes to support Delta foodweb for DS, LS, CS, splittail, steelhead, G/W sturgeon	3	2
P4a	Delta smelt	Increase export of DOM, POM and organisms from seasonal floodplain to provide food in Delta for DS, LS, CS, splittail, steelhead, G/W sturgeon	3	3

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes (contd.)				
P4d	Green & White Sturgeon	Increase frequency and magnitude of export of DOM, POM and organisms from seasonal floodplain to provide food in Delta for delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon	1	2
P2b	Green & White Sturgeon	Create additional juvenile rearing habitat for splittail, green and white sturgeon, steelhead and Chinook salmon	1	2
P4b	Longfin smelt	Increase frequency and magnitude of export of DOM, POM and organisms from seasonal floodplain to provide food in Delta for delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon	2	2
P4c	Splittail	Increase frequency and magnitude of export of DOM, POM and organisms from seasonal floodplain to provide food in Delta for delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon	4	4
P3a	Splittail	Increase production of food for rearing of CS, splittail, steelhead, (onsite = seasonal floodplain only)	4	4
P2a	Splittail	Create new juvenile rearing habitat for CS, splittail, steelhead, G/W sturgeon (esp. for American River CS and steelhead)	4	4

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes (contd.)				
P1a	Splittail	Create new spawning habitat for Splittail	4	4
P6a	Steelhead	Increase in upstream migration opportunity for CS and steelhead	2	2
P4e	Steelhead	Increase production of food for rearing Chinook salmon, steelhead, green and white sturgeon, and splittail from inundation and riparian vegetation (local)	2	2
P2c	Steelhead	Create additional juvenile rearing habitat for splittail, green and white sturgeon, steelhead and Chinook salmon	3	3

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Negative Outcomes				
N4a	All	Reduced flows in Sacramento River and distributaries to support successful outmigration.	2	3
N2a	All	Increased resuspension/mobilization and export of toxic compounds w/impact on covered species (consider sensitivity to changes in land use - none stated in assumptions)	2	2
N1a	All	Increased MeHg and impact on covered species (on floodplain and downstream)	2	3
N3d1	Chinook salmon-adults	Increased stranding of covered species	1	4
N3d2	Chinook salmon-juvenile	Increased stranding of covered species	2	4

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Negative Outcomes (contd.)				
N5a	Delta smelt	Increased habitat for non-native predators/competitors to covered species	1	3
N6a	Delta smelt & Longfin smelt	Decrease in turbidity downstream of Yolo and reduction in habitat for delta smelt and longfin smelt	1	3
N5d	Green & White Sturgeon	Increased habitat for predators/competitors to covered species	1	2
N3b	Green & White Sturgeon	Increased stranding of covered species	1	4
N5b	Longfin smelt	Increased habitat for predators/competitors to covered species	1	3

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Negative Outcomes (contd.)				
N3a1	Spilttail- Adults	Increased stranding of covered species	1	4
N3a2	Spilttail- Juvenile	Increased stranding of covered species	2	4
N5c	Splittail	Increased habitat for predators/competitors to covered species	1	3
N5e	Steelhead & Chinook salmon	Increased habitat for predators/competitors to covered species	1	3
N3c1	Steelhead- Adults	Increased stranding of covered species	1	4
N3c2	Steelhead- Juvenile	Increased stranding of covered species	2	4

Outcome Code	Covered Spp.	Description	Scenario 1 Magnitude	Scenario 1 Certainty	Scenario 2 Magnitude	Scenario 2 Certainty
Positive Outcomes						
P1a	Delta smelt – adult	Reduce entrainment induced mortality of covered fish species from the western Delta.	2	3	3-4	2-3
P1b	Delta smelt - Larval	Reduce entrainment induced mortality of covered fish species from the western Delta.	2	1	2-3	2
P1c	Longfin smelt – Adult	Reduce entrainment induced mortality of covered fish species from the western Delta.	1	3	2-3	2
P1d	Longfin smelt – Larval	Reduce entrainment induced mortality of covered fish species from the western Delta.	1-3	2	1-3	2
Negative Outcomes						
N3a	Delta smelt	The gate structure may be conducive to higher predator presence and therefore the risk of predation on covered fish species may increase	2	2		
N2a	Delta smelt	When closed, the gates could increase entrainment and mortality of Delta smelt in the central and southern Delta.	2	2		
N3c	Longfin smelt	The gate structure may be conducive to higher predator presence and therefore the risk of predation on covered fish species may increase	1	2		
N2b	Longfin smelt	When closed, the gates could increase entrainment and mortality of Delta smelt in the central and southern Delta.	2	2		

Scenario 1 D-1640 Baseline

Scenario 2 OCAP delta smelt BO

Appendix F-2

DRERIP Worksheets

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WOCM1
Dual Conveyance
(New North Delta Diversions with Hood Bypass Criteria and other Measures)

Scientific Evaluation Worksheet

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Action

Construct new diversion facilities in the North Delta along the Sacramento River between Walnut Grove and Freeport with a capacity to divert up to 15,000 cfs. The new diversions would be operated to divert large amounts of water during wet periods and less in dry periods. No diversion would be allowed unless flows downstream of the diversion points exceed minimum flow requirements known as the Hood Bypass Flow Criteria. Additional description of this action provided below.

Evaluation Team

John Cain (chair), Denise Reed (coach), Bruce Herbold (coach), Matt Nobriga, Wim Kimmerer, Steve Detwiler, David Fullerton, John Burke, Rick Wilder, Rosalie del Rosario, Josh Israel, Tracy Hinojosa, Rick Sitts, Chuck Hanson, Neil Clipperton (note-taker).

Date of Last Revision: June 3, 2009

Action Description and Clarifying Assumptions

For the DRERIP analysis, the following two by-pass flow Scenarios were evaluated:

Scenario 1- Mid-Range Hood Bypass Criteria (See figures 1 and 2).

- December 1 through June 30 maintain a Sacramento River bypass flow of not less than 11,000 cfs;
- July 1 through August 30 maintain a Sacramento River bypass flow of not less than 5,000 cfs;
- September 1 through November 30 maintain a Sacramento River bypass flow of not less than 7,000 cfs for fall salmon attraction and migration;
- Require at least 55% of river flows above minimum bypass flows during February-April, 45% during January and May, and 35% during December and June (see figure 2)[1].

Scenario 2 - Low (5,000 cfs) Hood Bypass Criteria (See figures 1 and 2).

- Set minimum bypass flow of 5,000 cfs year round except as provided in the bullet below;
- Require at least 55% of river flows above 5,000 cfs during February-April, 45% during January and May, and 35% during December and June (see figure 3) to maintain the shape of the hydrograph.

[1] For example, if there is 12,000 cfs inflow above diversion point during February, 450 cfs can be diverted and 11,550 must flow past diversions point as Hood Bypass flow.

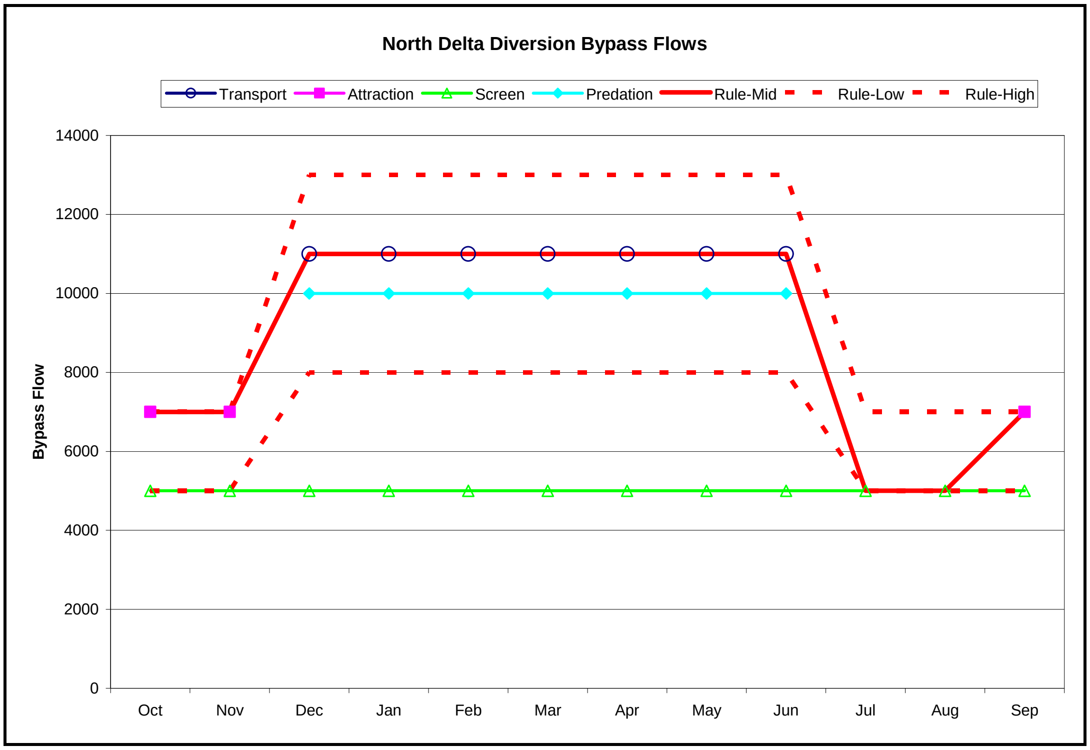

Figure 1. DRAFT Consultant's proposal for minimum Hood bypass flow rules: One rule at "Mid-range" ("Rule-Mid" or 11,000cfs) and second "5,000cfs rule" at minimum flows for fish screen ("screen") function.

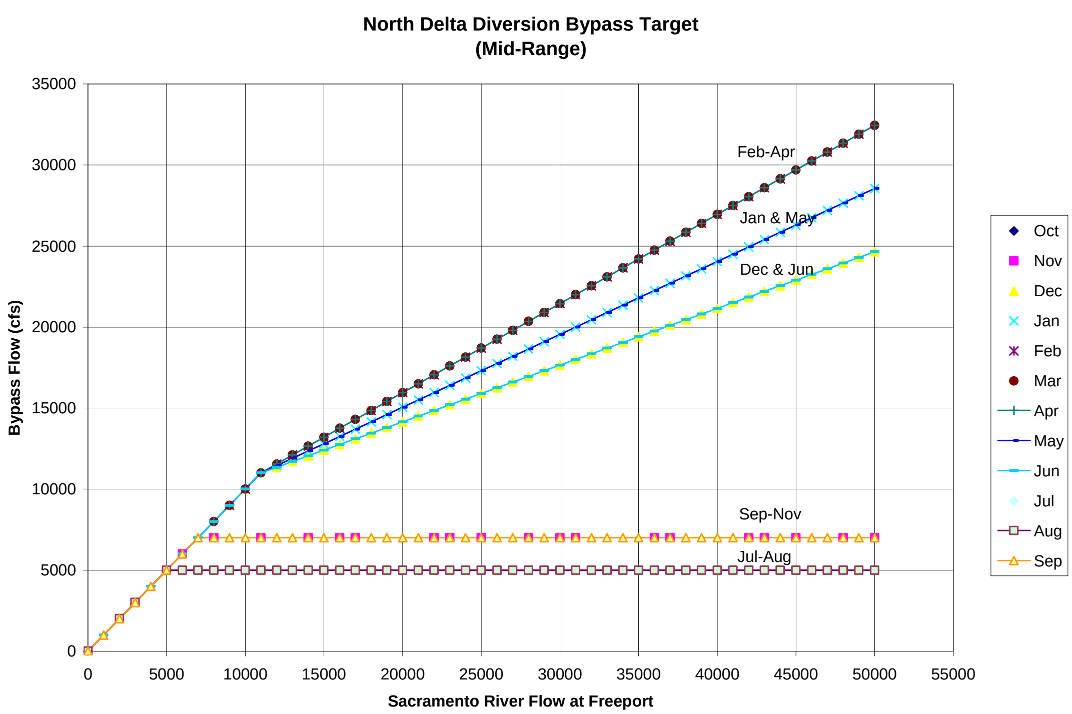

Figure 2. Consultant proposed minimum north Delta diversion bypass flows depicted as a function of Sacramento River flow for the "mid-range rule."

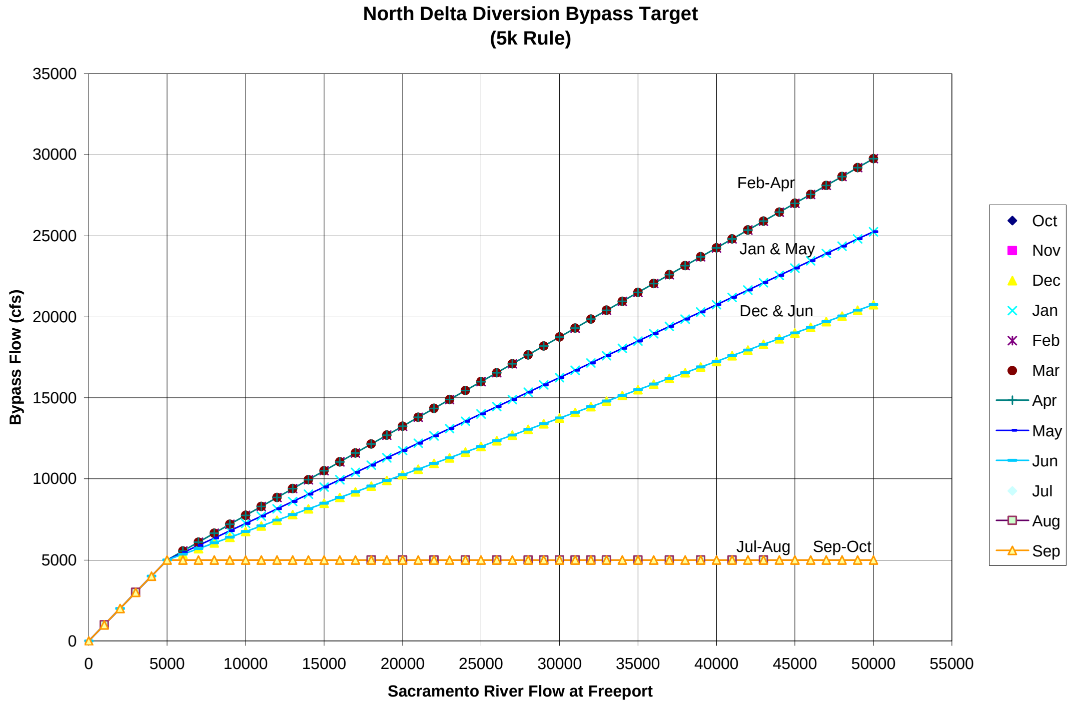

Figure 3. Consultant proposed minimum north Delta diversion bypass flows depicted as a function of Sacramento River flow for the 5,000cfs rule.

Approach

This action will be implemented in combination with several other actions and changes to the Delta environment described in greater detail in "*An Overview of the Draft Conservation Strategy for the Bay Delta Conservation Plan*", dated January 12, 2009. For the DRERIP analysis, the following was assumed:

1. **Total Diversions and Outflow:** Preferentially divert from the North Delta. Assume existing D-1641 outflow requirements, but 2-10% greater diversions than D-1641, depending on the scenaro.
2. **Diversion Infrastructure:** Five or more diversion intakes b/t Freeport and Walnut Grove each with a diversion capacity of 3,000 cfs or less.
   a. State of the art fish screens will prevent entrainment of juvenile fish (salmon, steelhead, sturgeon etc.) and will be operated to minimize entrainment of larval life stages of delta smelt and striped bass.
   b. All relevant screens are operating as designed 100% of the time that water is being diverted and are efficient at proposed operational flows.
   c. Individual diversion structures are sufficiently spaced to allow for recovery in between involuntary encounter with screens.
3. **Delta Cross Channel gate operations:** Closed from November through June and be open during July and August. In September and October, the Delta Cross Channel (DCC) would be open half the time, but actively operated to minimize harm to covered species through strategies such as a diel closure schedule.
4. **Cache Slough Tidal Habitat:** 10,000 acres of tidal marsh restoration will likely reduce tidal excursion up Steamboat and Sutter Sloughs. Development of tidal marsh may take time and may or may not achieve target area.

5. **South Delta Exports:** Preferentially divert from North Delta and only utilize South Delta diversions when diversions from North Delta are not adequate to meet D-1641. Minimum 14-day average OMR flows for July through November set at -5,000 cfs. Minimum 14-day average net OMR flows for December through June set at -3,500 cfs**.**
6. **Evaluation Baseline:** Evaluators considered population level effects relative to existing conditions.

Intended Outcomes as Stated in Conservation Measure

1. Reduced entrainment of juvenile San Joaquin, Mokelumne, Calaveras, and Cosumnes salmon and steelhead (March-June) in the South Delta (some runs were not evaluated).
2. Reduced entrainment in the south Delta of adult delta smelt that move east of Jersey Island (December-January).
3. Reduced entrainment of larval delta smelt (March-May).
4. Expand the potential to restore tidal habitat in the southern Delta.

Information Regarding Intended Outcomes

San Joaquin Chinook Salmon

The action implies that a dual conveyance system, as described in Scenario 1 or 2, would reduce entrainment of juvenile San Joaquin Chinook and steelhead. However, the following information must be considered in evaluating the action:

1. Very little San Joaquin River water makes it to the western Delta (at Jersey Point) except in the wet season of the wetter years (Fig 3-8, BDCP Draft Technical Memorandum, Feb 2009; Kimmerer and Nobriga 2008). Compared to the Reference Scenario (D-1641), this improves somewhat with Scenario 1 in the wetter years but there is no noticeable difference in the drier years.
2. Spring flows in the San Joaquin basin are correlated with adult returns 3 years later (Speed 1993) and survival of outmigrating smolts (SJRGA 2007)
3. South Delta Exports: Vernalis flow ratios are inversely correlated with adult production and juvenile survival. However, this relationship is not as strong as Vernalis flows alone. The action does change the Vernalis flows to south Delta exports ratio, with substantially lower TD:VNS ratios with Scenario 1. However it is not clear this change is sufficient to improve problems associated with low San Joaquin River flows.
4. Reduced negative OMR relative to D-1641 baseline may not be sufficient to ensure better passage of steelhead and Chinook emigrating from the San Joaquin basin.

Sacramento Chinook Salmon Runs

1. The North Delta serves as the primary rearing and migratory corridor for Sacramento anadromous fishes in the Delta.
   a. Juvenile Chinook salmon that rear in the Delta (spring-run, fall-run, and winter run) are assumed to be influenced by changes in critical habitat such as lowered river stages and associated reductions in cover and food availability and accessibility. It is assumed steelhead also rear in the Delta.
   b. Based on previous research, salmon migrating into the Delta as smolts are assumed to be negatively influenced by increased residence time and routing into Central and south Delta channels. Potential for entrainment in the south Delta persists in both of the proposed scenarios, though to a lesser extent.

   c. Upstream migrating adult salmon are assumed to have sufficient attraction flows (via Rio Vista requirements) and unimpeded passage (via Fremont Weir modifications).
   d. Sacramento River green and white sturgeon stage during the late winter and spring in the north Delta before migrating up the Sacramento River as late as May. Sturgeons typically reside close to spawning habitats in the river, and water temperatures appear to be a critical cue for spawning activity.
2. The potential direct impacts of Sacramento River diversions on juvenile anadromous fishes have not yet been assessed. This includes the effects of impingement (multiple and repeated), the efficiency and effectiveness of large fish screens and the degree to which aggregations of predators will reduce survival past the diversions. The fish facilities technical team assumes meeting screening according to DFG/NMFS criteria is sufficiently protective (R. Wantuck, personal communication, January 28, 2009).
3. Of particular importance to Sacramento juvenile anadromous fish habitat are the months of November through May, when juvenile anadromous fishes emigrate in relatively high abundance.

There are several major assumptions in this action

1. Dual conveyance reduces entrainment of juvenile (e.g., spring-run) Chinook salmon at South Delta Facilities assumes:
   a. The primary mechanism for entrainment at South Delta Facilities is reverse flows towards CVP/SWP facilities indexed by OMR.
   b. The likelihood of entrainment is increased when DCC gates are open during migratory period.

2. Dual conveyance affects the probability of juveniles reaching Chipps Island via two mechanisms:
   a. migration route: lower likelihood of Central and South Delta routes due to more positive OMR, increased QWEST, and DCC closure.
   b. Transport time: delayed travel time for outmigrating smolts through the north Delta increases risk of mortality through exposure to predation and rerouting to less favorable routes.

It is not possible to eliminate south Delta entrainment because water – and by extension some component of migratory fish populations – is transported by both tidal dispersion and the advective (net) flow of the rivers (Kimmerer and Nobriga 2008). Since both tides and river flows influence transport, it is possible for small percentages of water (and by extension fish) to be entrained in the south Delta from the Sacramento River even when river flows are high relative to exports (see Figure 5 in Kimmerer and Nobriga 2008). Thus, Sacramento basin juvenile salmon are still subject to South Delta entrainment when OMR is positive or slightly negative. This is even more pronounced for particles (fish) originating in the San Joaquin basin from which even very low export:inflow ratios are associated with high particle entrainment risk (see Figure 6 in Kimmerer and Nobriga 2008, and Appendix B). Although OMR is more positive under both dual conveyance Scenarios, the range of flows still encompasses reverse flows when juveniles are present and the frequency of fish entrainment increases when OMR flows are negative (see Appendix B). Negative OMR flows are correlated with high numbers of fish salvaged. Under Scenario 1, mean OMR flows in April are -1,400 cfs, yet under current conditions, daily salvage of winter-run and spring-run sized fish, occurred when OMR flows were greater than 1,400 cfs in April (see Appendix B). The occurrence of winter-run sized fish in the salvage facilities indicate fish from the Sacramento basin may be entrained via mildly negative OMR flows.

Scenario 1 would provide desirable conditions for outmigrating smolts only during spring. However, both dual conveyance Scenarios would create *undesirable* conditions for outmigrating smolts in fall and winter. This is based on Particle Tracking Modeling[2] (PTM) for the north Delta.

River stage for north Delta migratory corridors under either dual conveyance Scenario is lowered throughout the year, and at times lowered by ~30%. This will translate to reduced rearing habitat along sloughs and the mainstem Sacramento River.

North Delta diversions would decrease discharge in migratory sloughs[3], such that reverse flows in Sutter and Steamboat Sloughs would be more frequent. Reverse flows in migratory corridors during smolt migration increases risks to predation, routing into the Central Delta, and/or injury from more passes by fish screens.

Delta Smelt

The cause and effect relationship is a non-linear relationship between adult delta smelt salvage at the Banks and Jones diversions and OMR flows. A specific threshold for OMR flows above which salvage increases is not provided in Norbriga and Herbold, 2008. The CALSIM/DSM2 model constrains OMR flow for this action to -3500 cfs. Under D-1641, winter OMR was often more negative than -3500 cfs. Given the less negative OMR flows that stemmed from the modeling to support this proposed action, it is possible the action would protect most adult delta smelt and essentially all adult longfin smelt from entrainment at Banks and Jones pumping plants.

Although benefit to longfin smelt is not one of the originally intended outcomes, data from Grimaldo et al. (in press) indicate longfin smelt entrainment is rare when OMR is less negative than -5000 cfs.

Assumptions

Provided in BDCP Conservation Measure

1. See “Approach” and “Information Regarding Intended Outcomes” sections above.

Added by Evaluation Team

For purposes of this evaluation, the Team assumed that:

1. South Delta water export facilities remain in their current configuration (i.e. no modifications).
2. The baseline is equivalent to D1641 (i.e. Pre-Wanger type of operation). The 2008-2009 Biological Opinions are not considered part of the baseline.
3. D1641 includes VAMP with a San Joaquin River pulse flow in April-May.
4. New fish screens will operate at 100% efficiency, 100% of the time.

Problem(s) with Action as Written:

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[2] PTM end of 45 days; and 50% particles. Median monthly flows are from Calsim II Inputs of Sacramento River at Hood, Reference Conditions.

[3] “Preliminary Modeling Evaluation of Draft Conservation Strategy Core Elements” Update to BDCP Steering Committee, January 30, 2009. Powerpoint presentation, slide 11.

1. **Intended Outcome 1**: The Evaluation Team felt that Sacramento River salmonids should be added to the list of species to be evaluated because they are also entrained at the SWP and CVP facilities. There may be some effect on Mokelumne and Cosumnes river salmonids but this was not evaluated. Sturgeon were also added to the evaluation. The wording of Outcome 1 was changed from "entrainment…in the South Delta" to "mortality directly associated with South Delta project operations" because mortality from a suite of factors related to entrainment into south Delta channels and the pumping facilities seemed to be the relevant issue being addressed in this outcome. The date range (March-June) was removed from the outcome because there is no scientific basis to limit the analysis to only to this period.
2. **Intended Outcome 2**: As in intended Outcome 1, the wording of this outcome was changed from "entrainment" to "mortality directly associated with South Delta project operations". The Evaluation Team decided to add longfin smelt to the evaluation.
3. **Intended Outcome 3**: As in intended Outcome 1, the wording of this outcome was changed from "entrainment" to "mortality directly associated with South Delta project operations". The team also added longfin smelt to the evaluation of this outcome.
4. **Intended Outcome 4**: This outcome was not evaluated. The team concluded that it is not possible to evaluate the ecological value associated with the "potential" for habitat restoration.
5. **Fish Screens:** The assumption that the state of the art fish screens will eliminate entrainment at the intake facilities is untested. No similar set of structures as large as what is proposed exist on which this assumption can be fully evaluated. For the purpose of this evaluation, the team decided to accept the assumption because there are no data to support or refute it.
6. **Tidal Excursion:** The modeling supporting the assumption that tidal reintroduction to restore aquatic habitat in the Cache Slough area will substantially reduce tidal excursion up Sutter and Steamboat sloughs treats the "restored" areas as reservoirs that are filled with water. The analysis does not attempt to evaluate changes in tidal excursion as tidal marsh habitats are established over time.
7. **Modeling Notes:** Conclusions presented in this worksheet are sometimes based upon the modeling output presented by Armin Munevar from CH2MHill during our Team workshop on Jan. 21, 2009. These analyses rely heavily on the output of models, particularly CALSIM II and DSM2. The validation of these models for these analyses has not been peer-reviewed. Further, as in all models, the outputs depend heavily on the assumptions and parameters used as inputs. These include the operating rules, criteria, and limitations set by the proposed actions, as well as those included in the baseline. Changes in these rules as the actions are refined may alter the quantitative outcome of the Team's assessment. The models also use an 82-year historical record of flow as a boundary condition. Future patterns of flow, sea level, and temperature will be different from historical. This may cause the actual outcomes to diverge from the expected outcomes in terms of flow patterns, salinity, and exports. In particular, the shift to an earlier snowmelt peak forecasted by climate analyses has already been observed and rising sea level will increase the influence of tides in the project area. The Team suggests that future iterations of the analysis include sensitivity analysis with variations in operating criteria and precipitation patterns based on climate and sea level forecasts.
8. **Diversion Point Flexibility:** BDCP has proposed an assumption of 2-10% more water diversion than D1641 standards. A dual conveyance system would provide flexibility in switching between north and south Delta diversion points. However, this is not quantitatively demonstrated and this lack of quantitative information is problematic when analyzing potential outcomes in this worksheet. This Team recommends that BDCP

provide probability distributions of exports from the north vs. south Delta Diversion points that clarify the desired export rates.

Scale of Action

Large

Rationale:
This action will change the boundary conditions of the Delta on a landscape scale. It will change hydrodynamics and associated ecology throughout the Delta and Yolo Bypass.

Evaluation Summary Tables

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Outcomes Identified but Not Evaluated

Because of either marginal effects, limited time and/or the lack of specific information to support an evaluation, the following outcomes were identified by the team but were not evaluated:

- Entrainment of larval fish and eggs that can fit between fish screen mesh.
- Entrainment of juvenile salmon, steelhead, and sturgeon at non-project diversions in the Delta.
- Entrainment and predation mortality of Mokelumne and Cosumnes fall-run Chinook salmon and steelhead directly associated with South Delta project facilities and operations.
- Survival of out-migrating juvenile smelt due to increased travel time. Delta and longfin smelt are highly unlikely to spawn upstream of the North Delta diversions in large numbers. This may need to be re-evaluated if hydrodynamic modeling indicates strong reverse flows up the Sacramento River will frequently occur during smelt spawning migrations.
- Changes in reproductive success of salmon (egg-fry mortality) due to changes in reservoir storage and associated cold water pools.

Relation to Existing Conditions

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold? YES

Nature of Change: Adding additional points of diversion in the North Delta is beyond the scope of the current DRERIP models (including its Boundary Conditions model) and may exceed the conditions for which numerical models have been validated. For example, the conceptual models do not address the possibility of reverse flows on the Sacramento River, due to new diversions. They do not address the timing, magnitude and distribution of changes to Delta inflow that modeling indicates will result from new north Delta diversions. They do not specifically address fish passage at multiple long fish screens. Nor do they specifically address the changes stemming from major changes in Delta source water and water quality. Further, if the Delta's "plumbing" is changed, then ecological operating criteria (E/I ratio, X2) might need to be revisited. Given the dramatic change in the system presented by this proposal, the use of all models (conceptual, statistical and simulation) must be cautious. However, in the absence of any other information they have been used to the extent they can to support this evaluation.

Potential Positive Ecological Outcome(s)

Outcome P1: Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.

One of the key factors in evaluating the potential benefits of reduced entrainment and predation mortality associated with modified operations of South Delta project facilities is the presence of various covered fish species in the south Delta relative to the proposed operational modifications. Figures 4 and 5 below show the temporal distribution of salvage data for various Chinook salmon runs. These data provide an indication of when various runs are typically in the south Delta, including peak occurrence. These data are used throughout the evaluation below.

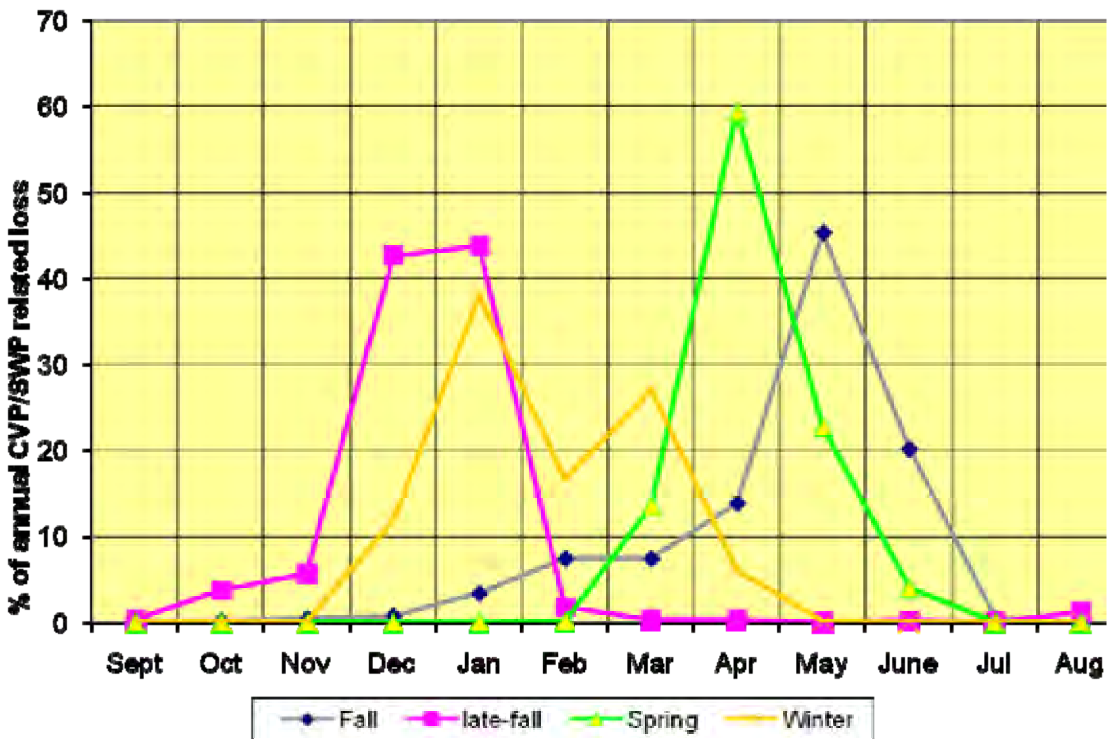


Figure 4. Temporal distribution of annual run-specific loss due to SWP/CVP pumping. Relative, run-specific loss associated with SWP/CVP pumping. Run-identification assignments based on expected size of each of the different runs on the date collected. Source: CDFG's Delta Fish Salvage Monitoring Unit.

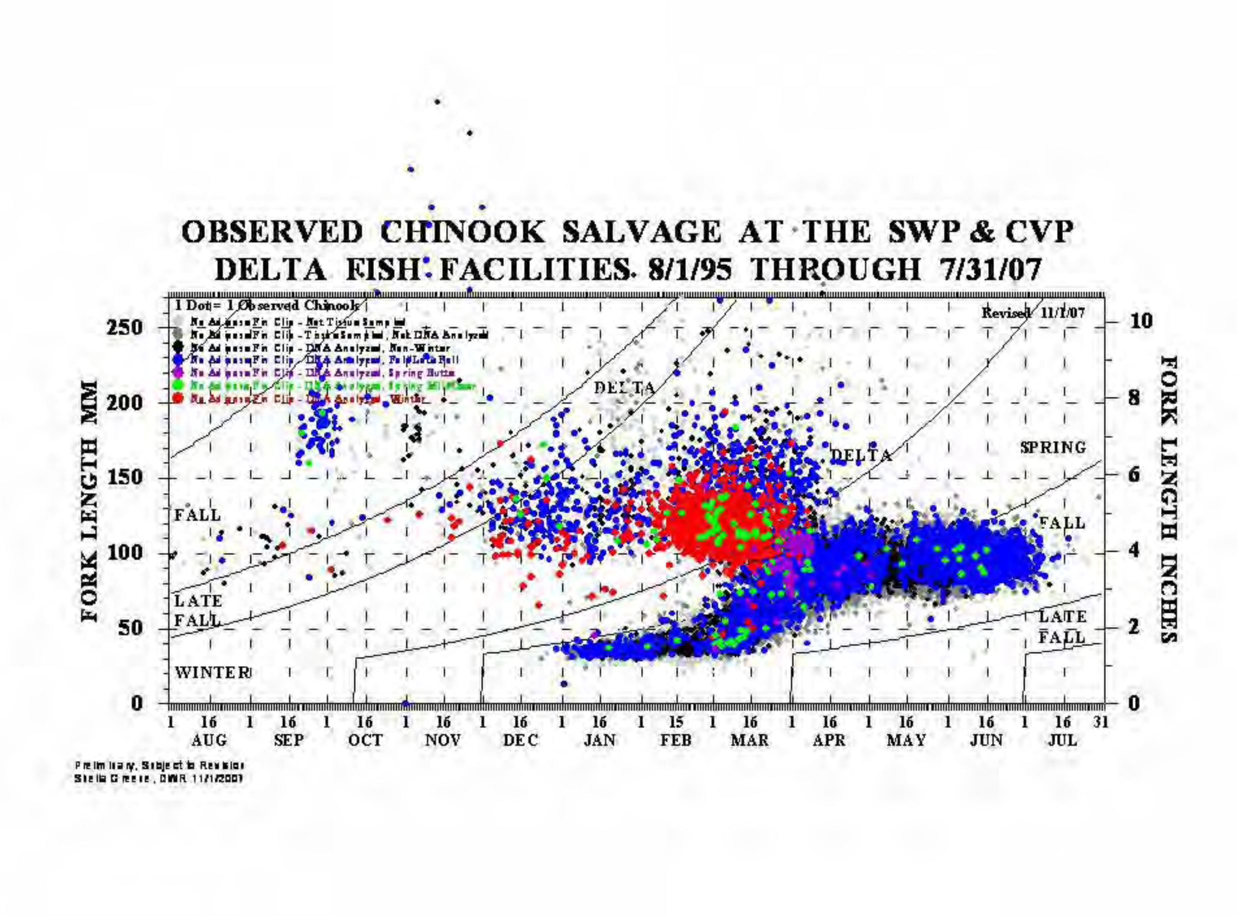
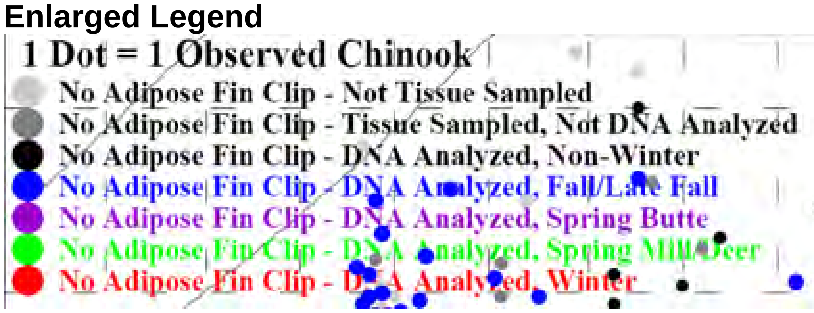


Figure 5. Observed Chinook salvage at SWP and CVP Delta Fish Facilities with DNA analysis. Source: Shiela Green, DWR,

Enlarged Legend



All the following information regarding correlations between survival and various other factors; must be used with a degree of caution in the evaluation of this action as the correlations do not provide information on mechanisms of mortality in the South Delta.

When export pumping is low, there can still be substantial salmon entrainment at the South Delta pumping facilities. However, the mechanisms affecting this entrainment are not well understood. As described in Appendix G, net flows, tidal cycles and salinity gradients all likely influence migratory patterns. Factors such as pumping, agricultural drainage influencing salinity gradients, and operation of barriers and gates (including the DCC) all likely interact to affect with the tidal cycles to influence salmon survival in the south Delta.

P1a. San Joaquin River fall-run Chinook salmon

This evaluation assumes San Joaquin River (SJR) system fall-run are not vulnerable to losses at the Hood facility.

With a North Delta diversion, water would be exported from the south Delta throughout the year, with monthly averages ranging from 1,900 cfs to 4,500 cfs (Scenario 1). Under certain conditions (in Scenario 1) the composition of source water changes at key regions of the Delta when compared to the reference Scenario (Figures 6a-b).

- Water in Old River at Tracy Road is predominantly San Joaquin water, with Sacramento water being drawn during critical years (Fig 3-9, BDCP Draft Technical Memorandum, Feb 2009).
- Very little of the San Joaquin River water makes it to the western Delta (at Jersey Point) except in the wet season of the wetter years (see Appendix H: Water Source Fingerprinting and Kimmerer and Nobriga 2008). Scenario 1 provides some improvements in the wetter years but there is no noticeable difference in the drier years.
- During the Vernalis Adaptive Management Program (VAMP) period, CVP + SWP exports are positively correlated with Vernalis flows (p. 65, Fig 5-16; 2005 SJRGA).

San Joaquin Chinook juveniles are bimodally distributed in the Delta system with a winter peak of small juveniles (<50 mm) entering the Delta in some years with high winter flows between January and March, and in all years a larger spring peak of outmigrating smolts (>70 mm) between April and June (2005 SJRGA).

- Reported numbers of fry and pre-smolt fish are generally underrepresented because salvage and trawls are less effective at capturing fry and pre-smolts (p. 69, 2007 SJRGA).

The San Joaquin River flows at Vernalis in the spring months are correlated with increased numbers of adult Chinook salmon returning to the San Joaquin Basin in subsequent years, as well as increased survival of outmigrating San Joaquin juvenile Chinook to Chipps Island.

- Adult escapement of San Joaquin Chinook salmon is positively correlated with increasing San Joaquin River flow at Vernalis (Fig 5-20, 2005 SJRGA; Marston and Mesick 2006; Dean Marston, DFG, unpublished data). High Vernalis flow to export ratios are also correlated with higher adult escapement in the San Joaquin Basin (Fig 5-21, 2005 SJRGA; Dean Marston, DFG, unpublished data).
- Survival of outmigrating juveniles increases with increased San Joaquin River flows, and in some cases this relationship is statistically significant. (Newman 2008; SJRGA 2007, p. 76; 2004, 2005, 2006 SJRGA). This relationship is more variable without the Head of Old River Barrier in place. Fewer fish are salvaged at CVP/SWP facilities when Vernalis flows are higher (2005 SJRGA).

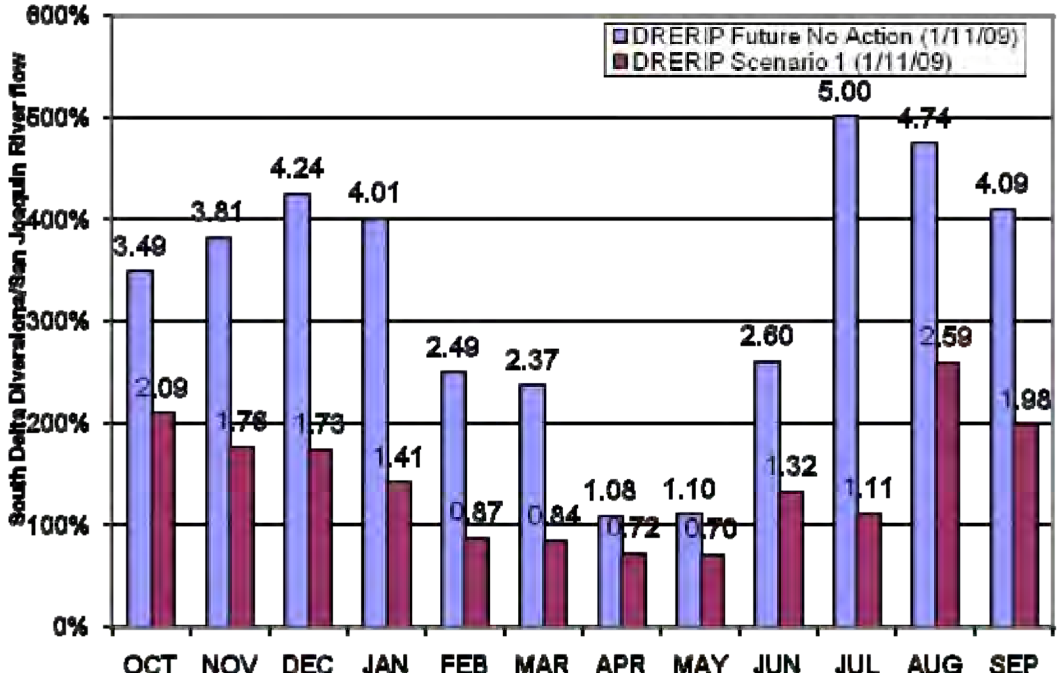


Figure 6a. Project South Delta Exports as Percent of SJR Flow (Scenario 1 & Reference)

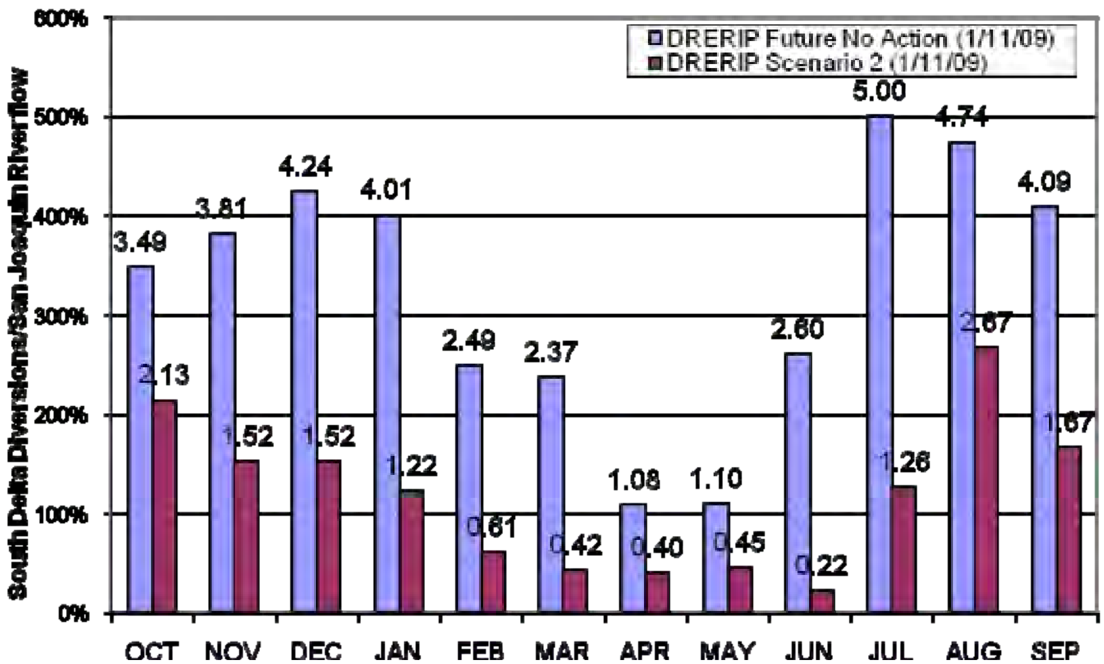


Figure 6b. Project South Delta Exports as Percent of SJR Flow (Scenario 2 & Reference)

The assumption that San Joaquin fish are entrained at pumps can be supported by comparing salvage to the timing, abundance, and size of salmon collected in San Joaquin basin monitoring, such as San Joaquin tributaries, San Joaquin River at Mossdale and salvage facilities (2007 SJRGA, p. 66).

- Timing of salvage rate and fish size can be compared with Mossdale trawl data and CWT recovery data for Merced River Hatchery smolts at the salvage facilities to provide indications as to the origin of the unmarked fish (p. 60, 2007 SJRGA). When marked Chinook juveniles are released in the San Joaquin tributaries some of them are recovered at the CVP/SWP fish facilities (Fig 5-29, 2005 SJRGA).
- During Jan-June, the size distribution of unmarked salmon in the Mossdale trawl overlaps with that of salmon salvaged at the fish facilities (p. 60; figure 5-25, 2007 SJRGA; p. 68 2006 SJRGA).

A high South Delta export to Vernalis flow ratio is positively associated with juvenile Chinook salvage at the CVP/SWP facilities (Figures 5-23 and 5-24 of 2007 SJRGA, p. 77 of 2007 SJRGA). However, the strength of this relationship is limited by the narrow range of exports (1,500-3,000 cfs) during the VAMP period (p. 63, 2005 SJRGA).

- San Joaquin adult escapement (2.5 years later) is higher when Vernalis flow to Export ratios increases (Fig 5-21, p. 69; 2005 SJRGA).
- San Joaquin juvenile survival to Chipps Island is higher when Vernalis flow: Export ratio is high (Figs 5-14, 5-15, 2005 SJRGA).
- Survival of juvenile CWT Chinook during VAMP period was positively correlated with Vernalis flow: Export ratio (p. 65, Fig 5-14; and p. 66 Fig 5-17, 2005 SJRGA).

According to Newman (2008): Flow was positively associated with the probability of surviving from Dos Reis to Jersey Point. San Joaquin fish that avoid Old River by either being released downstream (i.e. at Dos Reis) or due to HORB being in place had higher survival rates. But flows are lower by design when the barrier is in place so flow effect on survival is clouded. For fish entering Old River, there was little evidence for an association between exports and survival. With the HORB in, survival of coded wire tagged San Joaquin fish was positively associated with San Joaquin River flow but was not associated with exports. Newman (personal communication, May 4, 2009), however, explains the evidence for associations between exports and survival is likely swamped by the level of environmental noise in the south Delta, and the observations used in the analyses are limited by the narrow range of observed ratios between export and San Joaquin River flows.

Magnitude = 1 - Minimal

The water fingerprinting model results that show very little SJR water makes it past Jersey Point as shown in Appendix H: Water Source Fingerprinting. VAMP studies show very low survival during all years except when flow in SJR is high. As long as ratio of export to SJR flow is high, correlations indicate that entrainment of SJR fall Chinook will continue, and not be reduced. Figure 6b shows the ratio is reduced in both Scenarios in the January -June timeframe. However, even low negative flows on OMR will not prevent SJR salmon from being entrained to the pumps so this does not alter the score for Scenario 2. These effects could be better identified with examination of the effect of water year status on monthly changes in the flow ratio (e.g., the entire 82 year run as a box plot rather than simply the mean for each Scenario).

Certainty = 4 - High

Published studies indicate that San Joaquin Chinook salmon survival in the south Delta is influenced by multiple factors and is strongly correlated with San Joaquin River flows.

It is highly certain, based on these data that measures to address south Delta pumping alone will have a minimal effect on San Joaquin Chinook salmon populations without simultaneously addressing other factors such as San Joaquin River flows. The central and south Delta are known zones of entrainment under current water management regimes.

P1b. Sacramento Spring-run Chinook salmon

The focus here is on spring-run juveniles though the same rationale can be used, with consideration for changes in temporal distribution, for other runs of Chinook, and steelhead. Figure 4 shows that spring-run occur in the south Delta Feb-June with a peak in April.

The primary mechanism for juvenile entrainment at the South Delta Facilities is reverse flows towards CVP/SWP facilities via OMR. OMR flows are negative year round (Figure 7a) and draw Sacramento basin salmon into the SWP and CVP facilities. Evidence of entrainment of Sacramento fish at the SWP and CVP facilities is documented by genetically analyzed salvaged fish (Figure 5), as well as recovery of Coleman Hatchery late-fall releases at the facilities within weeks and months of release (data from 2004-2008 provided by Sheila Greene, DWR, unpublished data). Juvenile spring-run sized-fish are subject to entrainment when OMR is negative (Figures 7a-c).

Peak salvage of spring-run sized fish occurs in April, followed by March and May. (Source - Appendix B: OMR vs. Salvage Relationship Graphs).

Magnitude
Scenario 1: 2- Low
Scenario 2: 3 - Medium

Figure 7b shows negative OMR flows during spring-run migratory period still occur under Scenario 1. Under Scenario 1, median OMR flows are at least -1,400 cfs during April. During spring-run presence, Scenario 2 median OMR is negative only in May (Figure 6c). Because peak salvage occurs in April, Scenario 2 would be more protective than Scenario 1. Spring-run are salvaged at the pumps between March and June with a peak in April (see Figure 4 on page 11). This suggests a larger benefit based on improved OMR flows in February and March (both Scenario 1 and 2 have relatively good February and March OMR flows). However, as salvage does not peak until April, the importance of February OMR flows is not clear.

Certainty = 3
Species are present in the system when water is conveyed through the Delta. Juveniles are rearing or migrating through the Delta starting in November through May (data from DFG Knights Landing; CVP/SWP salvage; FWS trawl and beach seine). DFG salvage data shows juvenile spring-run are entrained at South Delta facilities.

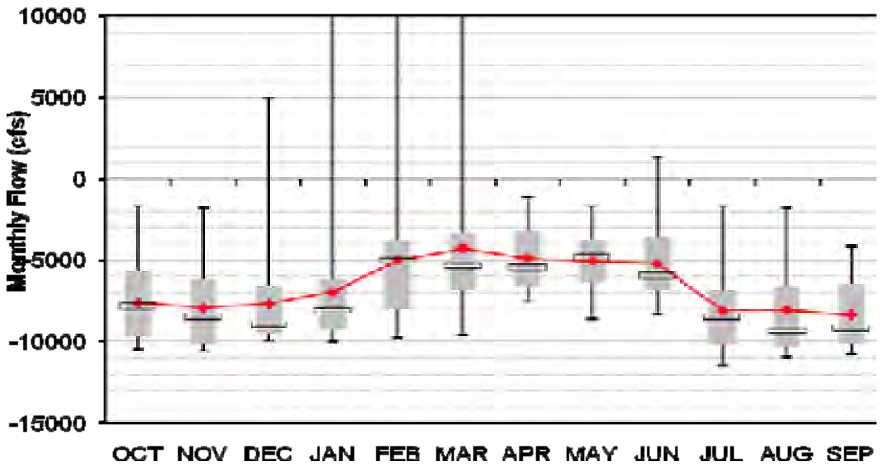


Figure 7a. Combined Old and Middle River Flows (Reference Conditions)

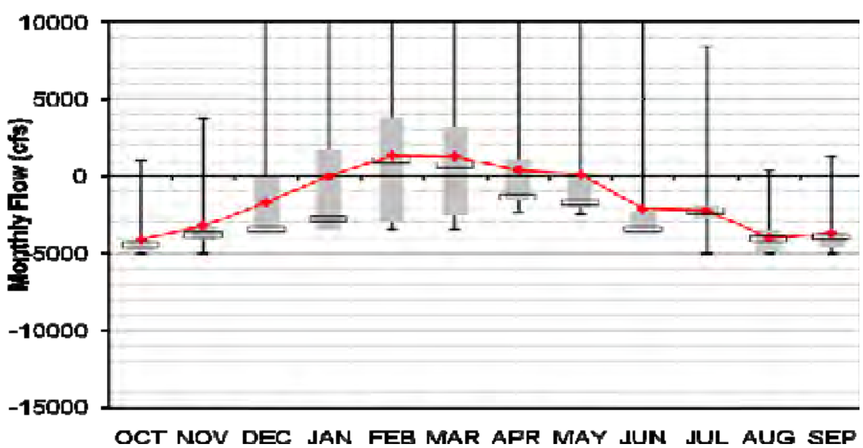


Figure 7b. Combined Old and Middle River Flows (Scenario 1)

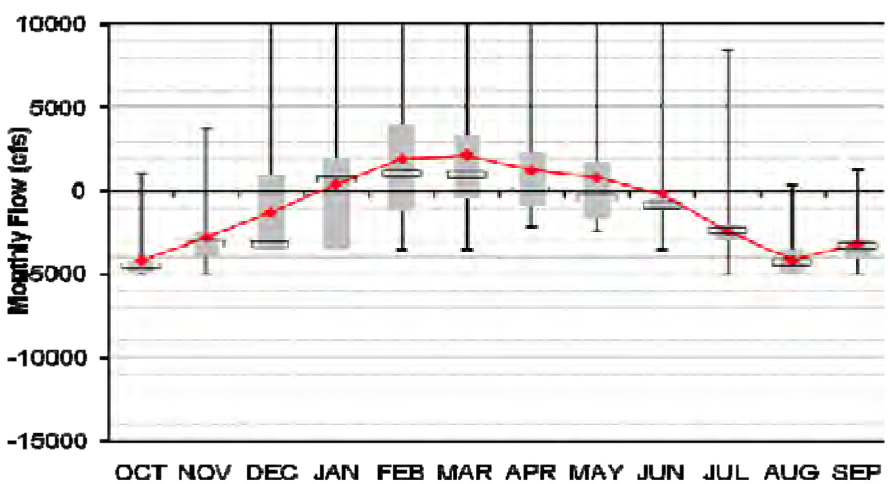


Figure 7c. Combined Old and Middle River Flows (Scenario 2)

P1c. Sacramento fall-run Chinook salmon

Sacramento fall-run Chinook are salvaged between December and June with a peak in May (see Figure 4). USFWS (2000) described the presence of juvenile fall-run Chinook from multiple monitoring sites in the central and south Delta during this period with a peak during February. These data included information on water year type and Chinook present later in the winter (March and April) in this region of the Delta appear to make up a larger proportion of the spring/fall Chinook captured in these locations during above normal and critical years than in wet years, when a larger proportion appears to emigrate earlier in the winter. OMR flows under the two Scenarios are both better than the reference conditions, (Figures 7a-c). It seems operation of south Delta diversions will produce higher fall-run Chinook juvenile mortality under Scenario 1 than under Scenario 2, due to the greater duration and earlier start of negative OMR flows.

One confounding factor is that the origin (hatchery vs. natural) of the fish reported on in USFWS 2000 is unknown.

Magnitude
Scenario 1: 2 - Low
Scenario 1 is similar to the reference condition and will expose fall run Chinook to negative OMR flows (and thus presumably levels of entrainment) closer to the reference condition earlier in the spring. Mortality will likely be reduced, but a significant period of emigration will still be subject to negative OMR flows (Figure 7b).; A negative (-) 2000 ± 500 OMR is associated with increased salmonid entrainment risks during April and May (see Appendix B). It is likely there is limited effect on productivity and diversity of fall Chinook due to this reduced mortality in the south Delta compared to the reference condition.

Scenario 2: 3 - Medium
Scenario 2 is less similar to the reference condition and will expose fall run Chinook to negative OMR flows at the tail of the fall run juvenile emigration period through the Delta (Figure 7c). Given the periodicity of fish and OMR flows, reduced mortality in the south Delta may have a minor population effect on fall run Chinook juvenile mortality.

Certainty = 3 - Medium
Salvage data are available to show entrainment on this run and modeling results show that the improvement in OMR flows occurs in many year types.

P1d. Late-fall-run Chinook salmon

Late fall run Chinook appear to emigrate out of the mainstem earlier than fall-run Chinook salmon, which belong to the same ESU. Late fall run Chinook are salvaged in August to June with a peak in January, and moderate levels of salvage in November, December and February (see Figure 4 and Figure 5 - DNA analyses conducted by USFWS) OMR flows under the two scenarios are both increased (less negative) compared to the reference conditions (Figure 6a-c). OMR flows are likely to be negative in more years under Scenario 1 than Scenario 2 but both represent an improvement over the reference condition.

One confounding factor in this analysis is its basis on length-ESU identification of Chinook. It is not clear length is the best delineator of late fall yearlings, which may be the same size as spring run Chinook yearlings or fall, which may be late emigrating juvenile fall run Chinook.

Magnitude
Scenario 1: 2 – Low
In Scenario1 late fall yearlings should be subject to entrainment similar to reference levels since in most years OMR flows remain at -2000 ± 500 throughout the winter in Scenario 1. Late fall run fry that are at the threshold for emigration into the central and south Delta in April and May will also be subject to negative OMR flows during most years and are then likely to be entrained. .It is likely there is limited effect on productivity and diversity on late fall Chinook due to reduced mortality in the South Delta compared to the reference.

Scenario 2: 3 - Medium
In Scenario 2, late fall yearlings should be subject to entrainment despite the change from the reference since OMR flows remain at >-2000 ± 500 throughout the winter in December and January in most years when these fish are present in the south Delta. Late fall fry Chinook may have reduced mortality in the south Delta during April and May since OMR is positive under Scenario 2 in these months for most years. There is likely limited effect on productivity and diversity of late fall Chinook caused by reduced mortality in the South Delta due to Scenario 2.

The affect of reducing OMR flows for this race should be similar to that of other races.

Certainty = 3 - Medium
The difficulty of specifically identifying late fall run yearlings leads to reduced certainty regarding the effects of this action on this run. The late fall magnitude score is based on the identification and the same data as the other runs (i.e. same as P1 c above).

P1e. Winter-run Chinook salmon

Sacramento winter run are present in the south Delta from December to April with a peak in January-March (Figure 1). While flows are less negative during this period than the reference conditions (Figure 7a) both scenarios still show negative flows in many years of up to -2000 cfs during this period (Figures 7a - b). OMR flows are likely to be negative in more years under Scenario 1 than Scenario 2 but both represent an improvement over the reference condition. The earlier arrival of these fish in the south Delta means they benefit less from reduced pumping than some other runs.

Magnitude
Scenario 1: 2-Low
Scenario 1 is more similar to the reference condition and will expose winter run Chinook to negative OMR flows (and thus presumably levels of entrainment) closer to the reference condition during late winter. Mortality will likely be reduced, but a significant period of emigration will still be subject to negative OMR flows. It is likely there is limited effect on productivity and diversity of winter Chinook due to this reduced mortality in the South Delta compared to the reference.

Scenario 2: 3-Medium
Scenario 2 is less similar to the reference condition and will expose winter run Chinook to negative OMR flows during fewer year (Figure 4c). Given the periodicity of fish and OMR flows, reduced mortality in the south Delta may have a minor population effect on fall run Chinook juvenile mortality.

Certainty = 3-Medium
Salvage data show entrainment of winter-run run (Figure 4 and 5) and modeling results show there is a difference in OMR flows (See Figures 7a-c).

P1f. White sturgeon

White sturgeon entrainment during the reference period was primarily between June and September (DWR and BOR unpublished salvage data) and appears related to successful spawning and recruitment of juvenile sturgeon into the Delta. White sturgeon actively emigrate at night (Israel et. al., 2009 page 4). White sturgeon juveniles have limited capacity to survive in brackish waters and likely enter the south Delta via the DCC when it is open and during reversal of flows in the western delta. OMR median flows in Scenario 1 go negative in April and remain negative into the winter, while OMR median flows in Scenario 2 become negative in May and remain negative into the winter. Operation of south Delta diversions under the two Scenarios likely will not differentially reduce white sturgeon mortality since it will remain negative during the period when white sturgeon are historically present in salvage.

Magnitude = 1 - Minimal
White sturgeon juveniles are entrained from June – September and will be subject to negative OMR flows during most years under Scenario 1 (Figure 7b) and Scenario 2 (Figure 7c). The conceptual model indicates little effect of this action on reducing mortality in the south Delta for white sturgeon.

Certainty = 3 - Medium
There is some evidence of high entrainment, yet some question regarding the data (Israel et al., 2009). These questions include the influence of the DCC on entrainment and the cyclic dynamics of recruitment in the population driving highly variable entrainment, thus population and/or external mechanism may be responsible for our observations. Little is known about the effect of the entrainment mortality on populations – DRERIP model indicates that the understanding of entrainment of juveniles on the population is low (Table 5), though the DCC and cyclic dynamics are recognized as influence entrainment estimates in other species. Please see Appendix F, White Sturgeon Salvage Data, for more details.

P1g. Green sturgeon

Green sturgeon may still be exposed to an open DCC between July and August under this action and enter the central and south Delta through this pathway. Juvenile green sturgeon actively emigrate during the night (Israel and Klimey, 2008; p. 2l). Green sturgeon entrainment between 1993 and 2003 (Fish Salvage Monitoring database, http://www.delta.dfg.ca.gov/Data/Salvage/) occurs every month, was greatest in February, and seems to occur more over the summer and fall than during the spring. OMR median flows in Scenario 1 become negative in April and remain negative into the winter, while OMR median flows in Scenario 2 become negative in May and remain negative into the winter (Figure 7a and 7b).. Operation of south Delta diversions under the two Scenarios likely will not differentially reduce green sturgeon mortality since it will remain negative during the period when green sturgeon are historically most present in salvage (summer and fall), and will not reduce their distribution within the zone of entrainment.

Magnitude = 1 - Minimal
Green sturgeon juveniles reside in the south and central Delta during all months (Israel and Klimey, 2008; pg 4), and will still be subject to negative OMR flows during most of their period of salvage (March – December) (Israel and Klimey, 2008; pg 4).

Certainty = 3 - Medium
The DRERIP conceptual model indicates high understanding of the effects of entrainment at the pumps on juveniles (Israel and Klimey, 2008; Table 5) but there have been no studies of the specific effects of OMR flows on green sturgeon.

P1h. Steelhead – Sacramento Run

Little information is available to support a specific evaluation of this action of steelhead. The Evaluation Team determined that in the absence of any additional information that steelhead should be evaluated similarly to spring-run and winter salmon (as described in P1c).

Magnitude = Scenario 1: 2- Low
Scenario 2: 3 - Medium
Figure 7b shows negative OMR flows during spring-run and winter-run migratory period still occur under Scenario 1. Under Scenario 1, median OMR flows are at least -1,400 cfs during April. During this period, Scenario 2 median OMR is negative only in May (Figure 7c). Because peak salvage occurs in April, Scenario 2 would be more protective than Scenario 1. This suggests a larger benefit based on improved OMR flows in February and March (both Scenario 1 and 2 have relatively good February and March OMR flows).

Certainty = 3 - Medium
Species are present in the system when water is conveyed through the Delta. Juveniles are rearing or migrating through the Delta starting in November through June). Good data to show juvenile steelhead are entrained at South Delta facilities (Nobriga and Cadrett 2001).

P1i. Steelhead – San Joaquin Run

Little information is available to support a specific evaluation of this action of steelhead. The Evaluation Team determined that in the absence of any additional information that steelhead should be evaluated similarly to San Joaquin fall-run Chinook salmon.

Magnitude = 1 – Minimal (for both scenarios)
The rationale for a minimal magnitude score is that in both scenarios, it is still an infrequent occurrence that any significant fraction of water originating in the San Joaquin basin is predicted to leave the Delta. Similar to the San Joaquin fall-run, this continued export of nearly 100% of San Joaquin River water was likely to confuse steelhead migration even though they are large fish that can swim strongly relative to Chinook smolts.

Certainty = 2 - Low (for both scenarios)
The tagging and survival studies that have been conducted for San Joaquin Chinook (e.g., Newman 2008; Vogel 2008) have not been conducted using San Joaquin steelhead. Since less is known about steelhead (in comparison to Chinook salmon) the certainty score is low.

P1j. Delta Smelt - Adult

According to the delta smelt model, “Delta hydrodynamics and resulting entrainment in water diversions are primary components of habitat suitability that affect delta smelt mortality.” (Nobriga and Herbold, 2008 p. 23 & Figures on pp 53-54 of the pdf). Kimmerer (2008) showed that nearly all adult delta smelt entrainment has been associated with negative OMR. Grimaldo et al. (in press) proposed a linear model that associated multi-month OMR and salvage. Other unpublished analyses based on monthly average OMRs have indicated that delta smelt entrainment does not increase substantially until OMR is less than -3500 cfs or so. Turbid water in the south Delta is required in addition to any particular OMR flow to cause adult delta smelt entrainment (Grimaldo et al. in press).

Magnitude = 3 (for both scenarios)
Average OMR flows of -3500 cfs during winter will reduce south Delta entrainment (Grimaldo et al. in press), but not entirely prevent it (Kimmerer 2008).

The magnitude of this action is medium for both Scenario 1 and Scenario 2 because both operate to an OMR ceiling of -3500 cfs during delta smelt's winter migration. Both scenarios predict median OMR very near -3500 cfs in December (Figures 7b and 7c). Scenario 2 (Figure 7c) provides better median OMR conditions in January, but both Scenarios have very similar predictions of average January OMR. Predicted OMR in February are typically sufficient to prevent adult entrainment in both scenarios because both scenarios show positive mean and median OMR in February.

Certainty = 3 - Medium
Factors leading to adult delta smelt salvage are broadly understood (Kimmerer 2008; Grimaldo et al. in press). Certainty is medium because:

- OMR and timing of first flush/sediment runoff events that lead to salvage are not predictable far in advance;
- If north Delta diversions reduce downstream Sacramento basin turbidity pulses, this might change the South Delta turbidity regime, which might reduce entrainment more than current data suggest if high turbidity in the south Delta happens less frequently.

P1k. Delta Smelt – Larval and Juvenile

DRERIP smelt model (pg 23) states that "Delta hydrodynamics and resulting entrainment in water diversions are primary components of habitat suitability that affect delta smelt mortality".

Magnitude = 3 - Medium (for both scenarios).
Delta smelt hatching primarily occurs from March-May and juvenile delta smelt often remain in the south Delta through June. During these months, OMR flows affect larval and juvenile delta smelt entrainment (Kimmerer 2008; Grimaldo et al. in press). Estimated south Delta entrainment loss in recent dry years is up to about 25%; but upper confidence limits are near 40% (Kimmerer 2008; Appendix Y). Appendix D shows that both outflow (or X2), and OMR need to be considered when evaluating larval-juvenile entrainment.

Appendix D shows that -5000 OMR can result in entrainment of up to about 25% of the population depending on concurrent outflow. In contrast, positive OMR is predicted to result in entrainment of less than < 2% of the population. The model results shown in Figure 7a, suggest the baseline operations would yield OMR around -5000 cfs for March-June, whereas both Scenario 1 and Scenario 2 result in positive OMR during March-June. Thus, both are sufficient to produce a roughly equivalent entrainment reduction on average; both could reduce peak entrainment loss from 25% to nearly 0%. In conclusion, the magnitude is medium (3) for both Scenarios.

Certainty = 3 - Medium
The influence of Delta hydrodynamics on young delta smelt distribution (Dege and Brown 2004; Nobriga et al. 2008) and entrainment (Sommer et al. 1997; Kimmerer 2008) is well-described in the literature. High outflows (low X2) shift the delta smelt population west so greater proportions of the individual fish are in Suisun Bay. Low outflows (high

X2) compel greater fractions of fish to rear in the Delta. OMR covaries somewhat with outflow because its range is constrained at high outflow. The more project operations tend toward highly negative OMR during low outflow periods, the greater the risk of entrainment for delta smelt. Appendix D (based on empirical data) summarizes this understanding showing the simultaneous influences of outflow and OMR.

P1l. Longfin Smelt - Adult

According to the longfin smelt model 'Sexually mature longfin smelt may be particularly susceptible to entrainment and mortality at water diversions because these fish tend to swim into freshwater prior to spawning and physiological preparations for spawning may leave them in a weakened state.' (Rosenfield, 2008; pg 19) Also see Figure 11. According to Rosenfield, 2008; pg 12, 'Water export operations of the CVP and SWP are highly likely to entrain larval longfin smelt because; larval LFS are not enumerated at the pumps. The problem is potentially serious during years when Delta outflows are low during the spawning period or following the hatching period for longfin smelt (late-winter and early spring). .Larvae (and spawning adults) may be placed at greater risk of entrainment at the south Delta export pumps by this shift of spawning location to the east.

Magnitude = 2 - Low
Average -3500 cfs during winter will reduce south Delta entrainment (Grimaldo et al. in press), but not entirely prevent it. DRERIP longfin smelt model indicates high population importance of south Delta entrainment (pdf pg 20). However, the Team disagreed strongly with the model. Appendix C shows the south Delta entrainment effect on longfin smelt has almost always been lower than the effect on delta smelt. It likely represents something << delta smelt's 15% median. This new assessment is based on the observation that longfin smelt has typically had higher to much higher fall midwater trawl abundance indices than delta smelt, but longfin smelt salvage has usually been lower than delta smelt. This means the magnitude of this action for longfin smelt is lower than it is for delta smelt. The generally lower importance of adult take is further supported by analyses DFG conducted for the SWP incidental take permit under CESA (http://www.delta.dfg.ca.gov/data/longfinsmelt/documents/LongfinSmeltIncidentalTakePermitNo.2081-2009-001-03.asp).

Certainty = 3 - Medium
Although this evaluation relied on newly generated unpublished data (Appendix C and DFG 2009), the data are derived from standard IEP datasets that have been used extensively in previous research. Participants are familiar with these datasets. Longfin smelt are impacted by south Delta entrainment to a much lesser extent than Delta smelt (i.e. data suggest a high probability that adult longfin are comparatively less impacted by south Delta diversions).

P1m. Longfin Smelt – Larval-Juvenile

According to Rosenfield, 2008; pg 14, 'Entrainment at water export facilities may be a significant source of mortality limiting successful transition of juveniles and sub-adults into sexually mature LFS' It also cites, (Rosenfield, 2008; pg 17), Grimaldo et al. in press as a source linking juvenile/young adult longfin smelt entrainment with OMR. The new DFG Effects Analysis for the SWP take permit (DFG 2009) provides considerable evidence that age-0 longfin smelt entrainment is influenced by outflow (X2) and OMR (see http://www.delta.dfg.ca.gov/data/longfinsmelt/documents/LongfinSmeltIncidentalTakePermitNo.2081-2009-001-03.asp) similar to that described above for delta smelt (Appendix D).

Magnitude = 3 - Medium
The longfin smelt DRERIP model does not provide a solid basis for determining a magnitude. Thus, this assessment is based on DFG (2009; see link above) and modeling of OMR flows (Figures 7a-c).

Peak age-0 delta smelt entrainment estimates averaged about 25% (Kimmerer 2008). Based on DFG (2009) peak larval longfin smelt entrainment is not quite as high – perhaps up to 15% in dry years and much less in wet years. Peak longfin smelt hatching occurs in Jan-Mar, but especially in dry years larvae and juveniles can rear in the Delta throughout the spring. Because longfin smelt entrainment is mainly a concern in dry years, this analysis focused on the lower whisker of the box plots in Figures 7a-c.

Figures 7a shows baseline January-March OMR often approaching -10,000 cfs (lower whisker of box plots). Both Scenario 1 and 2 improve the condition by capping winter OMR at -3500 cfs. The two scenarios have considerably different median OMR in January (about -3000 in Scenario 1 and > 0 cfs in Scenario 2). This could contribute to greater larval survival in Scenario 2, but the lower whisker for January-March is near -3500 in both scenarios. To the degree the lower whiskers reflect dry year pumping patterns, there is likely to be little difference between the scenarios in terms of reducing south Delta entrainment at the times it has the biggest effect. The -3500 cfs OMR is likely to be substantially more protective to longfin smelt larvae than the baseline OMR of -5000 to -10,000 cfs. The PTM analyses in DFG (2009) suggest this level of operational change could reduce larval entrainment by about 10% in dry years – a medium population level effect. Thus, we consider both scenarios to have a magnitude of 3.

Certainty = 3 – Medium
The information relating Delta hydrodynamics to longfin smelt entrainment is newer and unpublished. Further, unlike with delta smelt, the estimates of proportions of larval and juvenile longfin smelt lost to entrainment in the south Delta have only been partly quantified using PTM simulations weighted by dry year larval distributions (DFG, 2009). However, the PTM simulations strongly suggest that outflow pulses and negative OMR limits reduce larval longfin smelt entrainment in a manner analogous to delta smelt. Additionally, the salvage of juvenile longfin smelt, which is the visible fraction of entrainment, is clearly related to X2 and OMR, so there is no reason to believe the same basic hydrodynamic mechanisms could not explain entrainment risk for both smelts.

P1n. Splittail

State and Federal water projects sometimes have high salvage of splittail. The DRERIP splittail model (Kratville, 2008; pg 22) states, 'YOY splittail are typically captured in large numbers at the SWP and CVP fish salvage operations in the south Delta in late May through mid-July'. Splittail spawn in the San Joaquin River (Feyrer et al. 2005) and if corrected for abundance, an OMR effect on salvage might exist, but this has not been determined.

Magnitude = 2 -Low
The DRERIP splittail model (Kratville, 2008; pg 22) states that "The State Water Project and Central Valley Project show high rates of salvage when splittail populations are at high levels…" (See also Sommer et al.1997). Quantitative estimates of the proportion of age-0 splittail entrained in the south Delta do not exist. As for other migratory fishes, relative impacts are probably highest in dry years (Kratville, 2008; pg 27).

Certainty = 3 - Medium
Splittail relative abundance has been indexed using several of the IEP's trawls (Meng and Moyle 1995; Sommer et al. 1997; Kimmerer 2002; Feyrer et al. 2006). Splittail abundance varies with X2 (Kimmerer 2002; 2009). However, this is thought to be a surrogate for the reproductive opportunity provided by floodplain inundation in wet years rather than a reflection of entrainment loss (Sommer et al. 1997; Feyrer et al. 2006).

It is also likely these trawl-based relative abundance estimates are less reliable than estimates based on salvage, which has much higher sample sizes and detects age-0 fish every year. Salvage is both the best estimate of SWP/CVP entrainment loss and the best relative abundance estimate. Therefore, it is not possible to determine the effect of splittail entrainment on the population without using mark-recapture techniques.

The weight of available evidence suggests a small south Delta entrainment effect because loss is high when reproductive output is high and the population has shown resilience through time, and because most reproduction occurs in the Sacramento basin (Sommer et al. 1997; Feyrer et al. 2006; Moyle et al. 2004; Figure 5 in Kratville, 2008).

Outcome P2: Increased food availability for covered species due to higher productivity at lower trophic levels in the Delta associated with increased residence time.

The DRERIP Foodweb model (Durand, 2008; Section 1.12) references a positive relationship between phytoplankton and zooplankton production and residence time (Importance: High, Understanding: High, Predictability: High). However, Cloern (2007) hypothesizes that intermediate residence time maximizes lower trophic productivity. Cloern's view is more in line with studies of lake eutrophication and attempts to manage it via food web interventions; e.g., very high phytoplankton abundance is not necessarily associated with high zooplankton abundance (Drenner et al. 2002).

Magnitude = 2 - Low
Residence time may increase as a result of this action. However, the influence of residence time on the foodweb can be difficult to predict. Primary productivity may not transfer up through the food web to the target species.

Residence time refers to the time that a particle of water or some constituent of water remains in a location. This concept is applied here more as a broad concept than a specifically measured quantity (see Monsen et al. 2002 for a discussion of residence time). When the movement of water in the Delta slows either because of lower net flow or reduced tidal velocities, residence time increases (see Kimmerer and Nobriga 2008). Under the proposed scenarios, the decrease in inflow to the Delta due to the export of water from the Sacramento River, and the decrease in north-to-south flow of water toward the south Delta export pumps will generally increase residence time - particularly during summer.

Certainty = 3 - Medium
The influence of residence time on the foodweb can be difficult to predict. Few estuarine ecologists would claim that in general an increase in residence time due to a decrease in freshwater flow would increase fish productivity. Phytoplankton productivity may be maximized by a mix of residence times allowing time for biomass to develop but also with enough exchange to export some of that production to other areas (Durand, 2008; Section 1.12; Cloern 2007). However, the interaction between residence time and the species composition of phytoplankton that blooms is not well understood, and species matters to the transfer to higher trophic levels. Furthermore, areas of long residence time that have suitable substrate for settlement of Corbicula clams may simply grow more clams (Thompson et al., In Revision; p. 9).

In considering the transfer of productivity to higher trophic levels and ultimately to the target fish, it is helpful to recall that many species in the estuary respond positively to freshwater flow or its covariates, and that these responses may not be linked to changes in food supply (Kimmerer 2002). Although many if not all estuarine species are food limited (Durand, 2008; Thompson et al., In Revision), or have interactions between poor feeding conditions and thermal stress (Norbriga and Herbold, 2008), this does not necessarily imply that more phytoplankton production will produce more fish because habitat conditions have to be suitable for the fish to occupy or the prey need to be transported to habitats where the fish are rearing. In the case of delta smelt, both habitat suitability and prey transport to the low-salinity zone are most likely to be optimized by higher rather than lower freshwater flow.

Experiments to stimulate phytoplankton production in natural water bodies have been conducted to investigate nutrient limitation, and to explore the possibility of stimulating production of fish. These studies include lake fertilization experiments (Schindler 1977, Carpenter et al. 1995) and iron addition experiments in the ocean (Chisholm et al. 2001). The general conclusion of such studies is that natural ecosystems are complex and that consequences of any change in forcing, whether from nutrient enrichment or alteration of trophic structure, can be difficult to predict (Carpenter et al. 1995, Chisholm et al. 2001). For the Delta, we can draw this general lesson, and extend it to the link between stimulated phytoplankton production, and thereby fish production, through alteration of residence time. It is very difficult to predict the direction a natural system will take when phytoplankton production mechanisms are changed. A similar lesson can be taken from the divergence of outcomes in shallow waters with and without large numbers of clams (Lopez et al. 2006) and with and without large quantities of submerged plants (Nobriga et al. 2005).

Potential Negative Ecological Outcome(s)

Nine potential negative outcomes were identified and evaluated by the team:

N1 – Increased predation of juvenile salmon, steelhead, splittail, and sturgeon associated with the presence of new structures in the Sacramento River. This outcome is focused on predation at the new diversion structures themselves.

N2 – Increased predation of juvenile salmon and steelhead associated with new North Delta diversions affecting flows and residence times in the Sacramento River and other distributaries downstream of the new facilities

N3 – Increased mortality of juvenile delta smelt associated with the new North Delta diversion facilities and their operation. This is referring to the potential for entrainment if flows reverse in the Sacramento River.

N4 - Increased mortality of covered species due to potential degradation of water quality, particularly in the central and south Delta.

N5 – Reduced turbidity and associated reductions in delta smelt habitat due to operation of the new diversion facilities and the entrainment of sediment.

N6 – Increased frequency, duration, and extent of low dissolved oxygen conditions at Stockton adversely affecting salmon and steelhead migration on the San Joaquin River.

N7 – Loss of food material due to water diversions at the new North Delta diversion facilities.

N8 – Increased Microcystis biomass due to the new North Delta diversions.

N9 – Increased predation of juvenile Mokelumne River salmon due to modified Delta Cross Channel operations.

Each of these potential outcomes and the results of the evaluation are described below. It should be noted that the potential negative effects of impingement and entrainment at the new North Delta diversions were <u>not</u> evaluated by the team (except for the smelts). These effects could be significant and should be carefully examined prior to any final decision regarding the proposed new North Delta diversion.

One of the keys to understanding the potential effects of new North Delta diversions on different covered fish species is the periodicity and timing of these fishes in the Sacramento River in the vicinity of the proposed diversion structures. Table 1 below summarizes the peak occurrence of species in the North Delta, including the area of the proposed diversions.

Table 1: Relative Temporal Distribution of Juvenile Anadromous Fishes At Knights Landing

PRESENCE			
High	Medium	Low	None /Rare

Species	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Winter-run Chinook	Low	Medium	High	Medium	Low	Low	Low					
Spring-run Chinook		Low	High	Medium	Low	High	High	Low				
Fall-run Chinook			Low	High	High	Medium	Medium	Medium	Low			
Late-fall run Chinook		Low	Medium	Low			Medium	High				
Steelhead			Low	Low	Low	High	High	Low				
Green Sturgeon								Medium	Medium	Medium	Medium	Medium
White Sturgeon						Medium	Medium	Medium	Medium			

Data sources for: salmon and steelhead, California Department of Fish and Game rotary screw trap data at Knights Landing, 1996 – 2008; for sturgeon, California Department of Fish and Game Comments to NMFS Regarding Green Sturgeon Listing, 2002; Gaines, P.D. and C.D. Martin. 2002. Abundance and seasonal, spatial and diel distribution patterns of juvenile salmonid passing the Red Bluff Diversion Dam, Sacramento River. Red Bluff Research Pumping Plant Report Series, Volume 14. U.S. Fish and Wildlife Service, Red Bluff, California.

Outcome N1: Increased predation on juvenile Sacramento salmon, steelhead, splittail and sturgeon associated with the presence of new diversion structures in the Sacramento River.

The Evaluation Team assumed that new diversion structures in the Sacramento River would attract predators (mainly striped bass and Sacramento pikeminnow) because predators are attracted to instream structures and feeding opportunity "events" (Gingras 1997) and these two predators are large open-water and stream-associated fishes that have been shown to aggregate around instream structures in the Sacramento River from Red Bluff to the Delta. The team assumed that predation by largemouth and smallmouth bass would be less relevant adjacent to the new structures because these fishes are rare in channelized riverine habitats. New intake structures in the Sacramento River will create local hydraulic discontinuity that will create ambush habitat for striped bass and pikeminnow. Rip rap, concrete, and other material installed near the diversion facilities would reduce habitat suitability and cover opportunities for young covered fishes.

The team recognized that this outcome is highly dependent on the way in which the intake structure(s) is designed, constructed and operated. While some information is available regarding operation of the proposed diversion(s), the physical nature of the intakes and their position relative to the channel has not yet been determined. For the purpose of this evaluation, it was assumed that the intake structure(s) would be situated at or near mid-channel.

The team discussed the possibility that the diversion structures could be designed to create shallow-water habitat where fish could travel along the margins, but the team decided that such a design has not been accomplished elsewhere and thus, they should not assume such a design for this evaluation.

The analysis provided herein is preliminary in nature and is contingent upon the final design of the intake structures.

The following analyses regarding on-site predation are applicable to all Sacramento Chinook and steelhead runs given predators are present year round, independent of Chinook run timing.

Likelihood of Predation

<u>Prey size preferences for predators</u>: Striped bass and Sacramento pikeminnow more than about 12 inches long can efficiently capture salmon smolts that typically range from about 70-125 mm in length. They probably feed less efficiently on steelhead smolts (DFG 1999), which typically emigrate at about twice the size of salmon smolts (Nobriga and Cadrett 2001).

<u>Temperature effects on predation rate</u>: Water temperature affects the metabolic demand of all fishes, so all of the Delta's predators eat more as water temperatures increase from winter through summer. However, research on fish predation in Clifton Court Forebay has found no evidence that salmon, steelhead and striped bass losses are affected by temperature (DFG 1999; Clark et al. 2009). Therefore, we do not expect water temperature to greatly affect listed fish losses adjacent to new north Delta diversions. All of the Delta's predatory fishes eat year-round, though spawning striped bass seem to reduce their feeding frequency (DFG 1999).

Vulnerability

1. Hydraulics around diversion structures can increase predator foraging success because when prey fish become disoriented, predators aggregate.

2. Increased stress due to repeated involuntary contact with screens (impingement) leading to disorientation and an increase in predation downstream of structure could also occur, but fish treadmill experiments suggest that juvenile Chinook recover quickly from impingement and are not stressed (Swanson et al. 2004).

N1a. Sacramento Chinook salmon and Steelhead

Comments and/or Assumptions used in scoring:

Chinook were observed to frequently contact fish screens and contact rates were correlated with flows, light level, and fish size (Swanson et al. 2004). Contact rates increased with increases in sweeping velocity, were higher in the dark, and increased with larger fish size. Screen contacts were not injurious or lethal for juvenile Chinook salmon. At higher sweeping velocities (>60cm/s) juvenile Chinook swam close to their maximum sustained swimming velocity. Juvenile Chinook swam slower during dark conditions (simulated night) compared to light conditions (day).

Magnitude: 4 - High
Predator densities are assumed to be high close to a structure protruding into the channel and lower bypass flows will increase the exposure risk to predators. Because almost all Sacramento salmonids would have to pass these structures when Yolo Bypass is not flooding, the effect under the worst case could be a major population effect.

Certainty: 2 - Low
The certainty of this outcome is low because the data do not exist to estimate the fraction of salmonid fishes that are expected to be lost to predators while migrating past 1-5 water diversions. The lack of details regarding the number and design of the diversions adds to the uncertainty.

N1b. White sturgeon

White sturgeon larvae will be present in proximity to a north Delta diversion facility between March and May. Stevens and Miller (1970) captured most of their white sturgeon larvae between Collinsville and Rio Vista. Juvenile white sturgeon will be present in proximity to a north Delta diversion when water temperature remain >20°C (Table 1 in Israel et. al., 2009). These temperatures appear in this section of river initially in mid-May and become sustained by mid-June (J. Israel, UC Biotelemetry Lab unpublished temperature data).

This periodicity likely exposes white sturgeon larvae and juveniles to potential predation between March and June in the north Delta. Predation by a native predator, prickly sculpin (bottom dwelling ambush predator) of white sturgeon larvae and young-of-year is well documented in the Columbia River (Gadomski and Parsley 1995a) and rates of predation are influenced by level of light, cover, and size of white sturgeon. White sturgeon larvae and young-of-year were also consumed by catfish (Gadomski and Parsley 1995c). Thus, it seems likely that north Delta diversion operations where native and nonnative predators may aggregate to ambush prey would also lead to predation of white sturgeon larvae and juveniles during the months of March through June.

Screening criteria for larval and juvenile white and green sturgeon are not developed. Limited observations of green sturgeon around fish screens suggest they frequently made contact with experimental screens, contact was non-injurious, and survival was uniformly high (UCD Fish treadmill report, 2004).

Magnitude = 2 – Low
Operation of any diversion, where predators are likely to aggregate due to local hydraulics may increase predation upon sturgeon at the diversion location. Sturgeon larvae and juveniles are preyed upon by native and nonnative predators in other systems (Gadomski and Parsley 1995a and 1995c). Depending on operations the diversion (due to turbidity, light conditions) resulting predation at a diversion site may be expected to be on a limited fraction of the population and influence productivity of the population in a minor way. Strangely, if sturgeon voluntarily initiate and repeat contact with screens, an observation of fish screen studies (UCD Fish Treadmill Report, 2004), the frequency of sturgeon visits to fish screens will increase the likelihood of predation mortality and related population level effects.

Certainty = 2 – Low
Certainty of this effect is low due to lack of information on the specific design of the structure.

N1c. Splittail - Juvenile

Although this specific predation issue was beyond the scope of the DRERIP splittail model, the model does consider predation by nonnative fishes to be “important from a population perspective” (Kratville, 2008; pg 23-Table 2). Predators will aggregate around the new diversions (Gingras 1997; USFWS RBDD studies). Predators eat young splittail (DFG 1999, Nobriga and Feyrer 2007). Predators are opportunists and habitat and prey field will support (e.g., Shively et al. 1996).

When floodplain inundation does not occur, the splittail must migrate further upriver to find suitable spawning habitat (Kratville**,** 2008, Figure 1 based on Feyrer et al. 2005). Young splittail will seek shallow margin areas. They travel slowly back towards the estuary, not strongly influenced by net flows. Splittail juveniles use water temperature as a cue (Kratville, 2008; pg 18).

Magnitude = 4 - High
Most splittail reproduction occurs in the Sacramento basin (Sommer et al. 1997; Feyrer et al. 2006). Essentially all Sacramento basin splittail will have to pass the north Delta diversions in dry years because Yolo Bypass will not flood and many will pass during low bypass flow months (population center of distribution is near the upper margin of Delta during June-July; Feyrer et al. 2005). The two different bypass flow scenarios are not very different because these juvenile splittail are not really “going with the flow” and the structures are there in either case. Rather than go with the flow, splittail rear and grow in shallow habitats (Feyrer et al. 2005).

Certainty = 2 – Low
A good scientific understanding of splittail migration and predation is based upon a combination of peer-reviewed papers and non-peer-reviewed information (Kratville, 2008). Ecosystem variability is noted. For instance, the population effect of predation associated with the north Delta diversions will be relevant mainly in years the Yolo Bypass floods less than 3-4 weeks (Sommer et al. 1997; Feyrer et al. 2006).

Part of the resilience of splittail, as described in the model and most papers, is their ability to forego reproduction in dry years and to spawn heavily in appropriate years – much unlike salmon and steelhead and more like sturgeon, which would seem to reduce the population level magnitude of dry-year predation at these diversions. However, some splittail spawn in dry years (Feyrer et al. 2005) and the later and slower emigration of splittail likely means more effect than for salmon. Wet year production definitely drives population dynamics, but viability might be compromised during a 5-10 yr drought if their primary source of successful dry-year reproduction in the Sacramento River is greatly affected.

Splittail are good at avoiding a fish screen and so they will generally avoid impingement (Danley et al. 2002). However, multiple diversions are problematic because they will create a situation where large stretches of river habitat will be altered to engineer optimal conditions for the diversions. Deliberate flooding of Yolo Bypass would only happen in some years and will not generally encompass dry year splittail emigration timing (June-July; Feyrer et al. 2005). The splittail model suggests that under current conditions, predation of splittail near export structures is not a huge problem (Kratville, 2008; pg 34-Fig. 5). However, the proposed action will be under very new conditions, outside the scope of analysis in the conceptual model.

Outcome N2: Increased predation of juvenile salmon and steelhead associated with new North Delta diversions affecting flows and residence times in the Sacramento River and other distributaries downstream of the new facilities

Appendix I provides graphs and tables containing particle fate and travel time. This data informs the analysis of flow conditions, residence time and pathway of fish in the Delta as described in this worksheet.

Data from salmon tagging studies (e.g., Newman 2008; Perry and Skalski unpublished) suggest that predation rates on emigrating salmon vary spatially in the Delta. In theory, predation loss should also be a function of time spent migrating because predation loss accumulates at some rate – number lost per unit time. The concept behind this potential negative outcome is that water diversions at the new North Delta diversion facilities might change the proportions of fish migrating through different routes and/or increase the residence time of fishes that are ocean- or lower estuary-bound and thus, not trying to rear in the Delta.

A third possibility is that less net downstream flow through Sutter and Steamboat sloughs might lower water velocities and as a result, increase the foraging success of predators and/or increase the abundance of largemouth bass, which are not currently thought to be a predator of concern in the north Delta.

<u>Mechanisms contributing to increased predation</u>:

1. Lower net river flows increase travel time of outmigrating juvenile salmon through the system.
2. Flow changes disperse fish through Delta channels differently than occurs presently possibly causing more emigration through Georgiana Slough.

3. Predator habitat suitability increases in Sutter/Steamboat Slough relative to baseline because of lower net river flows.

Downstream migrating salmonids have been observed to migrate passively, dependent on riverine and tidal currents (Folmar and Dickhoff 1980). Physiological changes during smoltification trigger behavioral changes such as passive migration, swimming upwards to 80% slower and increased buoyancy (Folmar and Dickhoff 1980). Travel time is biologically significant because each day of migration depletes energy reserves and exposes individuals to threats, such as predation (Zabel 2002).

Particle Tracking Modeling (PTM) results are an applicable tool for analyzing salmon smolt life stage. PTM based upon monthly average flows indicates that it takes 3 days to pass 50% of particles from Freeport to Three Mile Slough (Appendix I). This represents a significant (perhaps 50-60%) residence time increase over baseline. Thus, this action may reduce the flow pulses that salmonid smolts use to quickly emigrate through the Delta. The entire salmon population could experience a 50% - 60 % increase in predation. Mortality is high, based on existing studies of salmon.

There is a need to understand how many fish survive their Delta emigration as flow changes. Travel time and routes are important. Different routes yield different rates of predation. Data could be extracted from the PTM to consider the differences between Scenario 1 and 2 by changing predation rate vs. time exposed (see Appendix I). The idea of PTM results having application to salmon is relevant for the smolt life stage (Folmar and Dickhoff 1980).

Under either dual conveyance scenario, some particles enter Georgiana Slough. If the predation rate is held constant, regardless of flow, the 1.5 extra days spent in travel time will lower survival, all else being equal.

<u>Movement/migration rate/survival of different runs of salmon</u>:

- Reach specific data on the speed and survival of juvenile Chinook migrating through the Delta are available from three separate acoustic tagging and monitoring studies. Two of these released fish in the Sacramento River (see Burau et al. 2007, Perry and Skalski 2008, Vogel 2008) and the other released fish in the San Joaquin River (see SJRGA 2008). Late-fall fun Chinook from the Coleman National Fish Hatchery were used in the Sacramento River acoustic tagging and monitoring studies (Burau et al. 2007, Vogel 2008). Fall-run Chinook from the Merced River Hatchery were used in the San Joaquin River acoustic tagging and monitoring study (SJRGA 2008).
- In addition to the acoustic tagging studies, migration and relative survival estimates are available for other runs and sizes of salmon from coded-wire-tag (CWT) studies (Brandes and McLain 2001; Newman and Rice 2002; Newman 2003; Newman and Brandes in press). In the Central Valley, CWT studies have been conducted using fall run, late-fall run, spring run, and surrogate winter run Chinook (surrogate winter run fish are late-fall or fall fish released to mimic the migration timing of winter run fish; RMPC 2008). For steelhead, only small acoustic tagging and monitoring studies have been conducted but these data are also available (CVFTC 2008).
- In each of the three acoustic tagging studies mentioned above the primary cause of fish loss is assumed to be predation. Some results provided direct anecdotal evidence of predation, for example aberrant tag movements were detected near one acoustic receiver and most likely represented tagged salmon that were inside of a predator (Vogel 2008). In the San Joaquin River study, researchers used a mobile acoustic receiver to detect tags that became motionless and most likely represented salmon that

had died or tags from eaten salmon that were defecated by a predator (SJRGA 2008). This study also identified predation events when multiple tags began to display identical detailed movement, indicating that a single predator had consumed multiple tagged salmon (SJRGA 2008).

Modeling results on net flow, reverse flows, velocity, and particle travel time:

- **Downstream flows (monthly averaged)** – Minimum flows do not change much, because under new operational scenarios, Hood diversion is not operational at extremely low flows. Flows during the high flow periods (Jan, Feb, and March) reduced (monthly averages down ~25%; monthly median down ~30%). Dec, April, May, and June have somewhat reduced flows (monthly averages and medians) in Scenario 2 vs. Scenario 1.
- **Particle travel time** – Insertions at three places (Freeport, Sutter, Steamboat) for two scenarios and at three different river flows (low, mid, and high).
- DCC operation, diversions at new north Delta facility and Cache Slough restoration affect travel time. Effect of new operations on travel time depends largely on river flow.
  - At low flows, not much change from reference scenario.
  - At mid flows, travel time down the Sacramento River decreases for Scenario 1 and increases for Scenario 2. Travel time down Sutter and Steamboat sloughs increases for Scenario 2.
  - At high flows, travel time down the Sacramento River increases under both scenarios.
- In dry years, modeling indicates that downstream flows would be reduced mainly in the wet time of year (winter peak flows truncated). In wet years, downstream flows reduced most of the year (higher flows allow for diversion year-round).

Williams (2006; SFEWS) states the following “The most detailed information on migration rates comes from fish in the Columbia River that are individually marked with passive integrated transponder (PIT) tags that are detected when fish move through passage facilities on the dams”. Rates for individual Chinook, sockeye, and steelhead between Rock Island and McNary dams were all highly variable (Giorgi et al. 1997). For age 0 Chinook, the average migration rate over four years was 15.5 km d-1, but increased with size from about 5 km d-1 on average at 60 mm to about 30 km d-1 on average at 140 mm. Migration rates varied directly with flow and inversely with temperature and day of the year, but not as strongly as with length. For yearling Chinook, the average migration rate was about 20 km d^{-1}, and was independent of length but increased somewhat with temperature, mean flow, and day of the year. Time of year had a strong effect on the migration rate of naturally produced yearling Chinook from the Snake River (Congleton et al. 2004).”

Spring-run Chinook will experience longer travel time. Chipps Island and Salvage data indicate that April is a peak abundance month (~2/3 of all spring-run) for spring-run Chinook salmon in the Delta. Mean monthly and median flows are ~16,882 cfs in April, mid flows defined by PTM results are ~13,200 cfs. So, flows during April in the mid-range occur ~66% of the time. High flows (defined by PTM of 28,000 cfs) are exceeded 27% of the time. Low flows (defined by PTM results) are not reached at any time during April.

Magnitude: 4 - High
Lower bypass flows will increase the exposure risk to predators due to increased travel time and different migratory pathways. . Because almost all Sacramento salmonids

would be exposed to higher predation the effect under the worst case could be a major population level effect.

Certainty: 2 - Low
The certainty of this outcome is low because the data do not exist to estimate the fraction of salmonid fishes that are expected to be lost to predators due to changing flow conditions. The lack of data on how different bypass flows would affect travel time and flow splits adds to the uncertainty.

Outcome N3: Entrainment of larval and juvenile delta and longfin smelt associated with new North Delta facilities and operations.

The team assumed this outcome was possible because delta and longfin smelt larvae can be drawn in the direction of net river flows (e.g., Kimmerer and Nobriga 2008; Kimmerer 2008). Note that the striped bass egg and larval survey conducted by DFG in the early 1990s collected some larvae identified as delta and longfin smelt from the mainstem Sacramento River in the region the diversions are proposed (Wang 1999). Delta smelt cannot travel past miles of screen without getting impinged (Swanson et al. 2005; White et al. 2007) or entrained so they have a high entrainment/impingement risk if they approach the screens. In addition to fish spawned in the Sacramento River near the diversions, modeling for BDCP indicates that on flood tides or during very low outflow springs, larvae below the Sacramento River – Cache Slough confluence might also be vulnerable to upstream draws. However, net flows in the mainstem of the Sacramento River near the diversions are expected to remain positive due to the combination of tidal prism and bypass flow criteria, so this is expected to occur only rarely.

Magnitude = 2 - Low
Both Scenarios:
The DRERIP smelt models do not address north Delta diversions. DRERIP delta smelt model indicates adult delta smelt are associated with turbidity; migrating adults are included in this generalization (Grimaldo et al. in press). Longfin smelt are also associated with turbid water in the Delta (Kimmerer et al. 2009). During low flows, the mainstem Sacramento River, including sites near the proposed diversions, has high water clarity. It is unlikely that a significant number of delta or longfin smelt would migrate into a low turbidity environment even with negative flow (extension of observations at south Delta diversions. (Grimaldo et al. in press,).

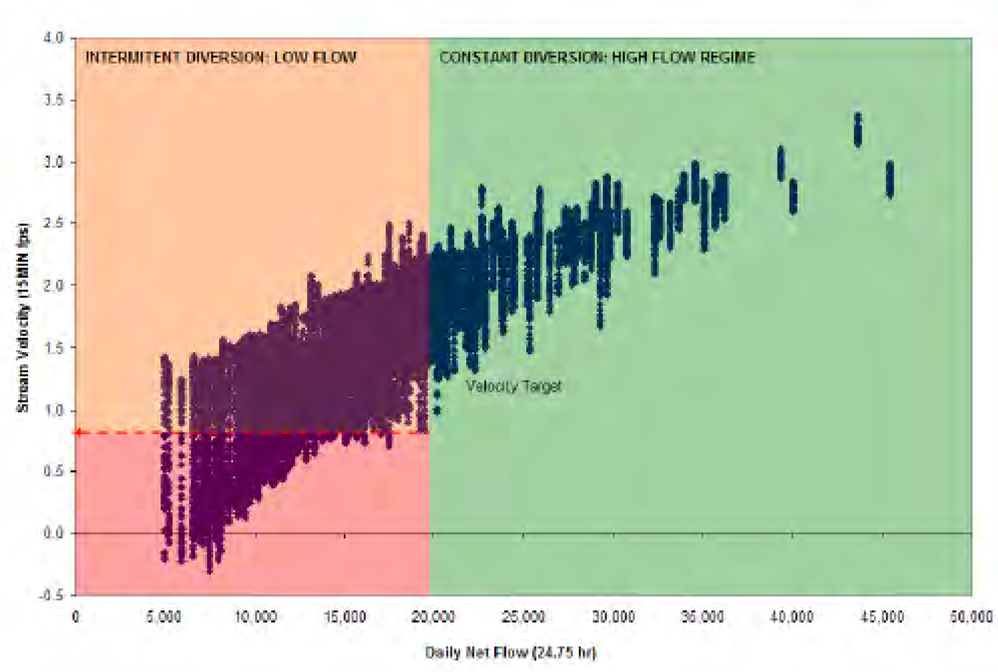
Larvae are not strongly associated with turbidity based on 20mm sampling (Figure 5 in Norbriga and Herbold, 2008), but this is inconsistent with Kimmerer et al. (2009), who reported a fairly strong effect of Secchi depth (turbidity) on delta smelt abundance based on 20 mm sampling. Therefore, larval delta and longfin smelt might be susceptible to reverse flows if spawning occurs nearby (Norbriga and Herbold, 2008, Figure 3). It is not thought that this would affect large fractions of their populations.

Certainty =
Scenario 1 (higher critical period flows): **3 - Medium**
Scenario 2 (lower critical period flows): **2- Low**

Data do not presently exist to evaluate this set of Scenarios objectively, but the scores differ by scenario because the higher the bypass flows, the less likely larvae will wind up near the north Delta diversions. The team recommends a particle tracking model run for low flow conditions, including proposed north Delta tidal marsh restoration and north Delta diversions, to determine the likelihood of particle entrainment toward the north Delta diversions from Cache Slough/lower Sacramento River.

The certainty that the effect would be low is higher for Scenario 1 because the higher Hood bypass flow criteria would reduce the frequency and magnitude of net reverse flows (see Figure 8).

Figure 8 - Diversion Operational Regimes (Tidal) in "Preliminary Modeling Evaluation of Draft Conservation Strategy Core Elements" dated January 30, 2009



Outcome N4: Increased mortality of covered species due to degradation of water quality which increases a stressor (on fish species of concern)

Overview of Water Quality Effects

Changes to hydrodynamics and transport associated with a dual conveyance approach (i.e. new North Delta diversion operated in addition to the existing South Delta pumps) might influence water quality and toxicity to species of concern through three mechanisms:

1) Increases in loading of selenium and agricultural chemicals in south Delta waterways due to increased South of Delta deliveries (D1641+10% for Scenario 2);
2) Changes in contaminant distribution (and possibly, concentrations) through shifting the primary export location north (reduces ammonia/um load, reduces Sacramento River pesticide and Hg loads, increases SJR loads of pesticides, sulfates, Se, etc. - essentially

there would be a shifting to a San Joaquin River (SJR) dominated risk in the South Delta). and;

3) Changes to fish exposure due to lower flushing rates and higher concentrations of contaminants in south Delta waterways.

<u>San Joaquin River loading of [Se], salt, pesticides</u>

Selenium, salt and pesticide loadings from the San Joaquin would likely increase in proportion to additional deliveries (D-1641 + 10% for Scenario 2). The exact increase is unknown, as allocation to specific crops will vary. Pesticide loading will increase, and salt/Se loading will decrease assuming a continued shift to orchards and away from bottomland crops. However, senior water right holders (exchange contractors) in the north San Joaquin Valley will possibly plant both.

For purposes of this analysis, it is assumed that the current regulatory baseline for San Joaquin River TMDL 2010 limit will be extended. Therefore, the contaminant profile predicted by this analysis is:

- Se loads will increase by <10% (influent concentrations the same).
- Pesticide loads will increase by ~10% above the current profile (reflecting continued shift to permanent crops).
- ECD's and pyrethroids etc. from municipal use will increase by >10% (because urban growth will shift water use from agricultural to municipal and industrial uses).

Habitat quality will degrade in the South Delta through elevated contaminant concentrations (see discussion on changes in fish exposure below).

Pesticide tailwater loadings/deliveries in the Delta could change with the new diversion and associated operational scenarios. Modeling included meeting salinity standards. Based on these results we assume no change in South Delta agricultural returns.

Within-Delta herbicide applications could change with altered operations or if other stressor actions try to manage aquatic plants with herbicide treatments. Also, hydrodynamic changes would likely change the effects of contaminants on the food web. These potential outcomes are not evaluated here, but should be further analyzed.

<u>Potential Mechanisms</u>:

- Increased concentration of SJR contaminants in the south and central Delta.
- Change in concentration of contaminants in the north Delta as a result of new diversion facilities.

How do operations influence route and duration of migration?

- Exposure to poor water quality varies with route and duration.

<u>Impact of shifting diversion point on concentration/loads:</u>

Current south Delta exports quickly remove most San Joaquin River water from the Delta most of the time (Kimmerer and Nobriga 2008). This and Sacramento inflows dilute Se and other loading from the San Joaquin River into the estuary. San Joaquin River water quality will become a bigger driver of estuary water quality under both scenarios. Some less stable contaminants may be partitioned or lost with higher residence time in the South Delta. Water quality at the confluence will continue to be dominated by Sacramento flows despite the increased movement of SJR contaminants to the confluence, because the proposed Sacramento River inflows would continue to greatly outweigh the SJR volumes. Source modeling conducted by CH2M Hill corroborates these assumptions.

Timing of source loading might change under the new operational scenarios, but modeling conducted by CH2M Hill suggests this is not likely. Total Delta exports under Scenario 1 (11K hood bypass) would decrease slightly in December to January and August to September, increase slightly in February to March, increase significantly in April to June, and change little in July, and October-November. Under Scenario 2 (5000 hood bypass), October to November are unchanged, January to March have slight increase, December and June have more moderate increase, April and May have a significant increase, and July though September have a slight decrease.

<u>South Delta residence time will increase during all months:</u>
The longer residence times of water may cause the Delta to shift towards an even more benthic-driven ecosystem with increased source loading from the SJR and decreased exports of contaminants. Decreased export of contaminants through South Delta pumping is expected to generally increase selenium and agricultural chemical exposure risk in the estuary, and particularly the south Delta. Bioaccumulation and biotransformation are expected to increase for contaminants in which this phenomenon is relevant (e.g., Se, Hg, breakdown or metabolite products from organics), which will change their environmental fate and increase both exposure and toxicity. The potential for net increased loads and contamination downstream, including the potential for more bioavailable forms (methyl-mercury or selenite/organic selenides) should be further analyzed quantitatively. This would require quantitative mass balance modeling. Possible changes in foodweb composition and dynamics will have an impact on bioconcentration factors (Presser et. al., in revision). This is an important factor that is hard to predict.

<u>Species occurrence matrix</u>: The interface and timing of species within their habitat determines exposure and therefore risk (see Table 1 for a temporal distribution of fish within the Delta).

<u>General analytical strategy</u>: North Delta diversions are expected to extract approximately 25% of Sacramento River flow based on CH2MHill modeling. Sacramento River flows would decrease reducing rates of fish transport and possibly increasing exposure time. Results from particle tracking models indicate that residence times will increase increasing exposure times.

<u>Methyl-Mercury</u>: Based on data from TMDL reports, most loading is from the Sacramento River. We presume this will be diverted resulting in reduced loadings to the Delta, but biomethylation potential may go up with additional tidal marsh and sulfate loads from the San Joaquin River.

<u>Selenium</u>: There will likely be a higher risk from increased loads from the San Joaquin River and increased residence time and bioconcentration potential. For organics, exposure time for delta smelt larvae (or other juveniles using passive dispersion) may increase (potentially in both the North and South Delta). Selenium in the food chain may increase, with greater impacts on splittail and sturgeon (possibly juvenile salmonids associated with other core elements—e.g. tidal marsh and riparian restoration). Benthic foragers could be affected through increased Se in Corbicula that serve as food for sturgeon, splittail and other fishes (Stewart et al. 2004, Teh et al. 2004).

Agricultural chemicals: Higher residence times may increase exposure and mortality. Larval smelt may be detrimentally impacted.

N4a, b. White and Green Sturgeon

Juvenile white and green sturgeon are year round residents of the Delta. The movements of these fish are primarily for foraging, with white sturgeon migrating downstream to cooler brackish or marine water during the summer and back to fresher water in the winter (Israel et. al. 2009). Once green sturgeon start their marine migrations, their behavior changes and they spend summer in estuaries and rivers, and winters migrating in the ocean (Israel and Klimey, 2008). Lastly, both species of sturgeon are able to tolerate hypoxic conditions (Israel et. al. 2009 and Israel and Klimey, 2008 – Ecology Sections) and likely are able to actively move away from these conditions when they become too severe. While sturgeons are bioaccumulators of contaminants and toxicants, the acute effect of contaminants on mortality or sub-lethal effects does not seem large (Israel et. al. 2009 and Israel and Klimey, 2008 - Stressor Sections) although levels are rising to where they maybe of concern (Stewart 2004). Thus, any increase in Se bioavailability to sturgeon might be significant in terms of reproductive success.

Magnitude = 3 - Medium
White and green sturgeon mortality is likely not closely linked to water-quality problems, though maternal effects and sub-lethal effects are likely. Little of the white sturgeon population passes through the south Delta. Very little of the green sturgeon population passes through the south Delta since spawning is restricted to the Sacramento side. However, selenium loads are already high and increased benthic bioaccumulation of selenium may amplify the risk to those fish feeding in the south Delta. Stewart et al. (2004) have concluded that sturgeon are on the cusp of reproductive impairment already.

Certainty = 2 - Low
These types of exposure to contaminants are likely long-term and cumulative, and not likely to change much due to changes in north or south Delta water operations.

N4c. San Joaquin Salmon

All adult and young San Joaquin salmon must pass through the south Delta. Operations models show salinity increasing in the south Delta, probably due to salt loading from the San Joaquin. This probably is a good estimate of the increase in concentrations of other contaminants coming from agricultural runoff. Rapid urbanization in the south Delta will also increase local loadings of contaminants from urban sources.
Together these suggest greatly increased likelihood of exposure of fish to diverse concentrations of contaminants at various points along their migration.

Magnitude = 4 - High
The entire San Joaquin salmon population is at risk to many chemicals that have been found to be toxic to fish.

Certainty = 2 - Low
Very little data exist to show an impact. Many contaminants known to be toxic or damaging to salmonids are known to be present in the SJR and their presence in the Delta is likely to increase in both concentration and duration. Few are directly

monitored, but bioassays show frequent toxicity to invertebrates. Thus, the magnitude is very high, but certainty is low for impacts on fish.

N4d. San Joaquin Steelhead

All adult and young San Joaquin steelhead must pass through the south Delta. Operations models show salinity increasing in the south Delta, probably due to salt loading from the San Joaquin. This probably is a good estimate of the increase in concentrations of other contaminants coming from agricultural runoff. Rapid urbanization in the south Delta area will also increase local loadings of contaminants from urban sources. Together these suggest greatly increased likelihood of exposure of fish to diverse concentrations of contaminants at various points along their migration.

Magnitude = 4 - High
The entire steelhead population is at risk to many chemicals that have been found to be toxic to fish.

Certainty = 2 - Low
Very little data exist to show an impact. Many contaminants known to be toxic or damaging to salmonids are known to be present in the SJR and their presence in the Delta is likely to increase in both concentration and duration. Few are directly monitored, but bioassays show frequent toxicity to invertebrates. Thus, the magnitude is very high, but certainty is low for impacts on fish.

N4e. Sacramento Splittail

Because they are predators of overbite clams (Feyrer 1999), splittail show comparatively high Se body burdens (Stewart 2004). The current bioaccumulation of Se by splittail is right at the margin of what is expected to cause some reproductive impairment. Thus, any increase in Se bioavailability to splittail might be significant in terms of population-level reproductive success.

Magnitude = 3 - Medium
The benthic feeding of splittail puts them more at risk of accumulating sediment bound contaminants and contaminants accumulated by bivalves. Stewart et al. (2004) have concluded that splittail are on the cusp of reproductive impairment already.

Certainty = 3 - Medium
Feeding behavior of splittail makes them likely to be exposed to benthic animals and sediments.

Outcome N5: Lower quality delta smelt habitat due to reduced turbidity (i.e. loss of sediment due to fewer pulse flows on the Sacramento River).

"Suspended sediment is the primary attenuator of sunlight in the water column of the Delta" (Schoellhamer et. al., 2007, pg 5 of 39 in the pdf copy). A key component of delta smelt habitat suitability is water transparency (Feyrer et al. 2007; Nobriga et al. 2008, which is cited several times throughout the DRERIP delta smelt model).

"Most sediment is supplied by rivers to the Delta only a few days per year during large floods. This episodic nature is driven largely by pulses from the Sacramento River that deposit in the Delta and move into San Francisco Bay (Fig. 1, Wright and Schoellhamer 2005). During water years 1999-2002, 82% of the sediment was delivered during the wet period (31% of the time)" (Schoellhamer et. al., 2007, pg 6 of 39 in the pdf copy). Most of the sediment enters the Delta as suspended sediment rather than bedload (Schoellhamer et. al., 2007, pg 8 of 39 in the pdf copy).

Water transparency is a result of sediment in the water column per above references from the sedimentation model. Because the action proposes to divert Sacramento River water during flood events that bring most of the sediment into the Delta, it is possible the diversions might exacerbate increasing water transparency downstream that has already increased in part due to dams and armored levees in the watershed (DRERIP sedimentation model).

Magnitude = 2 - 3, Low - Medium

There is some conflicting evidence regarding the magnitude of the diversion effect on sediment. Schoellhamer et. al., 2007 (p. 10) states that, "…human activities that alter watershed sediment supply are likely to have a greater effect on river supply to the Delta than those that modify the flow regime". This statement implies that the magnitude of the diversion effect on sediment will be small relative to the impact of dams and channel-floodplain disconnection in the watershed.

There is also evidence that the magnitude of the diversion effect on sediment will not be small (Schoellhamer et. al., 2007, Figure 4): current south Delta diversions take ~ 20% of sediment passing Stockton and coming from east side tributaries.

The Sacramento River loads most of the estuary's sediment and loads most of it during floods when north Delta diversion rates are assumed to be high in this evaluation. If north Delta diversions removed 20% of Sacramento sediment load, the sediment loss to exports would be 10 times higher than current levels.

Certainty = 1 - Minimal

Given that there is no known quantitative study of the potential effects of north Delta diversions on turbidity in the Delta, the level of certainty is minimal. It is made more uncertain by the time scale of any effect. For instance, Sacramento River sediment supply has declined by 50% over 50 years (Wright and Schoellhamer 2004), which implies the annual effect is very small. A conceptual understanding of the average annual sediment budget is provided in Schoellhamer et. al., 2007. A more refined understanding of sediment dynamics will be needed to inform operational protocols of the diversion.

Note that both the magnitude and the certainty in this evaluation apply to both Hood bypass Scenarios because most of the sediment transport will occur during high flows that greatly exceed either bypass flow criterion. Thus, in both Scenarios it could be expected that north Delta diversions would be at maximum pumping capacity during major sediment transport flows.

Assumptions used in Scoring:
Turbidity is a key component of Delta smelt habitat (Feyrer et al. 2007; Nobriga et al. 2008 as cited in Norbriga and Herbold, 2008). The estuary has been losing sediment supply for years (Schoellhamer et. al., 2007). This is an issue of large spatial scale and long time scale change in the Sacramento River sediment budget. Currently, sediment comes into the Delta on river flow pulses (Schoellhamer et. al., 2007). Suisun/San Pablo Bay experiences this pulse in sediment. To better predict the effect of north Delta diversions on the estuary's sediment budget, proponents should consider the rating curve of sediment vs. flow for the mainstem Sacramento River, and include sediment supply for Yolo Bypass then compare the results to a reduced supply of sediment scenario due to north Delta diversions. When flow is high enough to inundate the Yolo Bypass, then there is a sediment pulse to the estuary that is not susceptible to north Delta diversions, but this averages ~ 30% of Sacramento River sediment inputs on average.

Outcome N6: Increased frequency, duration and extent of low DO at Stockton and blockage of salmon/steelhead migration on the San Joaquin River.

The effects of low DO on species of interest center on the migration of San Joaquin populations of fall-run salmon and steelhead. Other effects can be expected on the distribution of fish that reside in the Delta, especially benthic foragers like sturgeon and splittail.

Dissolved oxygen in the Stockton Deep Water Ship Channel is controlled by inflow from the San Joaquin River, BOD loads of inflowing water, and BOD loads generated in the local area. Flow modeling suggests that the area of Stockton will receive a much higher fraction of San Joaquin River water for much of the year, in many years, under both scenarios. Thus, this will deliver water with higher nutrient concentrations which will promote the growth of phytoplankton. Death and decomposition of this phytoplankton in the deeper waters of the ship channel can be expected to increase the severity, duration, and frequency of periods of low dissolved oxygen ("eutrophication").

<u>Potential Mechanisms</u>:

- Lower pumping from south Delta will result in more of the south Delta being filled with San Joaquin River water and lead to longer residence times of water in south Delta channels. Together these changes can be expected to worsen DO problems known to occur in the South Delta. Proposed tidal marsh restoration in the south Delta could improve or worsen DO problems in the region depending on design.

N6a, b. San Joaquin Salmon and steelhead

Magnitude = 4 - High
All adult and young San Joaquin salmon must pass through the south Delta. Operations models suggest conditions that represent worsening of drivers known to control DO levels. This suggests greatly increased likelihood of delaying or blocking upstream migration of salmonids.

Certainty = 4 - High
The entire population is at risk of worsened conditions due to a problem already known to be important.

N6c, d, e. White and Green Sturgeon, and Sacramento splittail

Magnitude = 1 - Minimal
These species are widely distributed and spawning primarily occurs in the Sacramento Basin. Thus, a small part of the population is at risk.

Certainty = 2 - Low
These species are comparatively tolerant of low DO (Joe Cech references). They can likely avoid entering areas where DO would be lethal by avoiding areas of low, but non-lethal DO levels. Operations models suggest conditions that represent worsening of drivers known to control DO levels. Thus, the magnitude is low but certainty is high.

Outcome N7: Loss of Sacramento River food material for covered species into the Delta due to diversions of water and reduction in flow to the Delta.

Food resources (phytoplankton, zooplankton and other organic matter) may be diverted along with the water as a result of this project and downstream areas, particularly the north Delta, will be deprived of this input. However, the river is a minor source of phytoplankton and probably zooplankton to the Delta so this effect is likely to be small.

Magnitude = 2 – Low (for both scenarios)
The foodweb model does not address loading of organic matter (from the rivers) to the estuary. The concentration of "food material" (living phytoplankton, microbes, and zooplankton, labile organic matter) in the river depends on what is in the reservoirs and on the travel time from the reservoirs to the Delta. This source of variability is unknown. For a given river flow, these concentrations will not change with increasing diversions, although the loading to the Delta will decrease as diversion flows increase.

River flow provides the largest source of total organic matter to the Delta, which helps fuel the food web (Jassby & Cloern 2000) and contributes to the Delta's overall net heterotrophy (Sobczak et al 2002). Nevertheless, most of the food consumed by the Delta foodweb is either phytoplankton or derived from phytoplankton. Phytoplankton production within the Delta greatly exceeds river inputs according to the mass balance developed by Jassby et al. (2002). Furthermore, accumulation of phytoplankton biomass in the Delta is directly related to residence time (Jassby et al. 2002), and therefore inversely to flow, implying that the higher loading of material during high-flow periods is less important than how long the water stays in the Delta. The same is probably true for zooplankton although a mass balance has not been calculated.

Certainty = 1 – Minimal
Although it is a tautology that loading of organic matter to the Delta will decrease as more water is diverted from the Sacramento River, this does not allow us to predict how that will affect foodwebs in the Delta. Several additional factors are important in determining the influence of reduced Sacramento River flow on the Delta foodweb. Reduced flow corresponds with reduced turbidity, reduced loading of ammonium (Dugdale et al. 2007), increased temperature, increased residence time in the Delta, and increased contribution of the productive San Joaquin River. Together with continued high nutrient concentrations, these factors are generally associated with increased phytoplankton growth and biomass accumulation in the Delta.

We cannot predict whether this will result in blooms of phytoplankton that support the foodweb, or in blooms of nuisance species such as *Microcystis* (see next outcome). The combination of factors due to reduced flow, together with rising temperature, could cause eutrophication, possibly resulting in depressions in dissolved oxygen and fish kills. These have been largely prevented so far because of the “filtering” provided by turbidity, grazing, & hydrodynamics in this estuary (Cloern 2001). This filtering effect would be reduced, particularly during the summer, if a significant proportion of Sacramento River water were diverted.

Outcome N8: Increased Microcystis biomass due to the new North Delta Diversion which will affect aquatic food webs and covered fish species

Lower Sacramento River flows may reduce summertime turbidity and will reduce summertime Delta inflows, which may create a higher potential for more intense *Microcystis* blooms than have occurred previously.

Magnitude = 3 - Medium
Laboratory experiments showed that *Microcystis* is a poor food source for the copepods *Eurytemora affinis* and *Pseudodiaptomus forbesi* (Ger 2008). Whether the strains used were toxic or not, results indicate the higher the abundance of *Microcystis* relative to palatable phytoplankton, the lower the survival of the copepods. Thus, the effects of *Microcystis* on the foodweb depend not only on the concentration of *Microcystis*, but also on the availability of other phytoplankton that are suitable as food.

Phytoplankton biomass in the Delta has declined over the last several decades (Jassby et al. 2002). Meanwhile, blooms of Microcystis have increased. Localized blooms were initially observed in the late 1990’s, though the species was recorded previously in non-bloom forming quantities (Lehman et al 2008). In the last decade, annual blooms have extended over wide regions of the Delta, in salinities of 0.1-18, beginning in June and reaching their peak between September and October (Lehman et al 2008). The geographic range of the blooms has been expanding (POD Management Team 2007). Although *Microcystis* was previously most abundant in low-flow waters of the Central Delta (Old River), the most recent monitoring from 2007 suggests that its abundance in

Antioch has become comparable to that in the Central Delta (POD Management Team 2007).

The two calanoid copepod species *E. affinis* and *P. forbesi* comprise much of the diet of delta smelt and of young longfin smelt and other fishes. Both of these species have declined recently, although those declines have not been linked to *Microcystis* or any other cause. Nevertheless, a reduction in food quality in the Delta will affect these species and thereby reduce food availability to covered fish species.

By extension, if the north Delta diversions worsened *Microcystis* blooms in the Delta, then there might be less food available to some fishes including delta smelt. There is reason to believe that the reduction in Sacramento River flow would exacerbate blooms. Although nutrient concentrations and ratios have been implicated in formation of blooms elsewhere, these seem of less importance in the Delta (Lehman et al. 2008). Rather, bloom formation seems to depend on low freshwater flow, stratification, high water clarity, and high water temperature (Lehman et al. 2005, 2008), all factors that indicate more potential for bloom formation with low Sacramento River flow. In addition, increasing water clarity during the last several decades (Kimmerer 2004, Nobriga et al. 2008) may be a long-term contributing factor and would likely be exacerbated by low flow.

Microcystis is a freshwater phytoplankton with limited tolerance for high salinity. This does not imply that higher salinity in the Delta, a likely consequence of reduced flow, would reduce *Microcystis* bloom formation. Since *Microcystis* and other plankton (including larval fish) move with the water, the blooms would simply shift in extent with the landward movement of the salt field. Lehman et al. (2005) have also hypothesized that bloom toxicity may be elevated where salinity causes the Microcystis cells to lyse (burst open).

Certainty = 2 - Low
All of the evidence points to increased frequency of *Microcystis* blooms with lower Sacramento River flow. However, there are some missing pieces that preclude a higher certainty rating. First, we do not now have a model that allows reliable prediction of bloom formation, and therefore cannot quantify the effect of the change in flow. Second, the basis for assuming that *Microcystis* is having a substantial effect on the estuarine foodweb is predominantly from laboratory studies (Ger 2008) and field measurement of toxin concentration in foodweb organisms (Lehman et al. 2008). So far the only indications of population-level effects in the field are anecdotal (die-offs of copepods during times of high *Microcystis* abundance, Kimmerer unpublished). Third, the link to covered species will remain speculative until we have better evidence on these population-level effects, and on the degree to which summer food limitation drives covered species population dynamics.

Outcome N9: – Increased predation of juvenile Mokelumne River salmon due to modified Delta Cross Channel operations

Reduced flows into the interior Delta resulting from Hood diversions and expanded Delta Cross Channel (DCC) closures have the potential to adversely impact Mokelumne River juvenile emigrant salmonids by decreasing flows through the Delta forks of the Mokelumne River. The proposed operation includes the following expanded DCC closures:

- DCC will be closed continuously from November through January, where it is currently open up to 45 days during this period.
- DCC will be closed continuously from May 21 through June 15, where it is currently open up to 14 days during this period.
- DCC will be closed continuously from June 15 through June 30, where it is currently open continuously during this period.
- DCC will be closed half the time from September through October, where it is currently open continuously during this period.

The timing of extended DCC closures in relation to Mokelumne River fry, sub-yearling smolts, and yearling smolt emigration is depicted in Table 1. Comparing the timing and relative abundance for each species-life stage indicates that proposed DCC operations will impact an additional 15% of fry, 37% of sub-yearling smolts, and 27% of yearling fall run Chinoook salmon smolts. For steelhead proposed DCC operations will impact approximately an additional 36% of fry, 49% sub-yearling smolts, and 33% of yearling smolts. Furthermore, some emigrating steelhead smolts are known to outmigrate through the DCC and down the Sacramento River. Extended DCC closures would also reduce potential use and increase mortality for this migratory pathway.

Magnitude = 3

Certainty = 3

Important Gaps in Information and/or Understanding

Data Needs

- Specific analysis of tradeoffs associated with potential benefits and impacts of proposed new operation of the Delta Cross Channel.
- Acoustical studies

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Appendices

Appendix A: Further Information on Route Selection and Travel Time

- In Winter (Jan-Mar), dual conveyance Scenarios 1 & 2 would create *undesirable* conditions for outmigrating smolts. Dual conveyance Scenarios would increase particle residence time (i.e., vulnerability to predation, rerouting to interior Delta) AND reduce particle likelihood of exiting western Delta (i.e., fewer individuals would complete outmigration to Chipps Island).
    - These conditions would affect all salmonids (Greene 2006), except late-fall.

- In Spring and Fall (Apr-Jun, Nov & Dec), conditions are improved under Scenario 1, which allows for faster travel time through Sacramento River as well as more particles exiting Delta. However, Scenario 2 would create undesirable conditions for outmigrating smolts, with increased residence time and fewer particles exiting western Delta.
    - These conditions would affect all salmonids.

"High flow conditions" (mean = 28,000 cfs; characterize median flows from Jan-Mar; affects winter, spring, fall runs, steelhead)

- Both Scenarios 1 & 2 result in *slower particle travel time* through Sacramento River (from Freeport to 3 mile Slough) and *fewer Sacramento particles reaching western Delta*. These particles are going to Delta Island Channel Use and in channels.
- **Longer residence time and lower success in exiting Delta are not favorable conditions for outmigrating smolts.**
    - Sacramento River particles took longer traveling from Freeport to Three mile Slough under Scenario 1 (152% longer than Reference) and Scenario 2 (165% longer than Reference). For outmigrating smolts, increased residence time increases vulnerability to predation and rerouting to Central Delta.
    - More particles under Scenario 1 (78% of reference) make it to Sherman Lake compared to Scenario 2 (73% of reference).

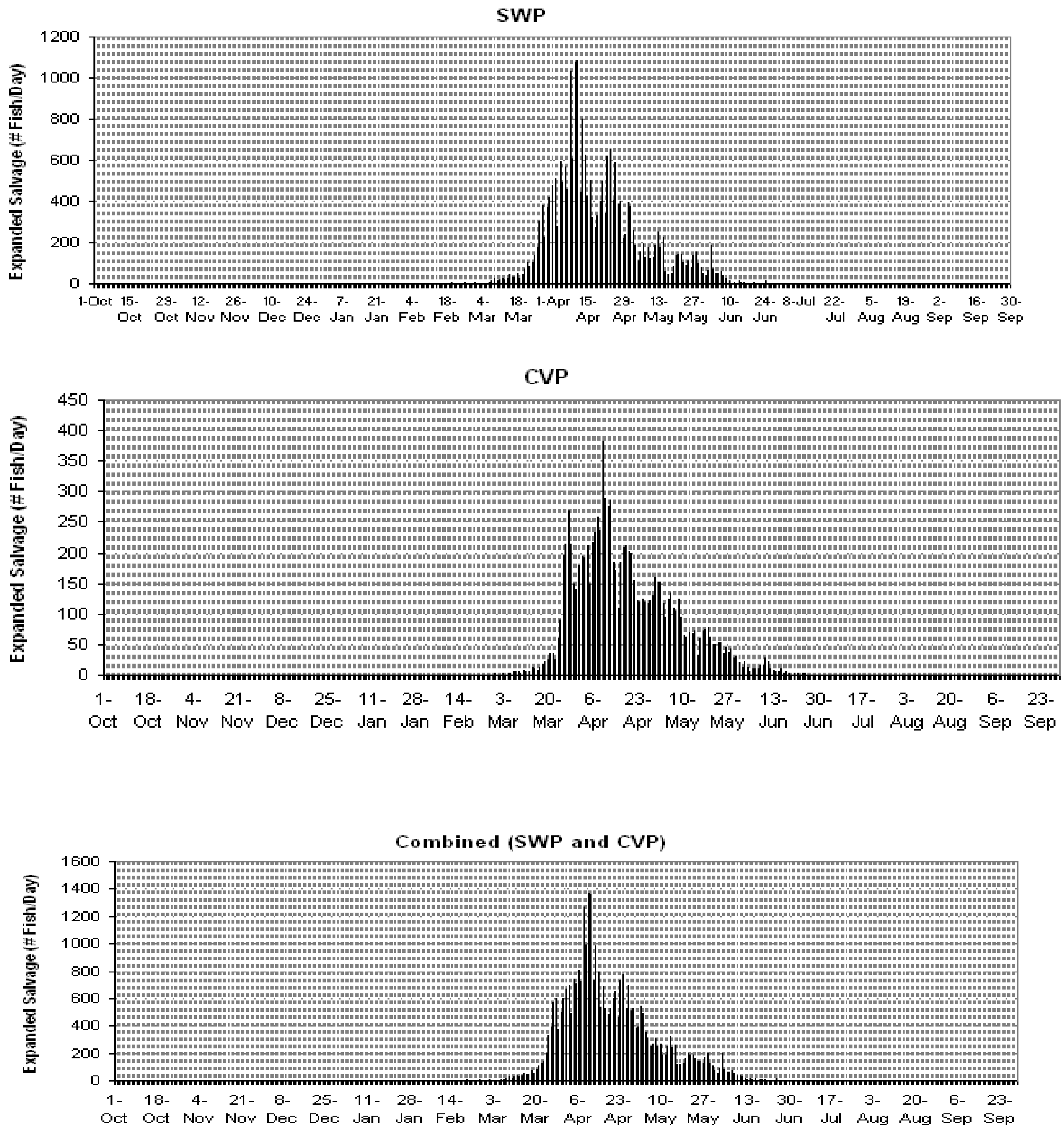
"Mid flow conditions" (mean = 13,200 cfs; characterize median flows from Apr-Jun; Nov & Dec) affects winter, spring, fall, late-fall runs, steelhead

- Scenario 1 results in *faster particle travel time* through Sacramento and *more particles making it to western Delta* compared to reference conditions.
    - Under Scenario 1, Sacramento River particles were 13% faster traveling from Freeport to Three mile Slough relative to Reference Scenario.
    - More particles under Scenario 1 (+40% of reference) make it to Sherman Lake relative to Reference Condition.
    - **Shorter residence time and higher success in exiting Delta are favorable conditions for outmigrating smolts.**
- Scenario 2 results in *slower particle travel time* through Sacramento River (from Freeport to 3 mile Slough) and *fewer Sacramento particles reaching western Delta* compared to reference conditions.
    1. Under Scenario 2, Sacramento River particles took 150% longer relative to Reference Scenario.
    2. Fewer particles under Scenario 2 (91% of reference) make it to Sherman Lake.

Longer residence time and lower success in exiting Delta are not favorable conditions for outmigrating smolts.

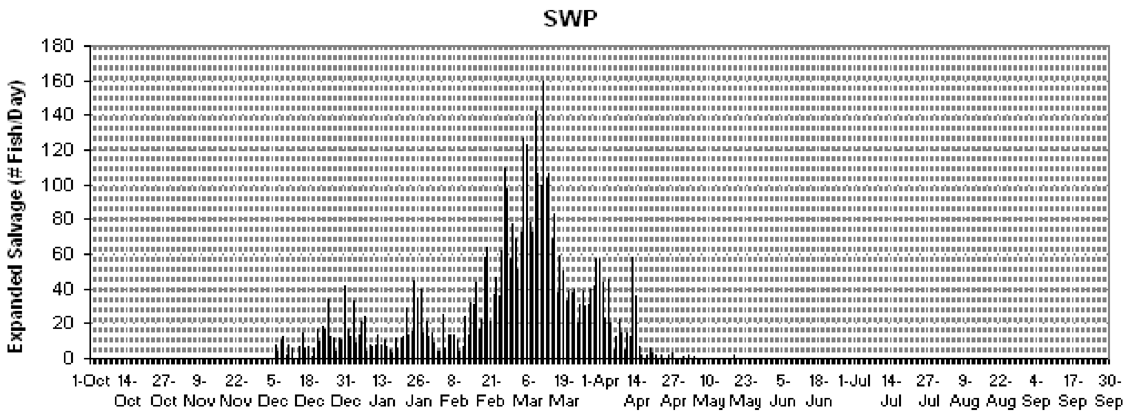
Appendix B: OMR vs. Salvage Relationship Graphs by Hansen

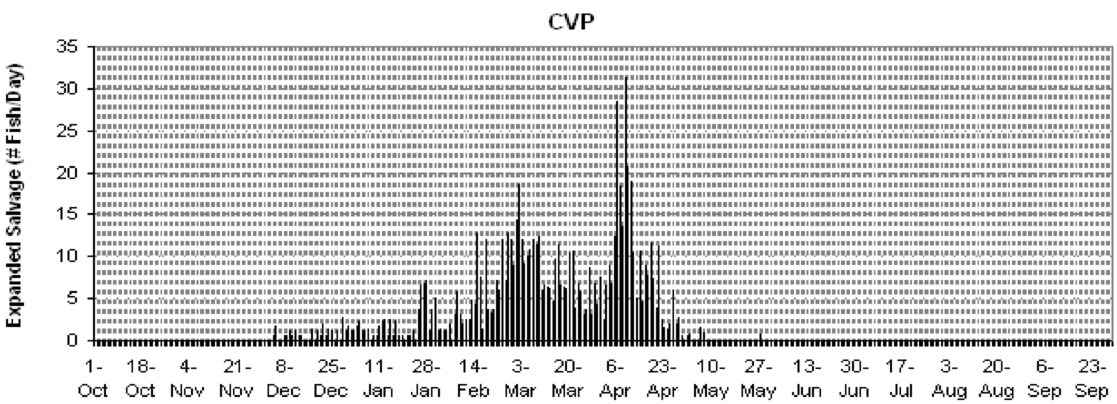
Seasonal Distribution of Salvage, 1995 to 2007
Spring-run Chinook Salmon

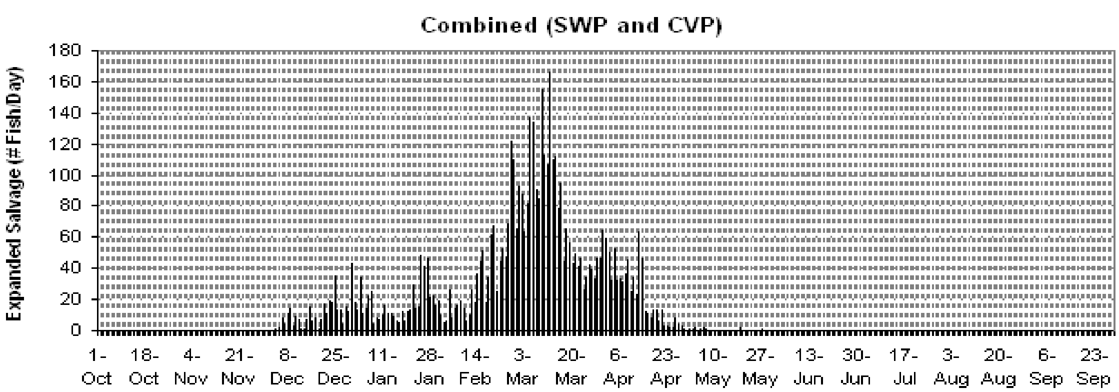


Source: California Department of Fish and Game (ftp://ftp.delta.dfg.ca.gov/salvage), non-clipped only.

Seasonal Distribution of Salvage, 1995 to 2007
Winter-run Chinook Salmon

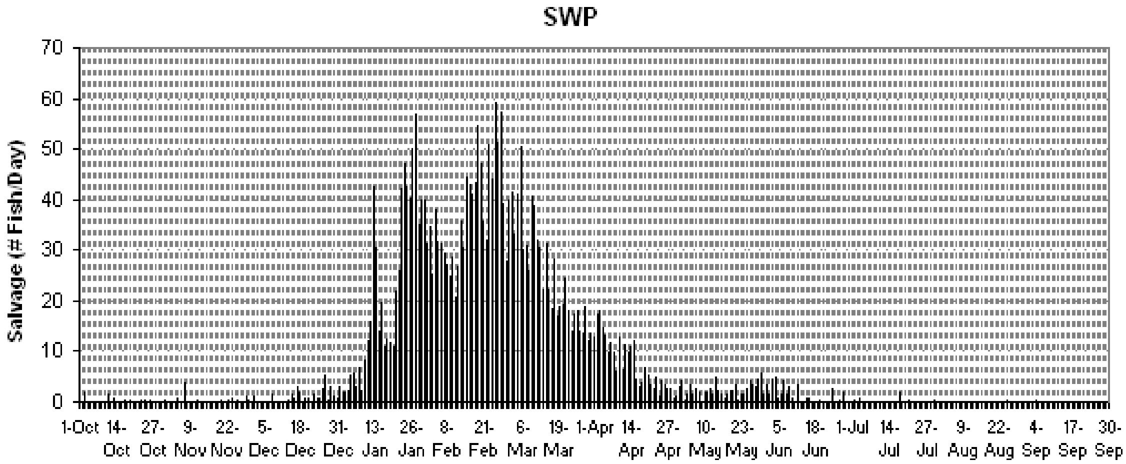


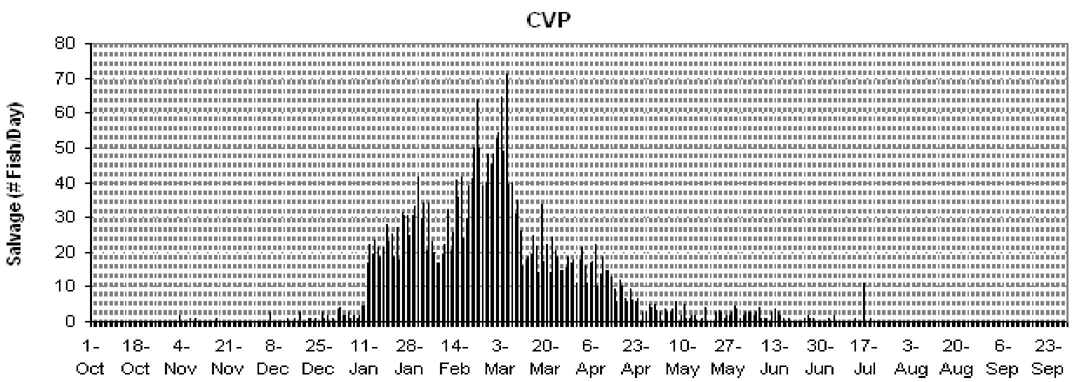


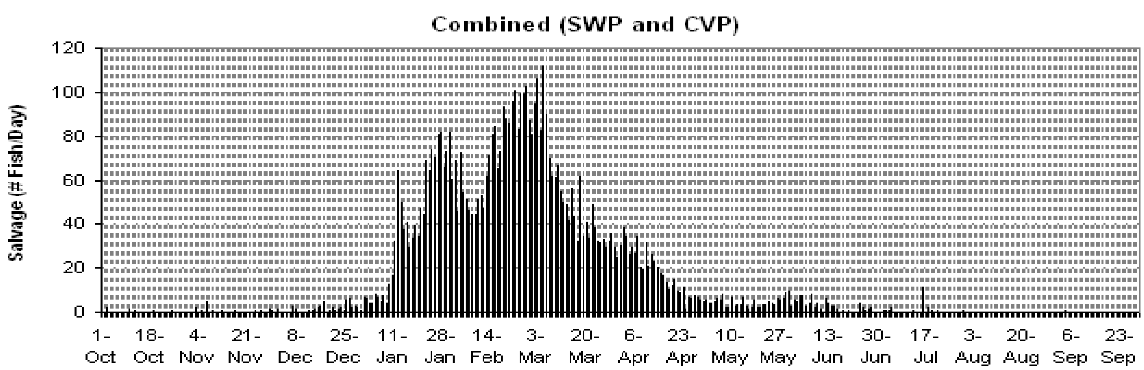


Source: California Department of Fish and Game (ftp://ftp.delta.dfg.ca.gov/salvage), non-clipped only.

Seasonal Distribution of Salvage, 1995 to 2007
Steelhead







Source: California Department of Fish and Game (ftp://ftp.delta.dfg.ca.gov/salvage), clipped and non-clipped.

Appendix C: Analytical results for BDCP ops study

Wim Kimmerer
January 23, 2009

The results presented here are to support the analysis of BDCP actions involving operations, specifically focused on changing flows in Old and Middle Rivers. These analyses have not been peer reviewed.

Summary

Question 1: Is the impact of export losses likely to be substantial for longfin smelt? The analysis I did suggests not: the ratio of salvage to abundance for longfin smelt is much smaller than that for delta smelt in most years. In dry years it is comparable or even higher.

Question 2: Can we estimate the impact of export losses on longfin as for delta smelt? I did a curtailed version of the analyses in Kimmerer (2008) for longfin smelt, essentially trying to calculate daily losses based on abundance in the south Delta, abundance overall, and Old and Middle River flows. The mean annual loss, compounded over 60 days, was 0.3% of the population. Longfin smelt apparently move out of the Delta rather soon after hatching, though, so the 60-day figure may be too long. In contrast, delta smelt remain in freshwater until ~July, resulting in longer exposure to export losses.

Question 3: Can we estimate the impact of export losses on splittail? No.

Question 4. How is salvage of adult delta smelt likely to change with changing Old and Middle River flows? This is still in progress. I have a model to relate salvage to OMR flow, but there are a couple of problems with it. I will work on this some more. I also need the flow Scenarios.

Question 1: Is the impact of export losses likely to be substantial for longfin smelt?
Approach: Generally, I compared the ratio of salvage to population size between delta and longfin smelt. Salvage is a poor proxy for export mortality, but probably scales the number of fish that are entrained in the southward-flowing water and thereby toward the pumps. A similar analysis to that of Kimmerer (2008) for delta smelt does not appear feasible, since that analysis relied on the 20mm survey which begins each year well after the spawning peak of longfin smelt.

I calculated total monthly salvage from 1980 through 1995 for each species. I then calculated the total by natal year: for delta smelt all salvage before May was assumed to be from the previous year's cohort, and for longfin smelt I assumed salvage before February was from the previous year (I ignored age of the fish so some 2-year-olds may have been in there). Note that salvage of both species is highest in spring. I took mean catch per trawl from the fall midwater trawl survey and calculated (approximate) population size assuming a volume sampled of 7000 m^3 and a habitat volume of 1.5×10^9 m^3 (these numbers don't really matter for the final result). I then took ratios of total annual salvage to total population size for each year and species. I combined that with estimated export mortality of juvenile delta smelt at the south Delta export facilities from Kimmerer (2008; SFEWS).

Results: Pumping mortality was ~ 1/3 of the salvage:abundance ratio of delta smelt but the two were uncorrelated. The ratio for longfin smelt was always lower than that for delta smelt except during 1989-1991 (Figure 1), which was a drought period when longfin smelt abundance was low. The salvage:abundance ratio for longfin was about 4% of that for delta smelt (median). The salvage:abundance ratio for delta smelt was not a good proxy for the estimate of export mortality; the two were uncorrelated, and the export mortality on average was about 1/3 of the salvage:abundance ratio.

Conclusion: These results show that the magnitude of the export losses to longfin smelt depend on the flow regime. Generally proportional salvage is much lower than that for delta smelt, and usually very near zero. However, during extended periods of low flow, the combination of low abundance and moderate export losses results in rather high ratio of salvage to abundance, so presumably mortality during those periods can be high.

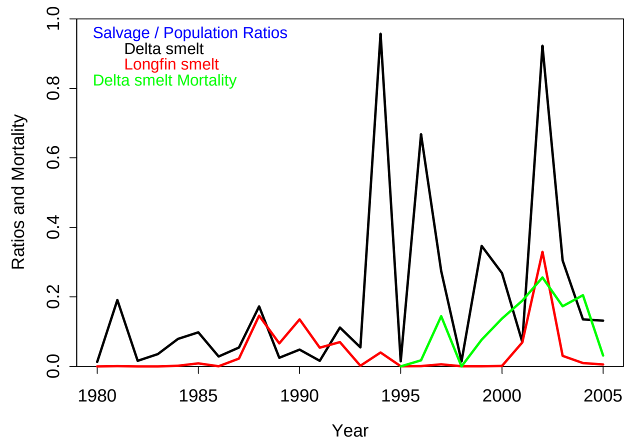


Figure 1. Time course of ratios of annual salvage to population size for delta and longfin smelt, and export-related mortality of delta smelt from Kimmerer (2008)

Question 2: Can we estimate the impact of export losses on longfin as for delta smelt?
Approach: I developed image plots of length by date for longfin smelt from both the 20mm survey and salvage data. The time course of the 20mm survey does not include the entire larval period of longfin smelt, which spawn earlier than delta smelt. The salvage data cover the whole period but do not include fish smaller than 20mm.

I used a similar approach to that applied to determine daily percent mortality of Age-0 delta smelt due to export pumping in Kimmerer (2008). See that paper for assumptions. No correction was made for efficiency of the 20mm net, since similar sizes were assumed to occur in the south Delta and other parts of the system. Mortality was calculated for each 20mm survey from 1995 through 2006. In contrast to the analysis for delta smelt I included stations in San Pablo Bay since longfin smelt are common there, and included the volume of that region (0.9×10^9 m^3, Kimmerer 2004) in the calculation of population size.

Results: The image plot from salvage (Figure 2) shows a peak around julian days 90-150 (April – May) in small fish, and a much lower peak earlier in the year of fish that are from previous year classes. Fish below the line in Figure 2 were assumed to be Age-0. The catch in the 20mm survey roughly corroborates the timing of the peak in salvage (Figure 3), although the start of the peak is earlier since the 20mm survey catches smaller fish.

Export mortality was much lower than that for delta smelt (see Kimmerer 2008 Figure 15; daily mortality based on the 20mm survey was as high as 6% d^{-1}). The highest value was a single, somewhat anomalous value of 0.12% d^{-1} in 1996 (Figure 5). The highest mean value was 0.02% d^{-1} in 2002. If this were compounded over a 60-day period of vulnerability, the result would be a loss of 1% of the population. The mean compounded loss was 0.3%. Note that the calculation for delta smelt was much more involved than this, which should be considered only an estimate for range-finding.

Even that estimate may be high. Delta smelt remain in the Delta until around July, possibly to avoid high temperature. Longfin smelt are larger in samples taken further from the pumps (Figure 6), indicating that they are probably leaving the area within some period after hatching. Therefore individual longfin smelt do not remain vulnerable to pumping for as long a period as delta smelt.

Conclusion: Longfin smelt are much less vulnerable to export pumping than delta smelt, although the 20mm survey is somewhat less suitable for making the calculation for longfin than delta smelt. The reasons for the difference are the lower fraction of the longfin smelt population that occurs in the southern Delta, and the earlier movement of longfin smelt to brackish waters out of reach of the pumps.

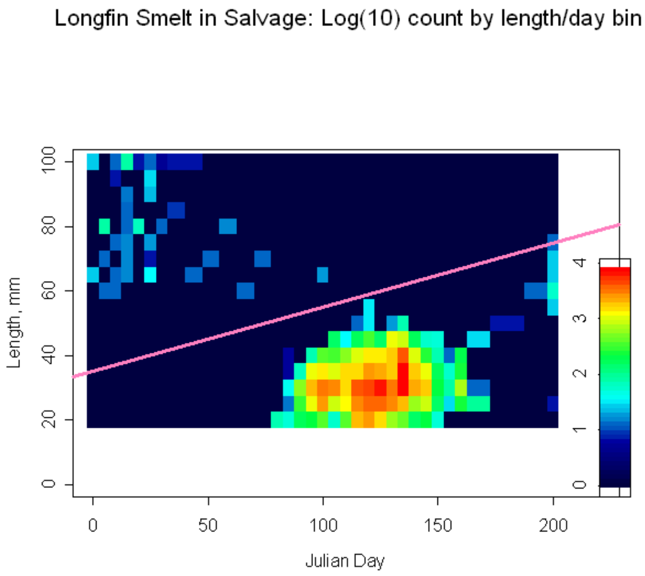


Figure 2. Image plot of catch (log scale) in the salvage facilities by length and day, 1995 – 2006.

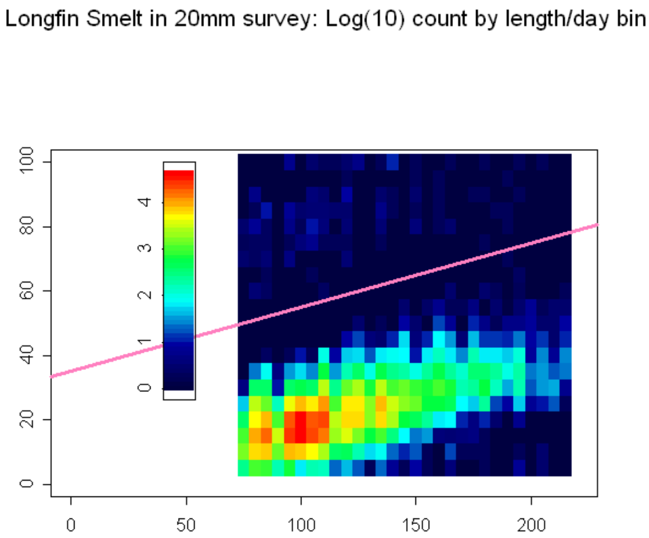


Figure 3. As in Figure 2 for the 20mm survey.

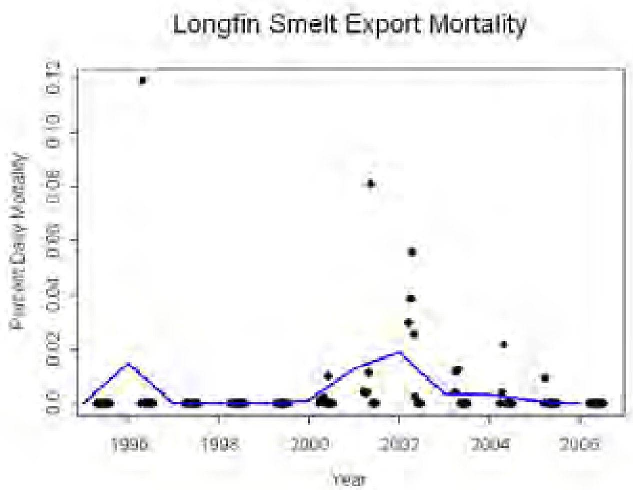


Figure 4. Daily percent mortality due to export pumping and annual mean. Each point represents data from one survey.

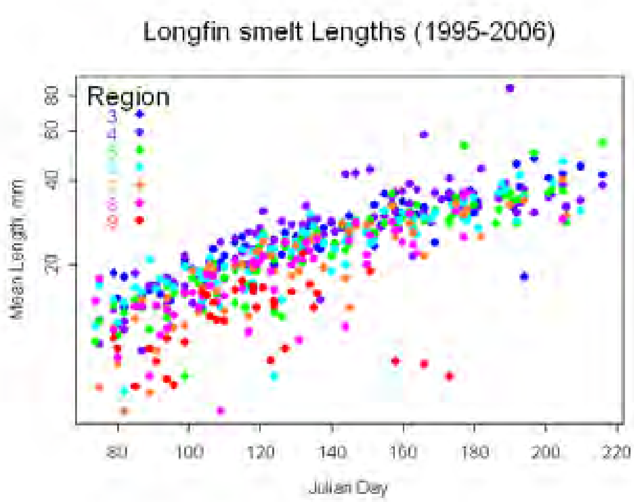


Figure 5. Mean length of longfin smelt from 20mm survey by day and region. The region is the first digit in the station number, and increases generally from San Pablo Bay (3) to the south Delta (9).

Question 3: Can we estimate the impact of export losses on splittail?

Approach: As for delta and longfin smelt except that I did not have the catch per trawl for this species. I therefore used the abundance index from the fall midwater trawl survey, and divided it by 500 (the mean ratio of index to mean catch per trawl for the 4 POD species ranges from 400 to 600). Otherwise the approach was the same.

Results: Salvage was generally higher, sometimes much higher than population size estimated from the MWT (Figure 6)

Conclusion: We can't estimate the impact of export losses on splittail. There is no other sampling program with the right combination of quantitative sampling and seasonal suitability to do this.

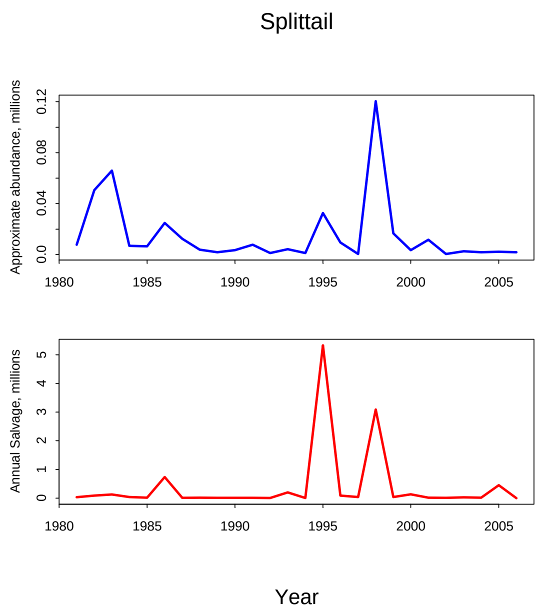


Figure 6. Approximate abundance and annual salvage of Sacramento splittail (millions).

Question 4. How is salvage of adult delta smelt likely to change with changing Old and Middle River flows?

Approach: The basic problem is that the salvage of delta smelt is sometimes high when OMR flows are strongly negative, and sometimes zero. Salvage is usually low when the flows are positive (but not necessarily zero). The question, then, is what benefit accrues from restricting OMR flows in winter.

The general approach was to find a suitable model of the effect of flow on salvage, and then use forecast changes in OMR flow from the 82-year set of Scenarios to estimate the change in salvage. If salvage is proportional to export-related mortality, then this should represent the proportional decrease in mortality.

Salvage data from December 12 through March were used in the analysis. A total of 5413 data points were available from 1981 through 2006: 2653 from the state facility and 2760 from the federal facility. The expansion factor to convert counts in the salvage facility to salvage was determined as the ratio of reported salvage to counts for delta smelt, or if that was zero, for all fish. Two cases had zero counts and one had a missing salvage value; these were eliminated. Thirteen cases (February 2006 in the state facility) had missing values for salvage of delta smelt; these were calculated using the expansion factor for all fish. Note that these expansion factors are approximate, in that the actual calculation is done for each of several time periods over the course of a day and summed over the day; however, the expansion factors for delta smelt and all fish were reasonably close so using daily values seemed a useful simplification to avoid having to work with massive amounts of uninformative data.

A suitable model of these relationships must be nonlinear, and allow zero salvage but not negative values; therefore a linear model is unsuitable. However, since the salvage data are based on counts of fish in the two salvage facilities, we can use a model with a Poisson error distribution in which the raw count data are modeled directly. The model is specified separately for the state and federal facilities, since they may have different relationships. The model is specified in steps:

$$\text{Salvage density} = e^{(a + b * \text{OMR})}$$

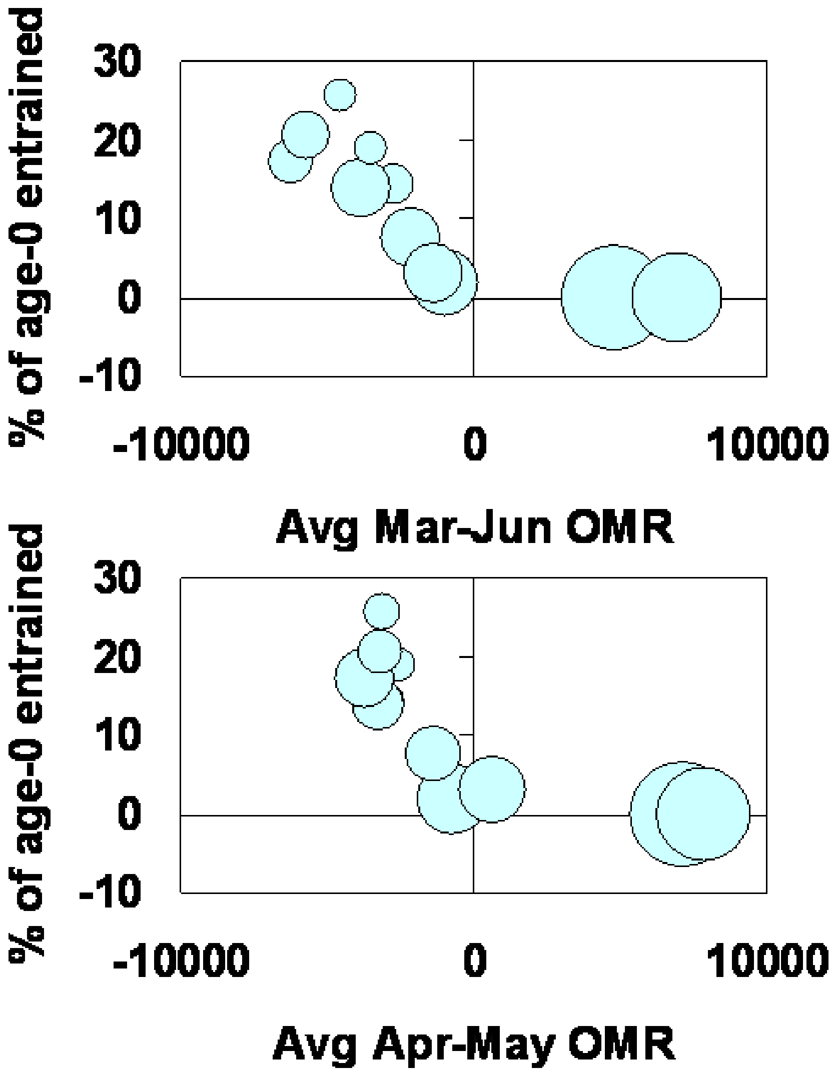
```
Expected Salvage = Salvage density * export flow
Expected count    = Expected salvage / Expansion factor
Observed count ~ Poisson (Expected count)
```

Where a and b are the coefficients to be estimated. Salvage density is the number of fish per unit volume of exported water. This is modeled as a function of OMR flow, since salvage would vary with export flow but salvage density would presumably vary only with OMR flow. Then the expected count is used as the mean of a Poisson distribution, and the raw count data were fit using a Poisson error distribution.

For practical reasons model was fit in a Bayesian analysis using WinBUGS. Uninformative priors for a and b were used, which has the effect that the analysis is similar to a likelihood analysis but is provides more information about the parameters. The prior distributions of the parameters were log normal for **a** (since it can't be less than zero), and normal for **b**, both with means of zero and variances of 10^6. Parameters were estimated from 10,000 iterations after a burn-in of 10,000 iterations to remove the effects of the assumed starting points.

Appendix D: Scatterplot of Average Flow In Old and Middle Rivers

Effects Figure 7



Upper panel is March – June. Lower panel is April – May. The percentage of the larval and juvenile delta smelt population entrained in the SWP and CVP export pumps. The entrainment estimates were taken from Kimmerer (2008). The bubble sizes are scaled to the average Delta outflow for the same averaging periods as the OMR flows.

Appendix E: Comparative Analysis of the Two Scenarios

This action proposes two Scenarios:

- Scenario 1 is the Mid-Range Hood Bypass Criteria where December 1 through June 30 maintain a Sacramento River bypass flow of not less than 11,000 cfs; and July 1 through August 30 maintain a Sacramento River bypass flow of not less than 5,000 cfs.
- Scenario 2 is the Low (5,000 cfs) Hood Bypass Criteria.

The Team evaluated modeling Scenario results for each of the two Scenarios. The modeling output was displayed in graphs that included the following variables:

- Monthly averages of combined OMR flows
- OMR in comparison to both the high bypass flow Scenario and to D1641 baseline.
- OMR in comparison to the low Bypass flow Scenario (#2) and to D1641 baseline
- average OMR flows (above) and dry year OMR flows
- frequency of different flows during the Delta Smelt season

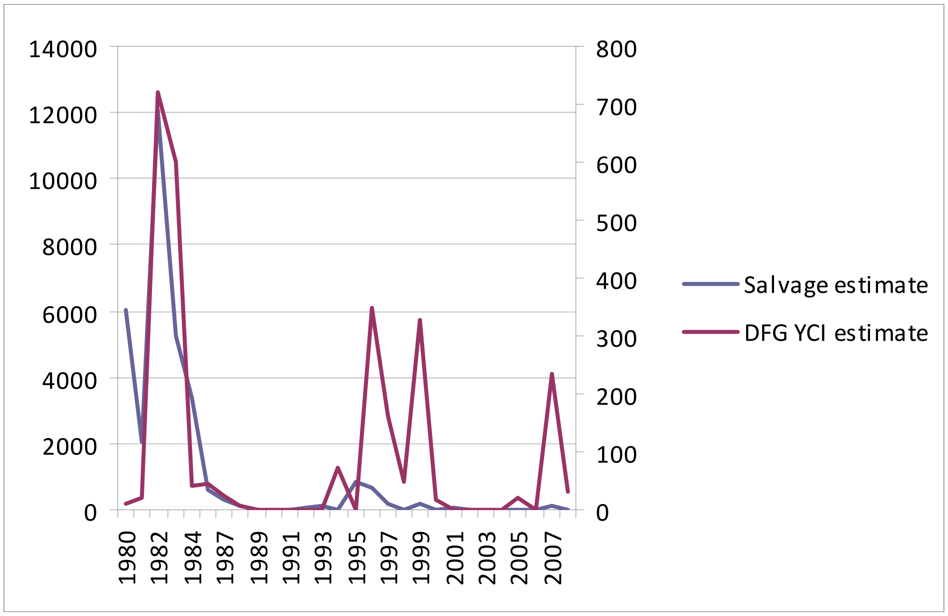
Based upon this analysis, the Team concluded that the positive and negative outcomes for each Scenario and the magnitude and certainty scores for each outcome would be similar under both Scenarios, unless otherwise noted in the individual outcome scores in the main body of this worksheet.

Appendix F: White Sturgeon Salvage Data and Analysis

Year	Salvage	DFG_YCI
1968	228	
1969	1393	
1970	518	
1971	397	
1972	3709	
1973	478	
1974	2238	
1975	4475	
1976	369	
1977	133	
1978	5953	
1980	6055	11.08
1981	2061	21.85
1982	12043	719.70
1983	5256	599.64
1984	3388	40.66
1985	586	44.04
1987	328	23.50
1988	132	8.47
1989	17	0.00
1990	29	0.00
1991	6	0.00
1992	62	0.00
1993	121	0.00
1994	3	72.49
1995	873	0.00
1996	676	348.61
1997	205	161.00
1998	23	46.73
1999	185	327.74
2000	0	18.19
2001	64	0.00
2002	30	0.00
2003	12	0.00
2004	24	0.00
2005	3	19.13
2006	24	0.00

2007	94	234.60
2008	28	30.19

Figure F-1: Analysis of White Sturgeon Salvage and YCI by Year



Appendix G: Flow, Salinity and Migration of Salmon

By, Greg Gartrell[4] and Bruce Herbold[5]
April 2009

This is a brief discussion of how flow and salinity likely affect salmon outmigration. The first section discusses the difference between average flow and tidal flow, and how the “net flow model” leads to incorrect conclusions. The second section applies a tidal view to salinity gradients to provide an alternative explanation of observations.

1) Net flow models versus a tidal view of the Delta

Net flow (whether QWEST or OMR net flow or any other net flow) in channels influenced by tides is a mathematical construct, not a physical factor felt by fish. QWEST was first used in an old “Carriage Water model” that attempted to describe how the outflow required to meet a given salinity level in the Delta increased with increasing exports. That model failed miserably: the hydrodynamics were wrong, the outflow levels the model predicted were wrong and the shape of the curve relating exports and outflow was backwards (predicting a monotonically increasing curve when the actual curve has a minimum value before increasing).

Net flows are averages of flows measured at a point (an Eulerian view), effectively the view of water movement from the river bank. This is not something that fish experience. This mathematical construct simplifies a complex flow field, and in the case of fish movement, confuses the picture just as the old Carriage Water Model confused the understanding of salinity in the Delta. Fish experience local velocity[6] as they move around (the fish-eye or Lagrangian view). Of course, to the extent that fish move with the flow, they experience no change in velocities any more than we sense the movement of the Earth through space, except that they feel accelerations due to factors like turbulence, fish body motion or changes in channel shape. However, the movement of water and fish with flow is very different when viewed without the averaging needed to calculate net flows. To give an idea of how badly a model based on average flows (Eulerian or Lagrangian average) in a tidal environment can be, consider the following:

a) Tagged salmon released north of Rio Vista have been caught after just a few days at Chipps Island where tidal flows are very high but net flows are very small. If the fish moved with the average flow, it would take them one to two months to arrive.
b) A salmon could start the day in Old River, travel with the instantaneous local flow down the river on the flood tide towards the export pumps, move across Woodward Cut and travel up Middle River on the ebb tide. The daily average flow (in this case Lagrangian average) would be pointing from Old River to Middle River, leading to the false conclusion that the salmon walked across the island. All information about the intermediate movement of the salmon is lost in the averaging. On the other hand, using the (Eulerian) average of the measured water velocity at one location in the channel (the USGS velocity meter for example) could give an average velocity of a

---
[4] Contra Costa Water District
[5] U.S. Environmental Protection Agency
[6] Flow in a channel is the average velocity times the cross-section. The velocity in a channel varies across the width and depth of the channel. Fish will experience the local velocity (in space and time), not the cross-sectionally averaged velocity, nor the overall flow in the channel.

few millimeters per second (or about 300 meters per day), an equally false conclusion.

Two problems with net flows prevent them from reflecting conditions that directly affect fish: they throw out important information in the process of averaging and they are derived variables (not independent variables) both mathematically and physically.

The following graphs illustrate these problems. The graphs show instantaneous flows.

Figure 1 shows Delta flows with the ebb and flood flows generally of the same magnitude in opposite directions. The average net flow is much smaller than any flow affecting the fish at a given moment.

Figure 1. Flow with flood and ebb nearly balanced, 1 = 10,000 cubic feet per second

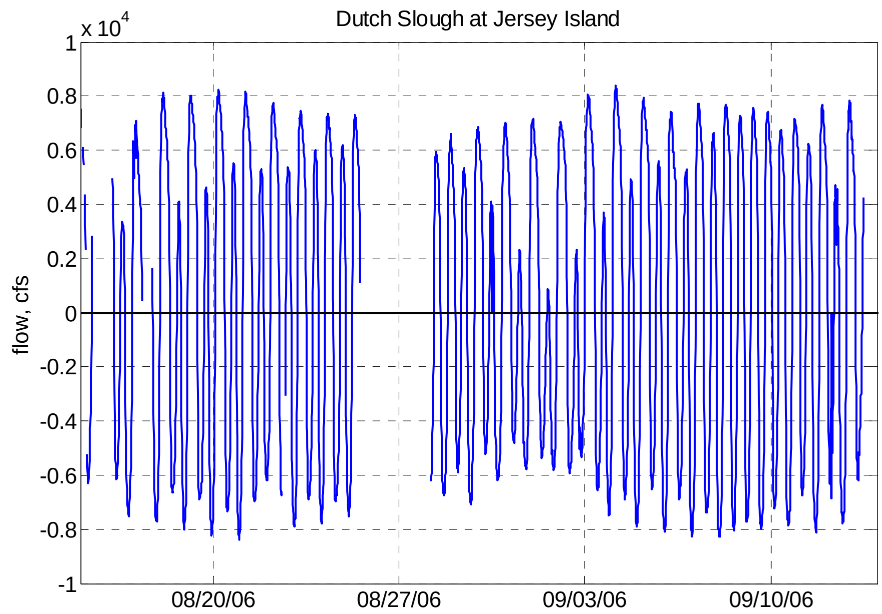
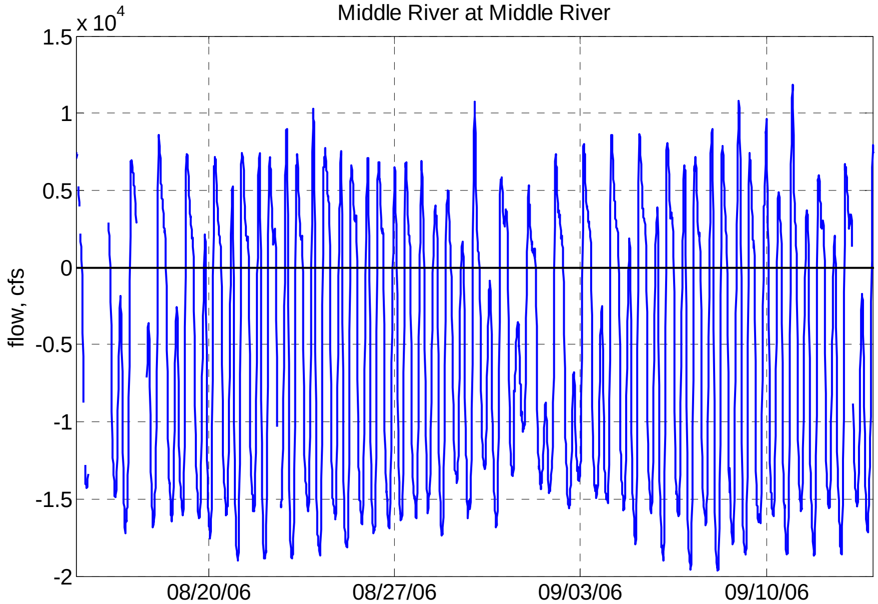


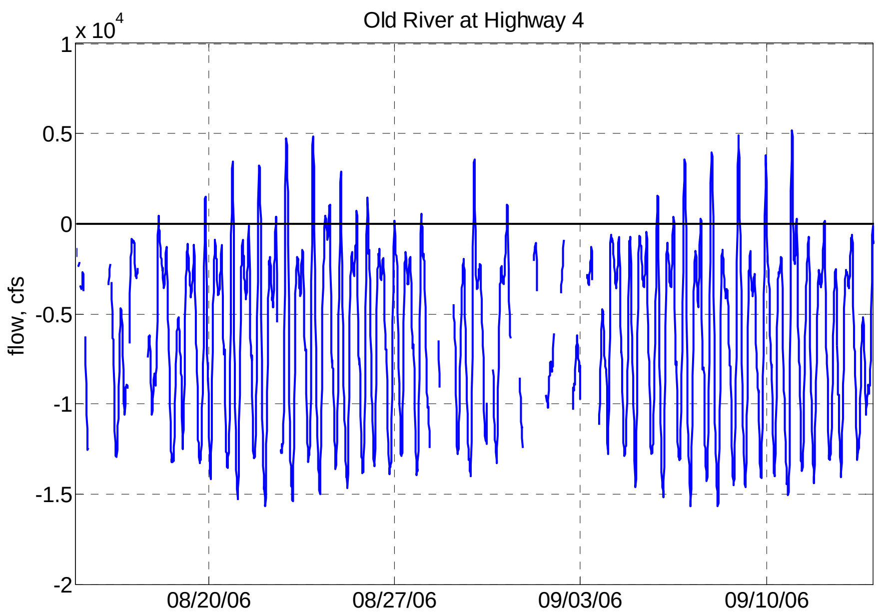
Figure 2 shows tidal flows with a stronger flood than ebb. While the direction of the average is obvious, the magnitude of the average is not. A fish experiencing this still has a chance to move in the opposite direction from the average if it uses the tides correctly (i.e., if it gets into the high velocity part of the channel on the ebb, and stays near the channel sides on the flood). Salmon clearly have the ability to pick the right tide based on cues, or they could not get from north of Rio Vista to Chipps Island in a few days.

Figure 2. Flow with strong flood tide compared to ebb, 1 = 10,000 cubic feet per second



Finally, Figure 3 shows a tidal flow where, at times, the ebb and flood are both less than zero. In this case, a salmon trying to surf the ebb will have a rough time of it. In fact, one can find no ebb tide at all for days at a time. This is a not a good situation if, in one flood tide, the salmon can end up in Clifton Court Forebay.

Figure 3. Flow in Old River at Highway 4, 1 = 10,000 cubic feet per second



Clearly, the situation in Figure 3 is going to result in high entrainment of fish: the export flows are so big that the ebb tide is lost and it is a one-way trip south, with tidal excursions double the normal 4 or 5 miles. When does this situation occur? It starts when exports are 5000 cfs to

7000 cfs. The Bay Institute argued in the OCAP lawsuit that high entrainment of salmon occurs when exports are over 7000 cfs: that is when the ebb tide is lost. That level of exports is also when delta smelt entrainment is high in January and February.[7] An examination of Figures 1 through 3 tells the story very quickly: this is about tides and export levels, not net flows. It is not the “net flow”; it’s the “no ebb flow”.

What about entrainment that occurs when net flows are small (or even positive)? The net flow view of the world fails completely (just like the old Carriage Water model) in this situation. When viewed with the tides in mind, the picture becomes clear, as the examples in the next section illustrate.

2) Salmon movement in a tidal environment

Consider salmon moving down the Sacramento River into the Delta. Some will make it to Chipps Island and beyond, but some will end up in the Lower San Joaquin River, via Georgiana Slough, through Three-Mile Slough or around Sherman Island. In this central delta area their advective (i.e. non-swimming) movement would be governed by tidal flows. Some will, even when export pumping is low and net flows are positive, go through False River into Franks Tract, where they (the survivors, anyway) have a good chance of being discharged out into Old River. Others can get sloshed into Middle River. This is their starting point for the Scenarios that are described below.

For San Joaquin Salmon, the starting point for the Scenarios below will be the San Joaquin River at the Head of Old River.

Scenario 1: High exports, typical San Joaquin River flow and salinity (i.e., low flow, high salinity).
In this case, exports are high and the ebb tide is very small or non-existent. It is a short trip down the river (the salmon simply cannot swim against 1 to 2 fps currents for long) to the export pumps for Sacramento salmon. San Joaquin salmon have two likely fates: those entering Old River have a quick trip to the export pumps; those moving down the San Joaquin River get to the Lower San Joaquin River and then some will make it to Chipps Island and some will move into Old and Middle Rivers and thence to the export pumps. In all cases salmon entrainment will be high.

Scenario 2: Low exports, typical San Joaquin River flow and salinity (i.e., low flow, high salinity). Sacramento salmon coming from the north experience substantial ebb and flood tides. However, one thing is peculiar in the central and south Delta compared to what should be found in an estuary: San Joaquin River salinity (generally as much as 1 mS/cm, with chloride levels over 150 mg/l) is much higher than Sacramento River salinity (about 0.15 mS/cm with chloride levels around 10 mg/l).[8] An obvious cue in a tidal system for the ocean is salinity (electrical conductivity or specific ions; two obvious ions would be sodium and chloride). What salmon in the central and south Delta see is a reverse salinity gradient because of high San Joaquin

[7] Pete Smith used OMR net flow to show this, but OMR net flow is a dependent, not independent variable. Exports and San Joaquin inflow are independent variables, and the correlation between delta smelt entrainment and exports/San Joaquin flows is better than the correlation between entrainment and OMR flows for the same time period.
[8] As an example, with flows increasing during the VAMP period, SJR salinity is currently about 0.4 mS/cm today (April 20, 2009). That level is also found near Collinsville today, but in between it is as low as 0.2 mS/cm (Jersey Point area).

salinity and saline discharges (ag and urban) within the Delta. Salmon attempting to follow the salinity gradient to the ocean would jump into the high velocity zone on the flood, rather than ebb. That takes them the wrong way, and exposes them to entrainment at the export pumps. (Even if export rates are very low, there is a good chance to get into the pumps).

The situation for San Joaquin salmon is probably very much worse: arriving in a low flow with high salinity and entering a reverse salinity gradient, the chances of a bad ending would lead one to wonder how any salmon at all find their way out. This is consistent with the extremely low survival rates reported by USFWS under all but flood conditions in the Delta.

In this case it is neither the "net reverse flow", nor the "no ebb tide"; it is the "reverse salinity gradient".

Scenario 3: Low exports, typical San Joaquin River flow and salinity (i.e., low flow, high salinity) with an Isolated Facility.
This case is little different from Scenario 2, except that the exports are liable to be less and the water quality situation could easily be worse. With apologies to our friends who authored the PPIC reports, it is likely to create an "Arkansas cesspool" from the "Arkansas Lake". With drainage (from the San Joaquin River and in-Delta agriculture) and urban discharges ringing the area (clockwise: Sacramento Regional, Stockton, Tracy, Discovery Bay, Ironhouse SD, Delta Diablo SD, Central Contra Costa SD), and little inflow, the central and south Delta are likely to become (with apologies to Thomas Friedman) "Hot (warm SJR water), Flat (gradients) and Crowded (with non-natives)". Entrainment, in the absence of screens will be high at both export pumps and agricultural intakes (you only have to see the vortex spinning above a siphon to realize just how fast the velocity is in the siphon), and confusion will be high. The number of fish orienting correctly to the ocean would be very small and even for them the very long transit time would probably subject them to extremely high mortality rates within the delta.

Scenario 4: Good flows and high quality on the San Joaquin River. Salinity gradients are not reversed and fish orient correctly to the tidal salinity gradient and tidal flows. This is totally different from Scenario 1, 2 or 3. The key is improved San Joaquin River flow and salinity.

Appendix H: Water Source Fingerprinting

SUMMARY OF PRELIMINARY MODELING OF DRAFT BDCP CONSERVATION STRATEGY – CORE ELEMENTS

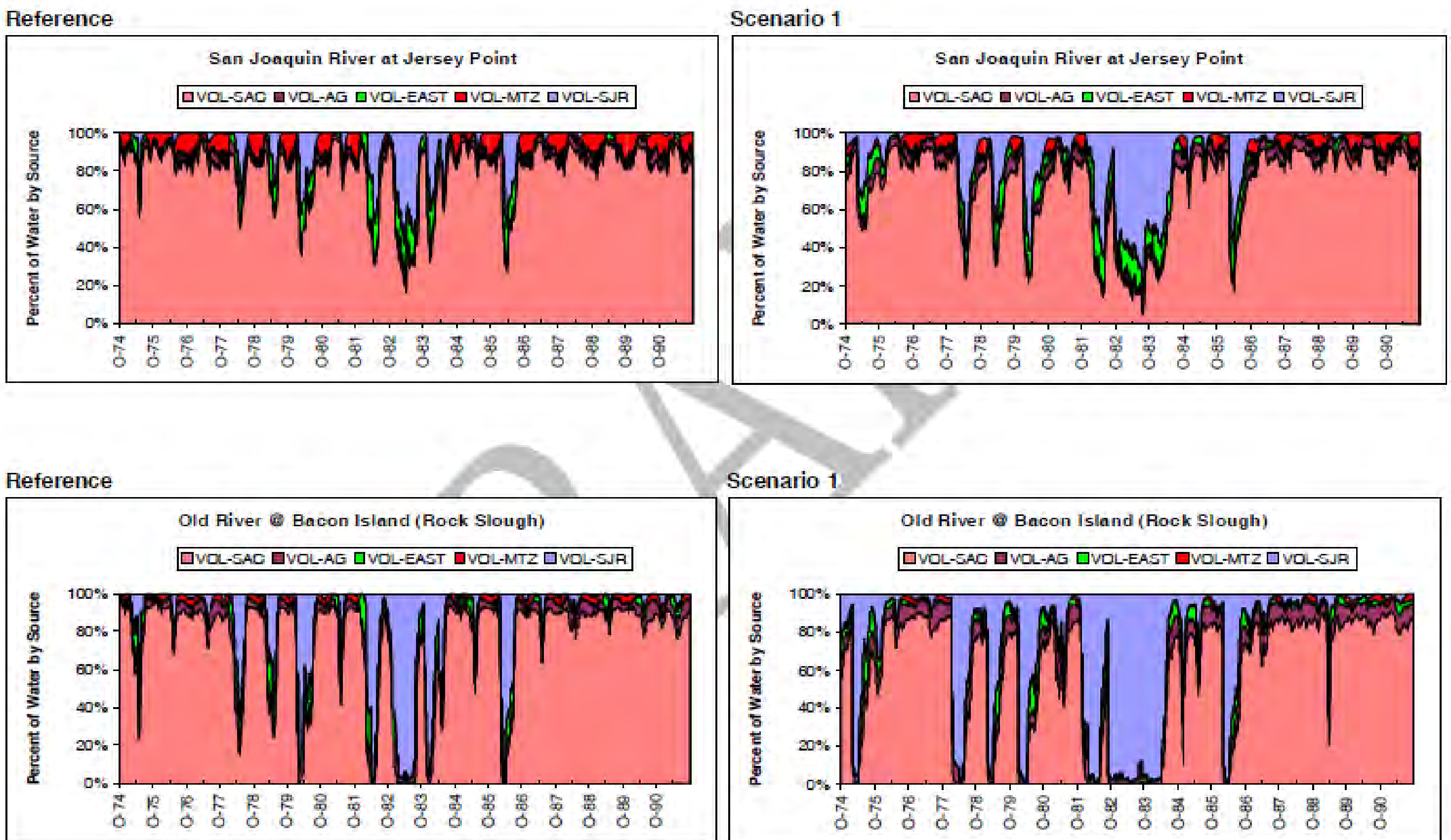


Figure 3-8. Simulated source water contributions at Jersey Point and Old River at Bacon Island for Reference and Scenario 1.

Source: BDCP, February 2009

Appendix I: Particle Tracking Summaries

The 13 graphs shown below provide the particle tracking summaries used in this worksheet, specifically, Outcome N1a. Several graphs provide information on transit time, particle fate flow conditions, residence time and pathway of fish in the Delta.

Table I-1

PTM Scenario	Insertion Date	30-day Mean Freeport Flow (cfs)			30-day Mean North Delta Diversion (cfs)			30-day Mean South Delta Diversion (cfs)		
		Reference	Scenario1	Scenario2	Reference	Scenario1	Scenario2	Reference	Scenario1	Scenario2
Low Event	6/1/1991	7,663	8,321	9,016	0	0	2,339	1,100	1,644	0
Mid Event	1/1/1976	13,196	13,208	13,209	0	1,214	4,515	8,242	4,982	4,982
High Event	2/1/1981	27,953	27,856	27,840	0	7,585	9,239	9,746	1,610	0

Figure I-1

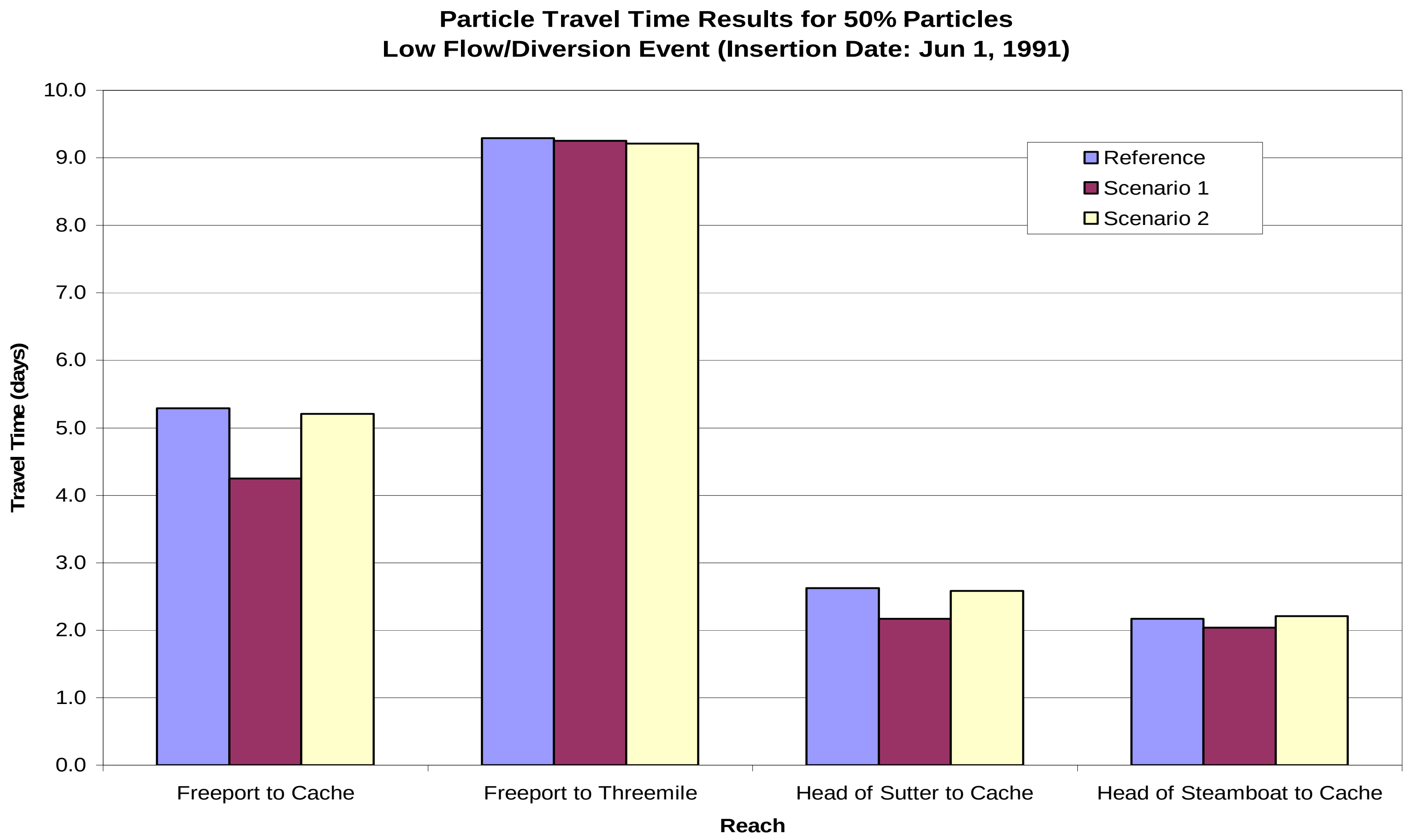

Particle Travel Time Results for 50% Particles
Low Flow/Diversion Event (Insertion Date: Jun 1, 1991)
Travel Time (days)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Reference
Scenario 1
Scenario 2
Freeport to Cache
Freeport to Threemile
Head of Sutter to Cache
Head of Steamboat to Cache
Reach

Figure I-2

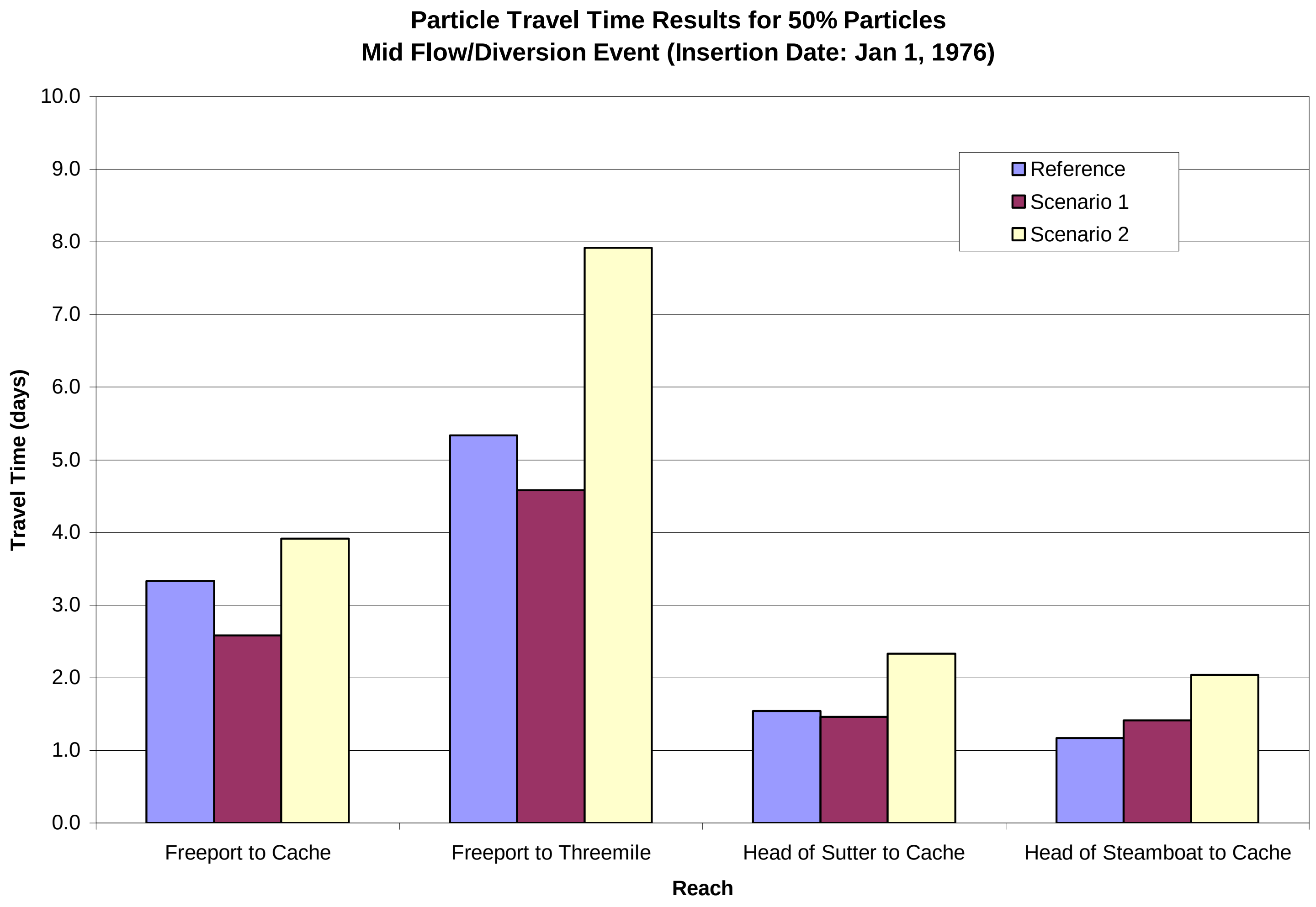

Particle Travel Time Results for 50% Particles
Mid Flow/Diversion Event (Insertion Date: Jan 1, 1976)
Travel Time (days)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Reference
Scenario 1
Scenario 2
Freeport to Cache
Freeport to Threemile
Head of Sutter to Cache
Head of Steamboat to Cache
Reach

Table I-3

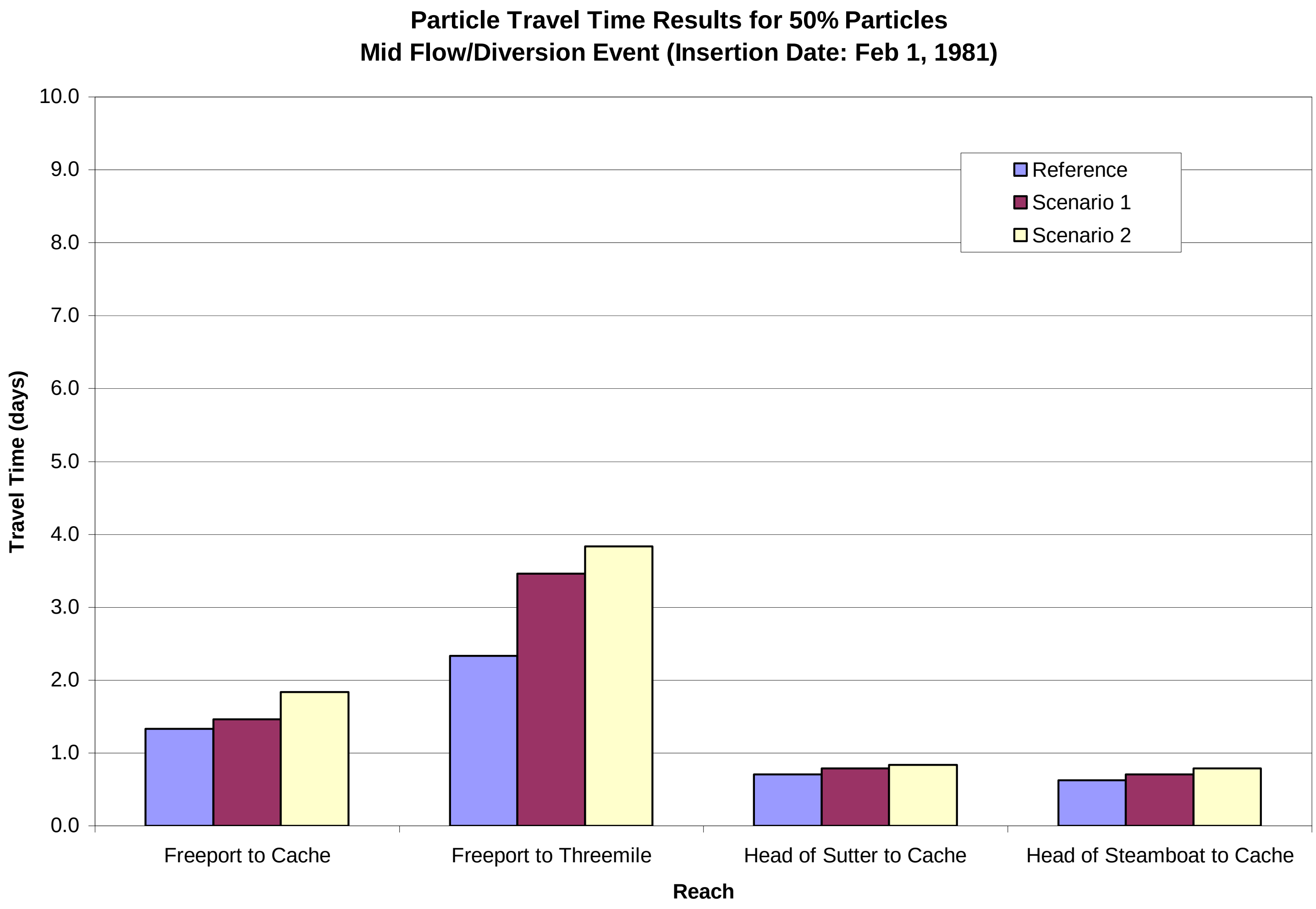

Particle Travel Time Results for 50% Particles
Mid Flow/Diversion Event (Insertion Date: Feb 1, 1981)
Travel Time (days)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Reference
Scenario 1
Scenario 2
Freeport to Cache
Freeport to Threemile
Head of Sutter to Cache
Head of Steamboat to Cache
Reach

Figure I-4

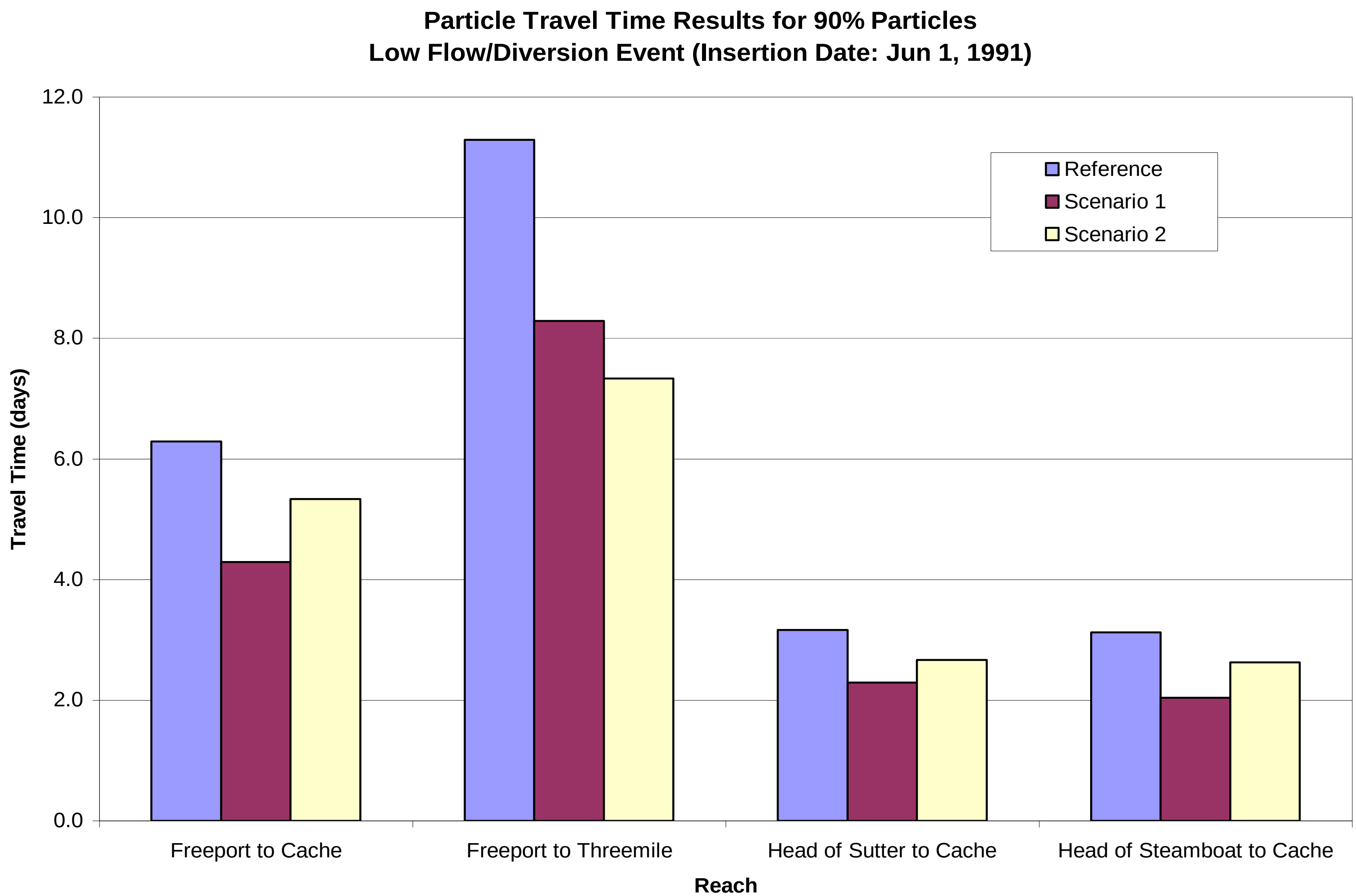
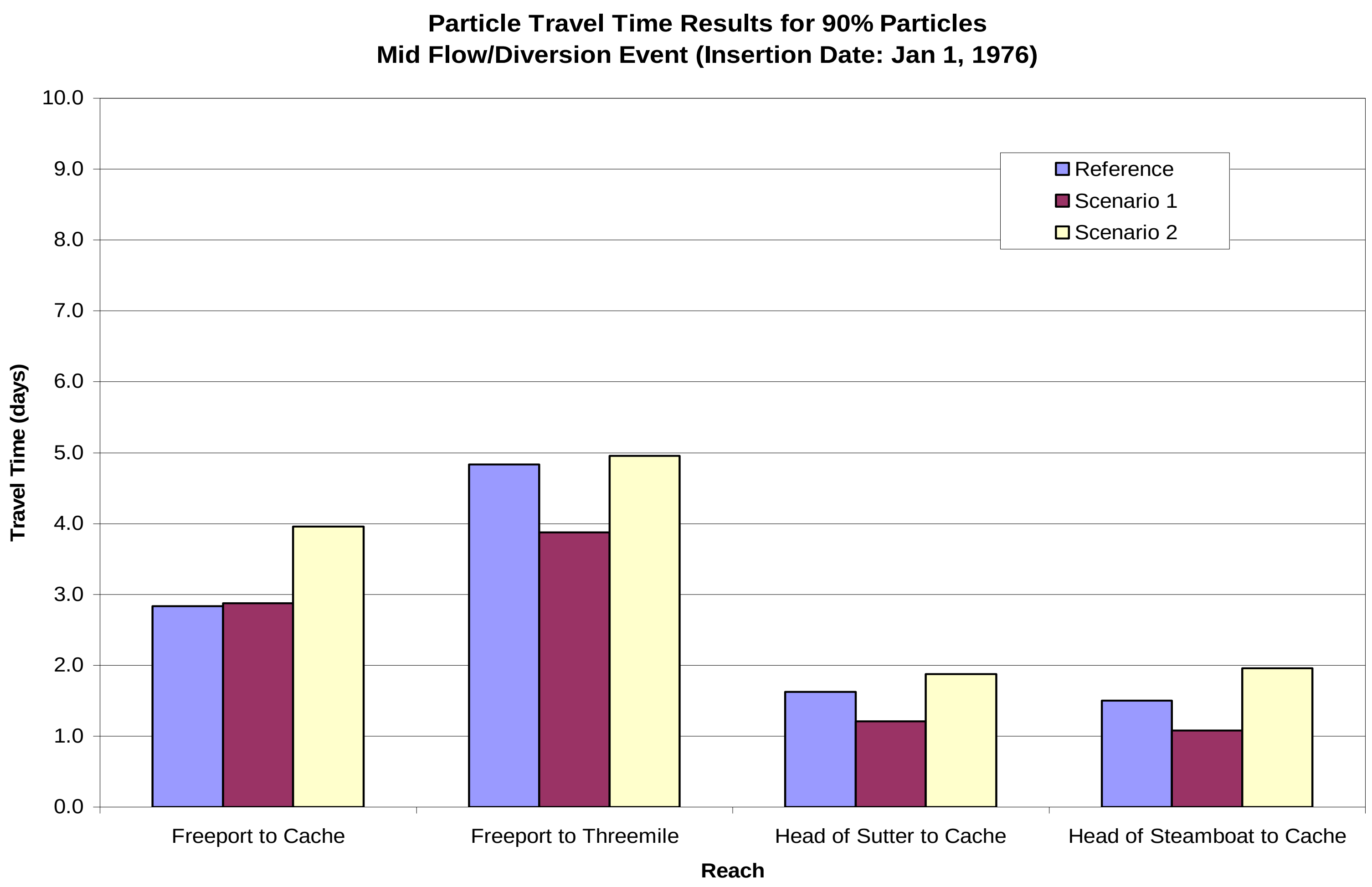

Particle Travel Time Results for 90% Particles
Low Flow/Diversion Event (Insertion Date: Jun 1, 1991)
Travel Time (days)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Reference
Scenario 1
Scenario 2
Freeport to Cache
Freeport to Threemile
Head of Sutter to Cache
Head of Steamboat to Cache
Reach

Figure I-5



Particle Travel Time Results for 90% Particles
Mid Flow/Diversion Event (Insertion Date: Jan 1, 1976)
Travel Time (days)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Reference
Scenario 1
Scenario 2
Freeport to Cache
Freeport to Threemile
Head of Sutter to Cache
Head of Steamboat to Cache
Reach

Figure I-6

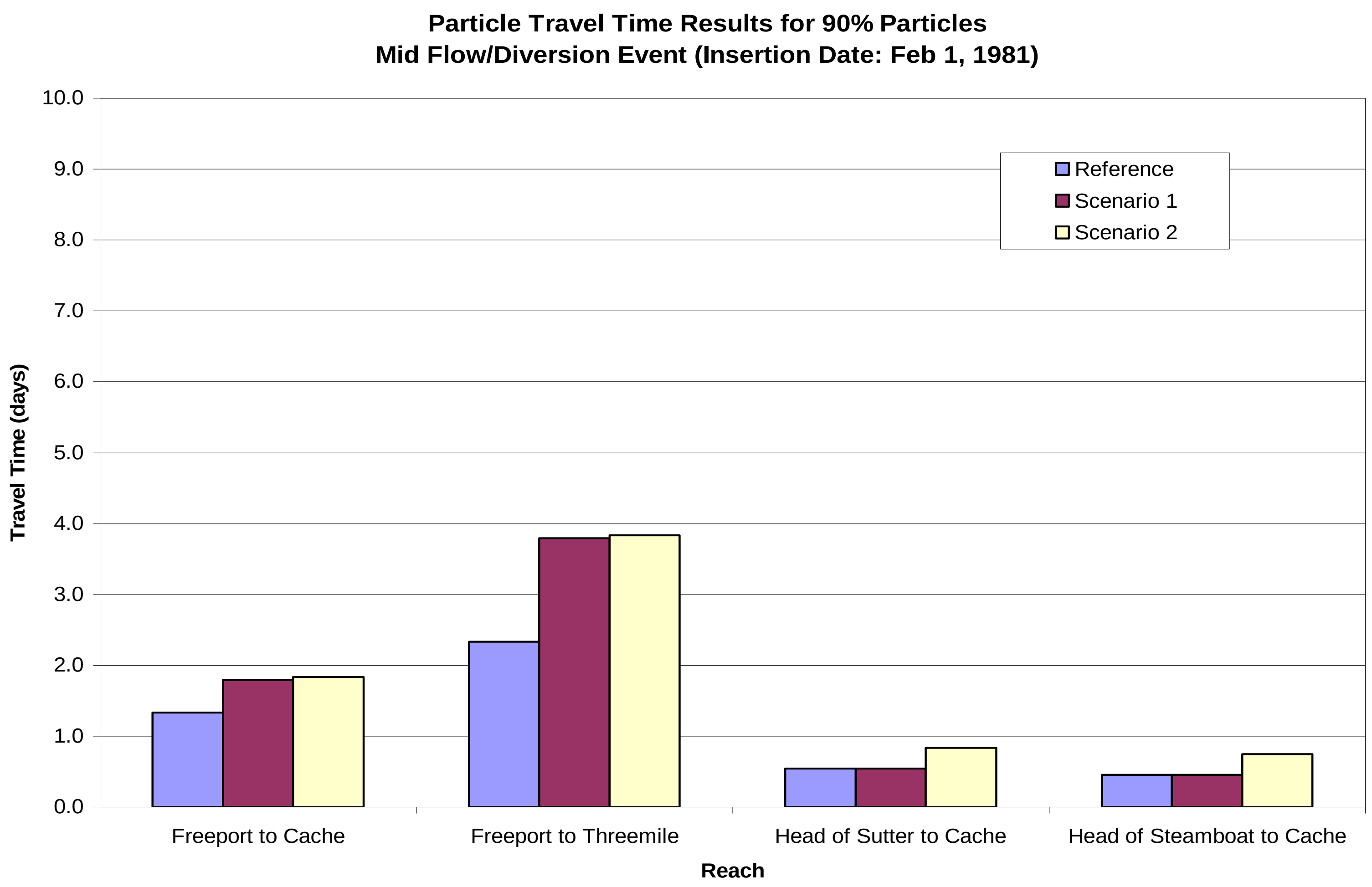

Particle Travel Time Results for 90% Particles
Mid Flow/Diversion Event (Insertion Date: Feb 1, 1981)
Travel Time (days)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Reference
Scenario 1
Scenario 2
Freeport to Cache
Freeport to Threemile
Head of Sutter to Cache
Head of Steamboat to Cache
Reach

Figure I-7

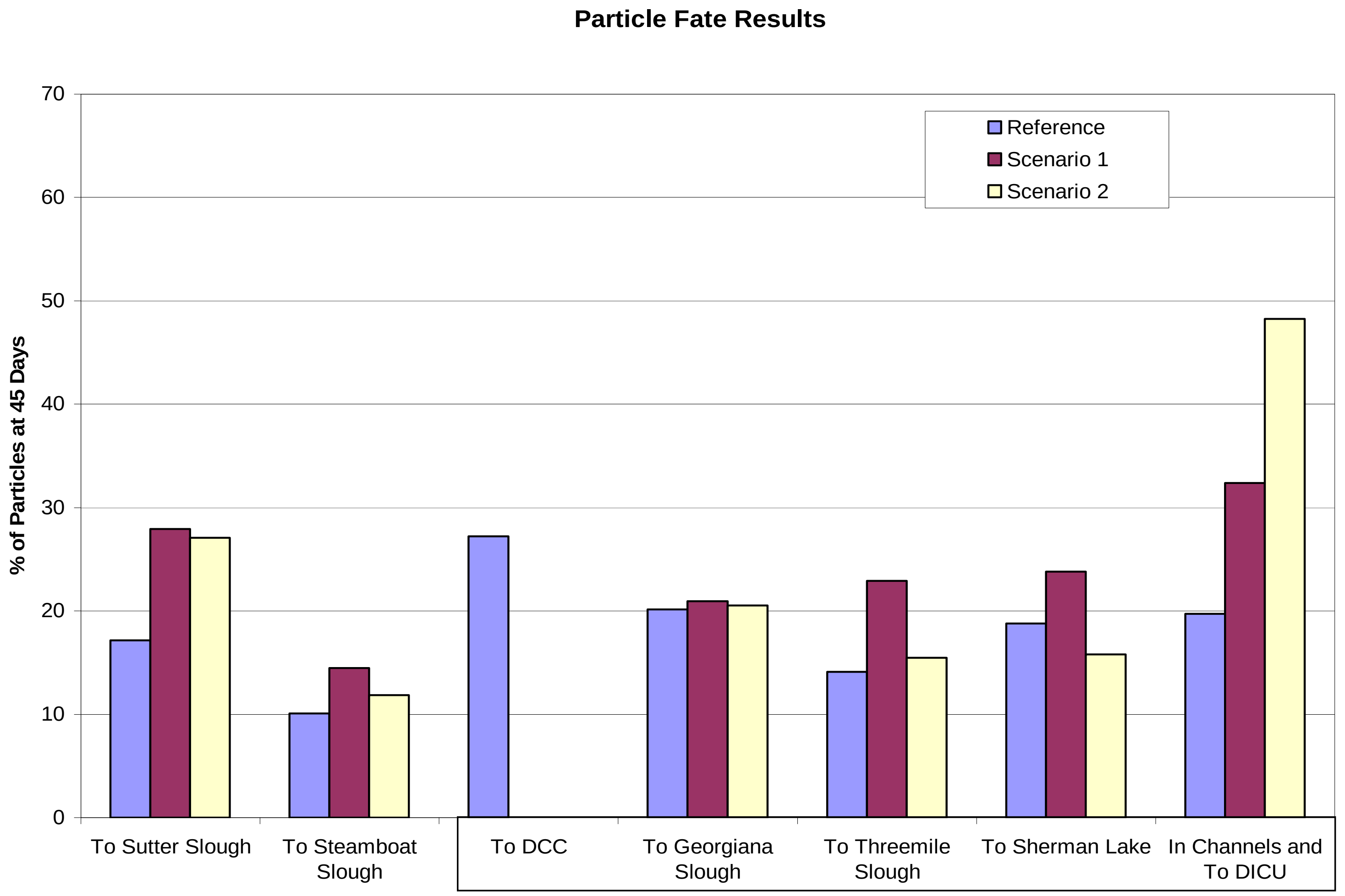

Particle Fate Results
% of Particles at 45 Days
70
60
50
40
30
20
10
0
Reference
Scenario 1
Scenario 2
To Sutter Slough
To Steamboat Slough
To DCC
To Georgiana Slough
To Threemile Slough
To Sherman Lake
In Channels and To DICU

Figure I-8

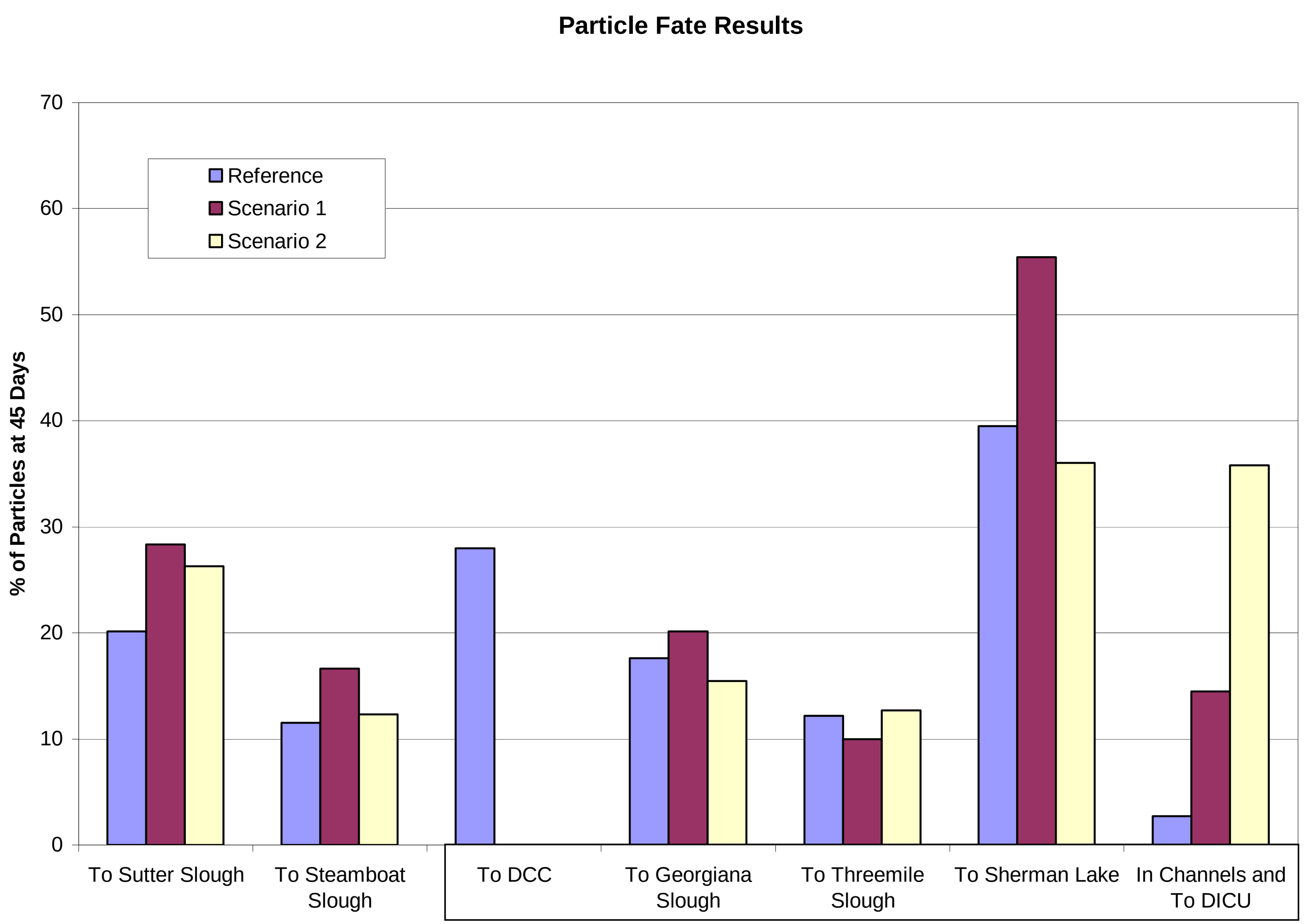
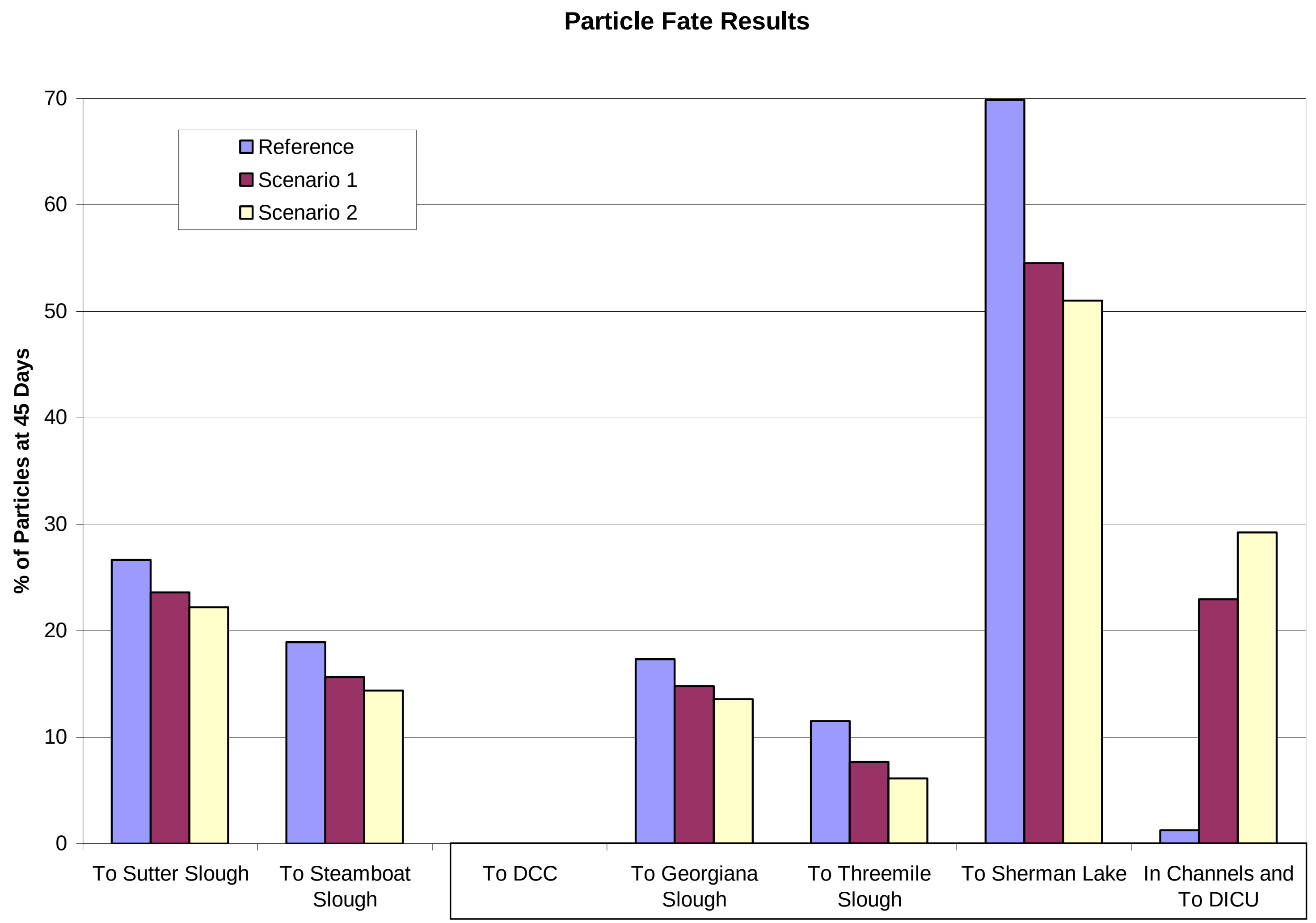
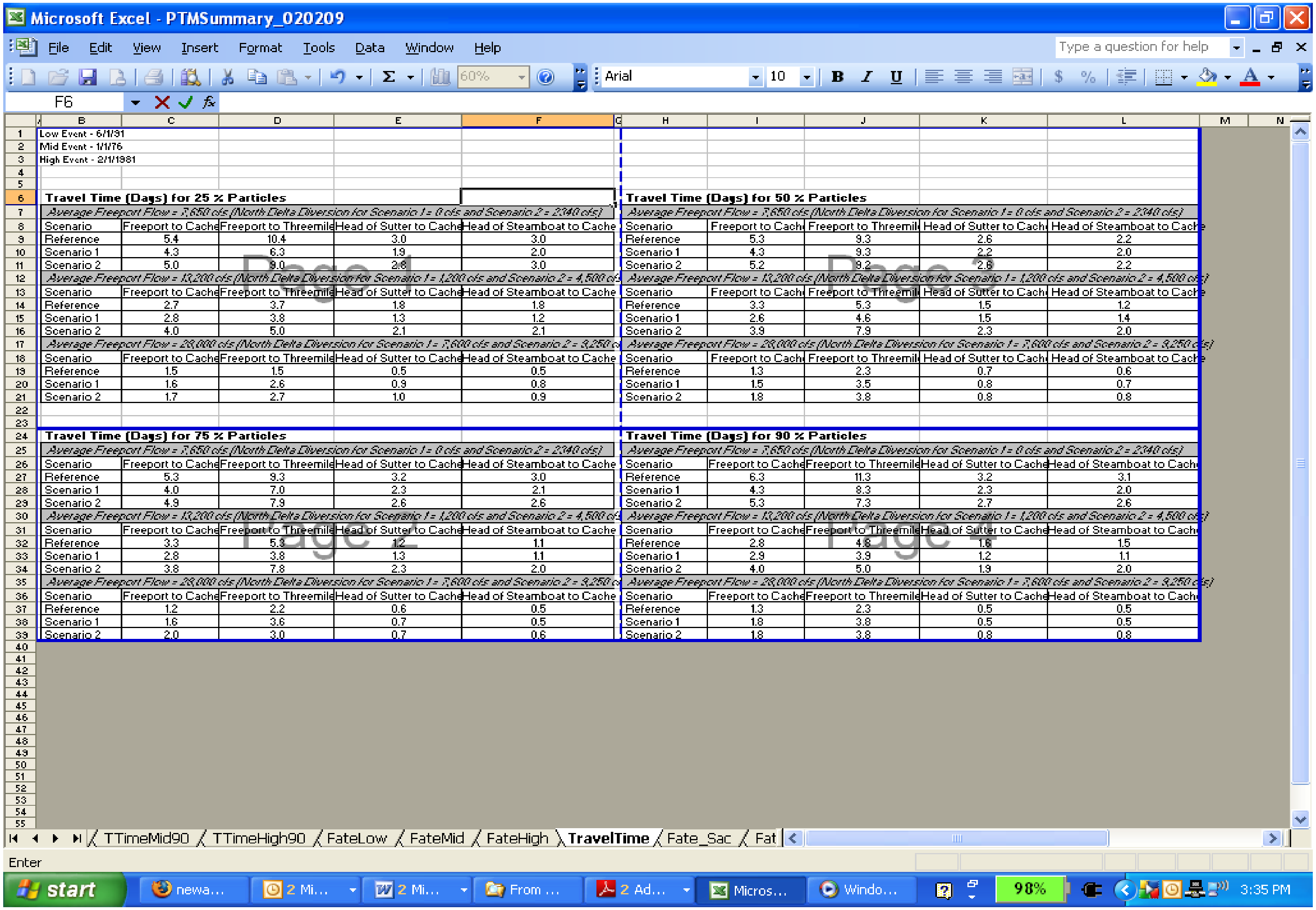

Particle Fate Results
% of Particles at 45 Days
70
60
50
40
30
20
10
0
Reference
Scenario 1
Scenario 2
To Sutter Slough
To Steamboat Slough
To DCC
To Georgiana Slough
To Threemile Slough
To Sherman Lake
In Channels and To DICU

Figure I-9



Particle Fate Results
% of Particles at 45 Days
70
60
50
40
30
20
10
0
Reference
Scenario 1
Scenario 2
To Sutter Slough
To Steamboat Slough
To DCC
To Georgiana Slough
To Threemile Slough
To Sherman Lake
In Channels and To DICU

Table I-2



Travel Time (Days) for 25 % Particles

Scenario	Freeport to Cache	Freeport to Threemile	Head of Sutter to Cache	Head of Steamboat to Cache
Average Freeport Flow = 7,650 cfs (North Delta Diversion for Scenario 1 = 0 cfs and Scenario 2 = 2340 cfs)				
Reference	5.4	10.4	3.0	3.0
Scenario 1	4.3	6.3	1.9	2.0
Scenario 2	5.0	9.0	2.8	3.0
Average Freeport Flow = 13,200 cfs (North Delta Diversion for Scenario 1 = 1,200 cfs and Scenario 2 = 4,500 cfs				
Reference	2.7	3.7	1.8	1.8
Scenario 1	2.8	3.8	1.3	1.2
Scenario 2	4.0	5.0	2.1	2.1
Average Freeport Flow = 28,000 cfs (North Delta Diversion for Scenario 1 = 7,600 cfs and Scenario 2 = 9,250 c				
Reference	1.5	1.5	0.5	0.5
Scenario 1	1.6	2.6	0.9	0.8
Scenario 2	1.7	2.7	1.0	0.9

Travel Time (Days) for 50 % Particles

Scenario	Freeport to Cache	Freeport to Threemile	Head of Sutter to Cache	Head of Steamboat to Cache
Average Freeport Flow = 7,650 cfs (North Delta Diversion for Scenario 1 = 0 cfs and Scenario 2 = 2340 cfs)				
Reference	5.3	9.3	2.6	2.2
Scenario 1	4.3	9.3	2.2	2.0
Scenario 2	5.2	9.2	2.8	2.2
Average Freeport Flow = 13,200 cfs (North Delta Diversion for Scenario 1 = 1,200 cfs and Scenario 2 = 4,500 cfs)				
Reference	3.3	5.3	1.5	1.2
Scenario 1	2.6	4.6	1.5	1.4
Scenario 2	3.9	7.9	2.3	2.0
Average Freeport Flow = 28,000 cfs (North Delta Diversion for Scenario 1 = 7,600 cfs and Scenario 2 = 9,250 cfs)				
Reference	1.3	2.3	0.7	0.6
Scenario 1	1.5	3.5	0.8	0.7
Scenario 2	1.8	3.8	0.8	0.8

Travel Time (Days) for 75 % Particles

Scenario	Freeport to Cache	Freeport to Threemile	Head of Sutter to Cache	Head of Steamboat to Cache
Average Freeport Flow = 7,650 cfs (North Delta Diversion for Scenario 1 = 0 cfs and Scenario 2 = 2340 cfs)				
Reference	5.3	9.3	3.2	3.0
Scenario 1	4.0	7.0	2.3	2.1
Scenario 2	4.9	7.9	2.6	2.6
Average Freeport Flow = 13,200 cfs (North Delta Diversion for Scenario 1 = 1,200 cfs and Scenario 2 = 4,500 cfs				
Reference	3.3	5.3	1.2	1.1
Scenario 1	2.8	3.8	1.3	1.1
Scenario 2	3.8	7.8	2.3	2.0
Average Freeport Flow = 28,000 cfs (North Delta Diversion for Scenario 1 = 7,600 cfs and Scenario 2 = 9,250 c				
Reference	1.2	2.2	0.6	0.5
Scenario 1	1.6	3.6	0.7	0.5
Scenario 2	2.0	3.0	0.7	0.6

Travel Time (Days) for 90 % Particles

Scenario	Freeport to Cache	Freeport to Threemile	Head of Sutter to Cache	Head of Steamboat to Cache
Average Freeport Flow = 7,650 cfs (North Delta Diversion for Scenario 1 = 0 cfs and Scenario 2 = 2340 cfs)				
Reference	6.3	11.3	3.2	3.1
Scenario 1	4.3	8.3	2.3	2.0
Scenario 2	5.3	7.3	2.7	2.6
Average Freeport Flow = 13,200 cfs (North Delta Diversion for Scenario 1 = 1,200 cfs and Scenario 2 = 4,500 cfs)				
Reference	2.8	4.8	1.6	1.5
Scenario 1	2.9	3.9	1.2	1.1
Scenario 2	4.0	5.0	1.9	2.0
Average Freeport Flow = 28,000 cfs (North Delta Diversion for Scenario 1 = 7,600 cfs and Scenario 2 = 9,250 cfs)				
Reference	1.3	2.3	0.5	0.5
Scenario 1	1.8	3.8	0.5	0.5
Scenario 2	1.8	3.8	0.8	0.8

Table I-2

Fate of Particles Inserted in Sacramento River Upstream of Freeport*							
% of Particles at the end of 45 days from the insertion							
Average Freeport Flow = 7,650 cfs (North Delta Diversion for Scenario 1 = 0 cfs and Scenario 2 = 2340 cfs)							
Scenario	To Sutter Slough	To Steamboat Slough	To DCC	To Georgiana Slough	To Threemile Slough	To Sherman Lake	In Channels and To DICU
Reference	17.2	10.1	27.2	20.1	14.1	18.8	19.7
Scenario 1	27.9	14.5	0.0	20.9	22.9	23.8	32.4
Scenario 2	27.1	11.9	0.0	20.5	15.5	15.8	48.2

Average Freeport Flow = 13,200 cfs (North Delta Diversion for Scenario 1 = 1,200 cfs and Scenario 2 = 4,500 cfs)							
Scenario	To Sutter Slough	To Steamboat Slough	To DCC	To Georgiana Slough	To Threemile Slough	To Sherman Lake	In Channels and To DICU
Reference	20.2	11.5	28.0	17.6	12.2	39.5	2.7
Scenario 1	28.4	16.6	0.0	20.1	10.0	55.4	14.5
Scenario 2	26.3	12.3	0.0	15.4	12.7	36.0	35.8

Average Freeport Flow = 28,000 cfs (North Delta Diversion for Scenario 1 = 7,600 cfs and Scenario 2 = 9,250 cfs)							
Scenario	To Sutter Slough	To Steamboat Slough	To DCC	To Georgiana Slough	To Threemile Slough	To Sherman Lake	In Channels and To DICU
Reference	26.7	18.9	0.0	17.3	11.5	69.8	1.3
Scenario 1	23.6	15.6	0.0	14.8	7.7	54.6	22.9
Scenario 2	22.2	14.4	0.0	13.6	6.2	51.0	29.2

**** Particles diverted through North Delta Diversion are redistributed assuming that the diversion would be screened and 100% efficient***

Table I-3

Average Freeport Flow = 14,250 cfs							
Reference							
Days from the Start of Particle Insertion	**% of Particles**						
	To Sutter Slough	**To Steamboat Slough**	**To DCC**	**To Georgiana Slough**	**To Threemile Slough**	**To Sherman Lake**	**In Channels and To DICU**
7	20.2	11.5	28.0	17.6	8.2	2.3	43.9
14	20.2	11.5	28.0	17.6	12.3	23.9	18.2
21	20.2	11.5	28.0	17.6	13.2	29.6	11.6
28	20.2	11.5	28.0	17.6	13.0	34.4	7.0
35	20.2	11.5	28.0	17.6	13.1	37.1	4.2
45	20.2	11.5	28.0	17.6	12.2	39.5	2.7
60	20.2	11.5	28.0	17.6	11.5	41.4	1.6
75	20.2	11.5	28.0	17.6	11.3	41.9	1.3

Table I-4

Average Freeport Flow = 24,500 cfs								
Reference								
Days from the Start of Particle Insertion	**% of Particles**							
	To North Delta Diversion	**To Sutter Slough**	**To Steamboat Slough**	**To DCC**	**To Georgiana Slough**	**To Threemile Slough**	**To Sherman Lake**	**In Channels and To DICU**
7	0.0	26.7	18.9	0.0	17.3	13.7	53.7	15.2
14	0.0	26.7	18.9	0.0	17.3	13.2	61.7	7.7
21	0.0	26.7	18.9	0.0	17.3	12.7	66.2	3.7
28	0.0	26.7	18.9	0.0	17.3	12.3	67.9	2.4
35	0.0	26.7	18.9	0.0	17.3	11.9	69.0	1.7
45	0.0	26.7	18.9	0.0	17.3	11.5	69.8	1.3
60	0.0	26.7	18.9	0.0	17.3	11.4	70.3	1.0
75	0.0	26.7	18.9	0.0	17.3	11.3	70.4	1.0

Table I-5

Scenario 1 (North Delta Diversion = 1,550 cfs)							
Days from the Start of Particle Insertion	**% of Particles**						
	To Sutter Slough	**To Steamboat Slough**	**To DCC**	**To Georgiana Slough**	**To Threemile Slough**	**To Sherman Lake**	**In Channels and To DICU**
7	26.1	15.3	0.0	18.5	7.7	14.9	58.9
14	26.1	15.3	0.0	18.5	8.8	34.8	38.0
21	26.1	15.3	0.0	18.5	8.7	38.6	34.2
28	26.1	15.3	0.0	18.5	8.9	43.8	28.8
35	26.1	15.3	0.0	18.5	9.2	46.4	25.9
45	26.1	15.3	0.0	18.5	9.2	50.9	21.4
60	26.1	15.3	0.0	18.5	9.2	54.8	17.5
75	26.1	15.3	0.0	18.5	9.2	57.6	14.6

Table I-6

Scenario 1 (North Delta Diversion = 6,000 cfs)								
Days from the Start of Particle Insertion	**% of Particles**							
	To North Delta Diversion	**To Sutter Slough**	**To Steamboat Slough**	**To DCC**	**To Georgiana Slough**	**To Threemile Slough**	**To Sherman Lake**	**In Channels and To DICU**
7	15.7	20.4	13.5	0.0	12.8	6.4	23.8	57.0
14	15.7	20.4	13.5	0.0	12.8	6.6	32.0	48.7
21	15.7	20.4	13.5	0.0	12.8	6.4	38.1	42.7
28	15.7	20.4	13.5	0.0	12.8	6.5	40.7	40.0
35	15.7	20.4	13.5	0.0	12.8	6.4	44.0	36.8
45	15.7	20.4	13.5	0.0	12.8	6.6	47.1	33.4
60	15.7	20.4	13.5	0.0	12.8	6.7	49.6	30.9
75	15.7	20.4	13.5	0.0	12.8	6.9	50.6	29.6

Table I-7

Scenario 2 (North Delta Diversion = 4,500 cfs)							
Days from the Start of Particle Insertion	**% of Particles**						
	To Sutter Slough	**To Steamboat Slough**	**To DCC**	**To Georgiana Slough**	**To Threemile Slough**	**To Sherman Lake**	**In Channels and To DICU**
7	21.8	10.2	0.0	12.8	5.2	2.2	79.8
14	21.8	10.2	0.0	12.8	8.2	16.6	62.4
21	21.8	10.2	0.0	12.8	9.2	19.1	58.8
28	21.8	10.2	0.0	12.8	10.1	23.3	53.8
35	21.8	10.2	0.0	12.8	10.5	25.4	51.2
45	21.8	10.2	0.0	12.8	10.6	29.9	46.7
60	21.8	10.2	0.0	12.8	10.5	33.7	43.0
75	21.8	10.2	0.0	12.8	10.9	36.7	39.6

Table I-8

Scenario 2 (North Delta Diversion = 8,100 cfs)								
Days from the Start of Particle Insertion	**% of Particles**							
	To North Delta Diversion	**To Sutter Slough**	**To Steamboat Slough**	**To DCC**	**To Georgiana Slough**	**To Threemile Slough**	**To Sherman Lake**	**In Channels and To DICU**
7	19.8	18.5	12.0	0.0	11.3	5.3	20.6	62.8
14	19.8	18.5	12.0	0.0	11.3	5.3	28.4	55.0
21	19.8	18.5	12.0	0.0	11.3	5.2	34.4	49.1
28	19.8	18.5	12.0	0.0	11.3	5.1	36.8	46.8
35	19.8	18.5	12.0	0.0	11.3	4.8	39.9	44.0
45	19.8	18.5	12.0	0.0	11.3	5.1	42.6	40.9
60	19.8	18.5	12.0	0.0	11.3	5.3	45.0	38.3
75	19.8	18.5	12.0	0.0	11.3	5.4	45.9	37.3

Table I-9

Fate of Particles Entering Sutter Slough
% of Particles at the end of 45 days from the insertion

Scenario	Average Freeport Flow = 7,650 cfs (North Delta Diversion for Scenario 1 = 0 cfs and Scenario 2 = 2340 cfs)		
	To Sutter	From Sutter	To Miner
Reference	17.2	6.5	10.5
Scenario 1	27.9	8.6	19.2
Scenario 2	23.2	5.8	17.3

Scenario	Average Freeport Flow = 13,200 cfs (North Delta Diversion for Scenario 1 = 1,200 cfs and Scenario 2 = 4,500 cfs)		
	To Sutter	From Sutter	To Miner
Reference	20.2	8.6	11.6
Scenario 1	26.1	9.1	17.0
Scenario 2	21.8	5.8	16.0

Scenario	Average Freeport Flow = 28,000 cfs (North Delta Diversion for Scenario 1 = 7,600 cfs and Scenario 2 = 9,250 cfs)		
	To Sutter	From Sutter	To Miner
Reference	26.7	12.0	14.7
Scenario 1	20.4	8.7	11.7
Scenario 2	18.5	7.7	10.9

Outcome Code	Covered Spp.	Description	Scenario 1 Magnitude	Scenario 1 Certainty	Scenario 2 Magnitude	Scenario 2 Certainty
Positive Outcomes						
P1a	Fall-run Chinook salmon- San Joaquin River	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	1	4	1	4
P1b	Spring-run Chinook salmon, Sac	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	2	3	3	3
P1c	Fall-run Chinook salmon, Sac.	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	2	3	3	3
P1d	Late Fall-run Chinook Salmon	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	2	3	3	3
P1e	Winter-run Chinook salmon	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	2	3	3	3
P1f	White Sturgeon	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	1	3	1	3
P1g	Green Sturgeon	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	1	3	1	3
P1h	Steelhead, Sacramento	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	2	3	3	3
P1i	Steelhead, San Joaquin	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	1	2	1	2

Outcome Code	Covered Spp.	Description	Scenario 1 Magnitude	Scenario 1 Certainty	Scenario 2 Magnitude	Scenario 2 Certainty
Positive Outcomes (contd.)						
P1j	Delta smelt-adult	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	3	3	3	3
P1k	Delta Smelt – Larval and Juvenile	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	3	3	3	3
P1L	Longfin Smelt - Adult	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	2	3	2	3
P1m	Longfin Smelt – Larval-Juvenile	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	3	3	3	3
P1n	Splittail	Reduced entrainment and predation mortality of covered species directly associated with South Delta project facilities and operations.	2	3	2	3
P2	All	Increased food availability for covered species due to higher productivity at lower trophic levels in the Delta associated with increased residence time	2	3	2	3

Outcome Code	Covered Spp.	Description	Scenario 1 Magnitude	Scenario 1 Certainty	Scenario 2 Magnitude	Scenario 2 Certainty
Negative Outcomes						
N1a	Sac Chinook & Steelhead	Increased predation on juvenile Sacramento salmon, steelhead, and sturgeon associated with local hydraulics at new North Delta water diversion structures	4	2	4	2
N1b	White sturgeon	Increased predation on juvenile Sacramento salmon, steelhead, and sturgeon associated with local hydraulics at new North Delta water diversion structures	2	2	2	2
N1c	Splittail- Juvenile	Increased predation on juvenile Sacramento salmon, steelhead, and sturgeon associated with local hydraulics at new North Delta water diversion structures	4	2	4	2
N3	Delta smelt	Increased mortality of juvenile delta smelt associated with new North Delta facilities and operations	2	3	2	2
N4a,b	Green & White Sturgeon	Increased mortality of covered species due to degradation of water quality which increases a stressor (on fish species of concern)	3	2	3	2
N4c	Chinook salmon- San Joaquin	Increased mortality of covered species due to degradation of water quality which increases a stressor (on fish species of concern)	4	2	4	2
N4d	Steelhead- San Joaquin	Increased mortality of covered species due to degradation of water quality which increases a stressor (on fish species of concern)	4	2	4	2
N4e	Splittail, Sac.	Increased mortality of covered species due to degradation of water quality which increases a stressor (on fish species of concern)	3	3	3	3

Outcome Code	Covered Spp.	Description	Scenario 1 Magnitude	Scenario 1 Certainty	Scenario 2 Magnitude	Scenario 2 Certainty
Negative Outcomes (contd.)						
N5	Delta smelt	Lower quality Delta smelt habitat due to reduced turbidity (i.e. loss of sediment due to fewer pulse flows on the Sacramento River).	2-3	1		
N6a,b	Chinook Salmon & steelhead- San Joaquin	Increased frequency, duration and extent of low DO at Stockton and blockage of salmon/steelhead migration on the San Joaquin River.	4	4		
N9	Chinook Salmon - Mokelumne River	Increased mortality of juvenile Mokelumne River Chinook salmon.	3	3-4		
N6c,d,e	Green & White Sturgeon, & Sacramento splittail	Increased frequency, duration and extent of low DO at Stockton and blockage of salmon/steelhead migration on the San Joaquin River.	1	2		
N7	All	Loss of Sacramento River food material for covered species into the Delta due to diversions of water and reduction in flow to the Delta.	2	1		
N8	All	Increased Microcystis biomass which will affect aquatic food webs and covered fish species due to the new North Delta Diversion.	3	2		
N9	All	Increased predationof juvenile Mokelumne River salmon due to modified Delta Cross Channel operations	3	3		

Scenario 1

Mid-Range Hood Bypass Criteria.
- December 1 through June 30 maintain a Sacramento River bypass flow of not less than 11,000 cfs;
- July 1 through August 30 maintain a Sacramento River bypass flow of not less than 5,000 cfs;
- September 1 through November 30 maintain a Sacramento River bypass flow of not less than 7,000 cfs for fall salmon attraction and migration;
- Require at least 55% of river flows above minimum bypass flows during February-April, 45% during January and May, and 35% during December and June

Scenario 2

Low (5,000 cfs) Hood Bypass Criteria
- Set minimum bypass flow of 5,000 cfs year round except as provided in the bullet below;
- Require at least 55% of river flows above 5,000 cfs during February-April, 45% during January and May, and 35% during December and June (see figure 3) to maintain the shape of the hydrograph.

WOCM 2:
Fremont Weir and Yolo Bypass Inundation

Scientific Evaluation Worksheet

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Action Description and Clarifying Assumptions

Option #1 Period of Potential Operation: December 1-May 15

Desired Duration of Inundation: 45 days
Target Spill Discharge into Bypass: 4000 cfs
Predicted area of inundation: 22,982 acres
Predicted mean depth of inundated area: 2.2 feet
Predicted travel time: 6.5 days
Spill Frequency of Fremont Weir (assuming 4000 cfs and 45 day duration with a spill intermission of no more than 7 days): 48% of years (38 of 79), compared to 6% of years (5 out of 79) at existing weir height.

Option #2 Period of Potential Operation: January 1-April 15

Desired Duration of Inundation: 30 days
Target Spill Discharge into Bypass: 2000 cfs
Predicted area of inundation: 17,421 acres
Predicted mean depth of inundated area: 2.3 feet
Predicted travel time: 9.3 days
Spill Frequency of Fremont Weir (assuming 2000 cfs and 30 day duration with a spill intermission of no more than 7 days): 54% of years (43 of 79), compared to 6% of years (5 out of 79) at existing weir height.

Approach

1. Fremont Weir would be notched to an elevation of 17.5 feet (NAVD88) approximately 225 feet wide and fitted with an operable gate(s) that, when operated, would allow Sacramento River water to flow into the Yolo Bypass when Sacramento River stage at the weir exceeds 17.5 feet. Channel dimensions would avoid channel velocities of >3 ft/s.
2. A trapezoidal canal (225' width, side slopes 2:1) would be excavated to convey water past the higher elevation natural levee of the Sacramento River upstream of the new gate at the Fremont Weir and 10,000 feet past accumulated sediment below the new gate in the Bypass to the Tule Canal.
3. The existing Fremont Weir fish ladder would be removed and replaced with a new fish passage facility designed to effectively allow for the passage of adult salmonids and sturgeon from the Yolo Bypass past the weir into the Sacramento River.
4. To the extent necessary, the Bypass would be graded, existing berms or levees would be removed, and berms or levees would be constructed to improve the distribution and hydrodynamic characteristics of water moving through the Bypass, prevent stranding of covered fish species, and protect property.
5. If needed, a structure would be constructed in the Sacramento River in the vicinity of the new weir gate to encourage the passage of juvenile salmonids migrating down the Sacramento River into the bypass.

Note: At flood stage (>33.5 feet) the weir would overtop as under current conditions.

Intended Outcomes as Stated in Conservation Measure

Positive Outcomes:

P1 (intended): Create additional spawning habitat for splittail

P2 (intended): Create additional juvenile rearing habitat for Chinook salmon, splittail, steelhead, and green and white sturgeon

P3 (intended): Increase production of food for rearing of Chinook salmon, splittail, steelhead, (onsite = seasonal floodplain only)

P4 (intended): Increase frequency and magnitude of export of DOM, POM and organisms from seasonal floodplain to provide food in Delta for Delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon

P5 (intended): Increase frequency and magnitude of transport of organic carbon and organisms from Cache Slough/Bypass tidal marshes to support Delta foodweb for Delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon

P6 (intended): Reduce losses due to stranding and illegal harvest Chinook salmon, steelhead, and green and white sturgeon

P7: Increase delivery of readily suspendable sediments to north Delta and improved Delta smelt habitats

P8 (intended): Increase survival of out migrating juvenile salmonids by providing migration route with lower predation and entrainment (at North and South Delta diversions) risk.

Negative Outcomes:

N1: Increased MeHg and impact on covered species (on floodplain and downstream)

N2: Increased resuspension/mobilization and export of toxic compounds w/impact on covered species

N3: Increased stranding of covered species (consider grading proposed in the approach)

N4: Reduced flows in Sacramento River and distributaries to support successful outmigration.

N5: Increased habitat for non-native predators/competitors to covered species

Conceptual Model Information Regarding Intended Outcomes

Additional spawning habitat for splittail is supported by the Floodplain Model (Opperman, 2008) which notes that splittail population dynamics are strongly associated with annual patterns of flow and floodplain inundation (Moyle et al., 2004), and the importance of flooding of the Yolo Bypass in particular as a factor influencing the strength of the splittail year class (Sommer et al., 1997). Adult splittail move into inundated areas in late February or early March and spawning occurs in March and April. Recent research from the Yolo Bypass suggests that spawning is most likely to occur near the vernal equinox (late March) (Feyrer et al. 2006). Opperman, 2008 also notes the use of floodplain habitats, including the Yolo Bypass, by juvenile Chinook salmon but notes that little is known regarding steelhead. The Floodplain model makes no mention of green or white sturgeon, but the sturgeon models (as noted in the Outcomes Table) document loss of habitat as a stressor. Both sturgeon models note that Freemont Weir is a barrier for sturgeon. The Outcomes Table identified food production and increased food availability as outcomes in the Floodplain model and as drivers in the Delta smelt and longfin smelt models. Opperman, 2008 notes that salmon emigrate from floodplains as long as drainage connectivity is available and that certain features, such as pits, can lead to stranding.

Assumptions

Provided in BDCP Conservation Measure
The Toe drain would be graded where appropriate

Added by Evaluation Team
The evaluation team recognized that there may be future changes in land use but since predictions were not available only current land use was considered relative to the availability of toxic compounds for resuspension (Outcome N2).

Problem(s) with Action as Written

None identified

Scale of Action

Large

Rationale:
This represents an order of magnitude increase in frequency of inundation of existing floodplain habitat in the Delta.

Evaluation Summary Tables

Summary tables listing magnitude and certainty scores for each outcome, by species, are provided in Appendix A. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes following this section.

Relation to Existing Conditions

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

No. While this action represents a huge increase in the area of frequently inundated floodplain within the Delta it is expected that the area will function similarly to existing floodplains and the understanding generated from studies of Yolo Bypass and the Cosumnes River, as well as other areas, will be applicable to understanding the consequences of this action.

Potential Positive Ecological Outcome(s)

Outcome P1: Create additional spawning habitat for Splittail

P1a.1 Splittail Scenario 1

The Splittail Model (Kratville, 2009 - pages 9 and 12) describes how floodplain habitat supports splittail spawning:

- "Splittail are considered to be obligate flood plain spawners (Moyle 2002)."
- "Large scale spawning occurs only in years with significant inundation of flood plains in the Sacramento-San Joaquin watershed."
- "Splittail need water levels and inundation duration in ranges that were historically present (30 - 90 days)…The minimum length of inundation is required to achieve strong year classes when associated with large scale flood plain inundation as occurs on the Yolo Bypass. Longer inundation periods allow for extended and multiple spawning events as well as other food web associated benefits."

On page 14 of Splittail Model (Kratville, 2009), modification and loss of floodplain habitats is identified as a key limiting factor:

- **"**The substantial loss of floodplain from conversion to agriculture and urban areas and loss of river edge spawning habitat is probably the key limiting factor for splittail populations (Moyle et al. 2004)."

Magnitude = 4
The action is expected to have a landscape scale effect based on the increased frequency of flooding and extent of additional floodplain habitat.

Certainty = 4
The importance of floodplains for splittail spawning is well established by published papers based on evidence from this system.

P1a.2 Splittail Scenario 2

The rationale for the important of floodplain habitat to splittail spawning is same as for P1a.1 above.

Magnitude = 3
The lesser extent and decreased duration of flooding (30 days) compared to P1a.1 makes this scenario a regional scale habitat effect.

Certainty = 4
The importance of floodplains for splittail spawning is well established by published papers based on evidence from this system.

Outcome P2: Create additional juvenile rearing habitat for splittail, green and white sturgeon, steelhead and Chinook salmon

P2a.1 Splittail Scenario 1

Table 1 page 3 in Splittail Model (Kratville, 2009) indicates larvae use floodplains February through May and juveniles use floodplain February through July. Page 8 states "must have seasonally flooded lands on which to spawn for early rearing of larval and juvenile fish". Page 12 notes "Although some are swept off floodplains and downstream by flood currents (Baxter et al. 1996), many splittail larvae and juveniles remain in riparian or annual vegetation along shallow edges on floodplains as long as water temperatures remain cool" (Sommer et al. 2002, Moyle et al. 2004). This outcome is supported by peer reviewed publications from the Cosumnes River and Yolo Bypass (Crain et al. 2004, Moyle et al. 2004, Sommer et al. 1997, 2001, 2007, Feyrer 2006, 2007).

Magnitude = 4
Splittail rely on shallow water habitat which is extremely limited without floodplain inundation (Sommer et al. 2008)

Certainty = 4
Supported by publications based on the Yolo Bypass in peer reviewed journals.

P2a.2 Splittail Scenario 2

The rationale for the importance of floodplain habitat to splittail rearing is same as for P2a.1 above.

Magnitude = 3
The lesser extent and decreased duration of flooding (30 days) compared to P2a.1 makes this scenario a regional scale habitat effect.

Certainty = 4
Supported by publications based on the Yolo Bypass in peer reviewed journals.

P2b. Green/white sturgeon Scenario 1 and 2

There is no evidence of juvenile sturgeon use of floodplains. Sturgeon caught in Yolo Bypass studies are adults (Harrell and Sommer 2003).

Magnitude = 1
There is little evidence of floodplain use by sturgeon.

Certainty = 2
Some data available but only for adults.

P2c. Steelhead Scenarios 1 and 2

Steelhead are present in the area at the time of flooding (McEwan 2001, Figure 3). According to Mossdale trawl data from the Sacramento River steelhead are emigrating January through August, with the peak in January through May. The Floodplain Model (Opperman, 2008, pg 27) indicated little information is available on steelhead use of floodplain habitats. However, the steelhead model (Williams and Rosenfield, in preparation, page 155, Figure 2) shows floodplain use. Juvenile steelhead have been caught on the floodplain in Yolo (Sommer et al. 2001). There is some reference to additional observations in Williams 2006 (Chapter 9, page 174). McEwan (2001) and Moyle (2002) also support the presence of steelhead on floodplains.

Magnitude = 4
There is sufficient evidence of the use of floodplains by steelhead; Action includes major increase in habitat availability.

Certainty = 2
Few direct observations of steelhead benefiting from floodplain habitat.

P2d. Chinook salmon Scenario 1 and 2

Chinook salmon juveniles are present in the area during the proposed floodplain inundation period of late winter and spring.

- Knights Landing data indicates:
  Winter Run Juvenile peaks Nov –Feb
  Fall run peaks Jan – Feb then Apr -May
  Late Fall run peaks on Dec and April
  Spring Run peaks are Dec-Jan and March – April (CDFG rotary screw trap)

Chinook salmon juveniles use the floodplain for rearing. The restored floodplain would create rearing habitat for fry/parr that enter the Delta in the winter, coincident with inundation of the floodplain. These fry would be able to feed and grow in the floodplain, and their larger size would increase the likelihood of survival in the ocean.

- "Recent work shows that the bypasses do indeed provide habitat for juvenile Chinook, that they grow well there, and that most avoid stranding". (Williams 2006)
- Juvenile salmon collected from the inundated Yolo Bypass were substantially larger and grew more rapidly then juveniles collected from Sacramento River (Sommer et al. 2001).

Fall-run Chinook fry (<70mm) rear primarily in the upper freshwater delta. Peak fry rearing is February through March and young fry appear to be most abundant in shallow water and shoreline habitat. Rearing occurs for two months or more (Kjelson et al. 1982).

- Central Valley Chinook salmon may have relied extensively on floodplain in the past; historically much of the Central Valley was floodplain habitat (Hunter et al. 1999)
- Sommer et al. (2005) reported extensive use of Yolo and Sutter bypasses by fall-run Chinook salmon.
- Moyle et al. (2007) reported use of Cosumnes River floodplain by Chinook salmon.

Magnitude = 4
Compared to current conditions, the frequency and extent of inundated floodplain habitat for Chinook salmon will be significantly increased representing a landscape scale habitat effect.

Certainty = 4
There is high certainty that juvenile salmon are in the vicinity (based on data), and juveniles rear in restored floodplain based on documented rearing in the Yolo Bypass and the restored Cosumnes River floodplain (various published papers).

Outcome P3: Increase production of food for rearing of Chinook salmon, green and white sturgeon, splittail, and steelhead, on the seasonal floodplain

P3a. Splittail Scenario 1 and 2

The use of floodplains for rearing is established (P2a above). The Splittail Model (Kratville, 2009) notes, "After yolk sac absorption the larvae begin feeding on small rotifers (Bailey 1994). Prey composition shifts as they increase in size to cladocerans and chironomid larvae (Kurth and Nobriga 2001). Larval splittail to 15mm feed heavily on zooplankton, primarily made up of cladocerans. Chironomid larvae begin to dominate after 15mm in length has been achieved (Feyrer et al. 2007)." The model also notes that flooding of the Yolo bypass is associated with "a large hatch of an endemic chironomid, *Hydrobaenus saetheri*" (Cranston et al. 2007, Benigno and Sommer 2008). Floodplain Model (Opperman, 2008 - pgs 20-25 and Figure 5) describes floodplain food production and notes a positive relationship between temperature and zooplankton and the influence of floodplain flow velocity on macroinvertebrates,

Magnitude = 4
Splittail are floodplain dependent (Moyle et al. 2004; Sommer et al. 2007) and food resources are large on the floodplain.

Certainty = 4
There are substantial data and publications on splittail use of seasonal floodplain.

P3b. Green and white sturgeon Scenarios 1 and 2

The draft White Sturgeon Model (Israel et. al., 2009 - page 8) indicates "White sturgeons are unique in that their digestive systems are nearly fully formed both physically and physiologically at the larval stage (Gawlicka et al. 1995). Nothing is known about the diets of white sturgeon larvae in the wild, although laboratory studies suggested that they consist of benthos, periphyton, and possibly pelagic fry and zooplankton (Brannon et al. 1984, Buddington and Christofferson 1985)." Juvenile white sturgeon also may consume tube dwelling amphipods, mysids (*Neomysis spp*), isopods, benthic invertebrates, and fish eggs or fry, including those of other sturgeon (Brannon et al. 1987, PSMFC 1992). The draft Green Sturgeon Model (Israel and Klimley, 2008 - page 9) indicates that no studies have been undertaken of food resources for larval green sturgeon. However, there is no evidence of juvenile sturgeon use of floodplains. Sturgeon caught in Yolo Bypass have been adults (Harrell and Sommer 2003).

Magnitude = 1
There is no evidence of juvenile sturgeon use of floodplains. Sturgeon caught in Yolo Bypass have been adults.

Certainty = 2
Historical sampling in Yolo Bypass has not been well-designed to capture young sturgeon, thereby reducing certainty about this issue.

P3c.1 Steelhead Scenario 1

We know of no observations in the literature that support steelhead feeding on floodplains; however, it can be assumed that they are utilizing the same food sources as juvenile salmon (see P3d), given their life-history similarities. Moyle et al. 2004 states that stream-dwelling rainbow trout feed mostly on drifting aquatic organisms, terrestrial insects, and bottom dwelling organisms which are in abundance on floodplains.

Magnitude = 3
Effect demonstrated for species with similar life histories.

Certainty = 3
There have been some studies on similar species within the system.

P3c.2 Steelhead Scenario 2

We Know of no observations in the literature that support steelhead feeding on floodplains, however, it can be assumed that they are utilizing the same food sources as juvenile salmon (see P3d), given their life-history similarities. Moyle et al. 2004 states that stream-dwelling rainbow trout feed mostly on drifting aquatic organisms, terrestrial insects, and bottom dwelling organisms which are in abundance on floodplains.

Magnitude = 2
Magnitude is lower than scenario 1 because inundation frequency and duration is lower

Certainty = 3
See P3c.1

P3d.1 Chinook Salmon Scenario 1

Juvenile Chinook salmon use of floodplain habitats is well established (Sommer et al. 2001b, Whitener and Kennedy 1999). Opperman, 2008 (page 29) notes that the higher growth rates of juvenile Chinook on Central Valley floodplains, relative to river habitats, has largely been attributed to the greater availability of prey items within floodplain habitats (Jeffres et al. 2007, Sommer et al. 2001b). This includes Dipterans (Sommer et al., 2001) and zooplankton (Grosholz and Gallo 2006). Chinook salmon likely take advantage of small fishes on the floodplain (Williams and Rosenfield, In preparation pg 8) and (Moyle et al. 2004).

Magnitude =4
Extensive floodplain area inundated and high likelihood of appropriate food production.

Certainty = 3
Juvenile Chinook salmon use of floodplain habitats is well established.

P3d.2 Chinook Salmon Scenario 2

Rationale is similar to P3d.1. Differences in scores reflect reduction in scale of floodplain inundation.

Magnitude = 3-4
Reduced scale and duration of floodplain inundation compared to P3d.1

Certainty = 3
Juvenile Chinook use of floodplain habitats is well established.

Outcome P4: Increase frequency and magnitude of export of DOM, POM and organisms from seasonal floodplain to provide food in Delta for Delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon

P4a. Delta smelt Scenarios 1 and 2

Delta smelt Model (Norbriga and Herbold, 2008 - pg 12) describes the importance of zooplankton to Delta smelt. Opperman, 2008 notes that the most important variables influencing zooplankton production on floodplain are hydraulic residence time and the availability of food resources (e.g., phytoplankton and periphyton). Grosholz and Gallo (2006) also found that zooplankton densities peaked about 2-3 weeks after disconnection between river and floodplain (draining phase). The Foodweb Model (Durand, 2008) notes that DOC reaches the estuarine foodweb via bacteria and notes this is well understood in this estuary. The model also notes recent studies by Sobczak et al. (2005) that indicates that some zooplankton tend not to use phytoplankton exclusively, supplementing their diets substantially with particulate organic matter or ciliates: According to the fall midwater and Kodiak trawl data and Sommer et al. (in prep), Delta smelt rear in areas immediately downstream of Yolo Bypass.

Magnitude = 3
Delta smelt rear immediately downstream from Yolo Bypass where exported food would be readily available.

Certainty = 3
Delta smelt Model (Norbriga and Herbold, 2008 - pg 12) describes the importance of zooplankton to Delta smelt. Opperman, 2008 notes that the most important variables influencing zooplankton production on floodplains are hydraulic residence time and the availability of food resources (e.g., phytoplankton and periphyton) - see above paragraph.

P4b. Longfin Smelt Scenarios 1 and 2

The Longfin Smelt Model (Rosenfield, 2008 - pg 15) notes that early stage longfin smelt juveniles probably rely on *Eurytemora affinis* as a prey item during April and May with other copepods becoming important later in the year. Food limitation is considered a stressor on juveniles and sub adults. Opperman, 2008 notes that the most important variables influencing zooplankton production on floodplains are hydraulic residence time and the availability of food resources (e.g., phytoplankton and periphyton). Grosholz and Gallo (2006) also found that zooplankton densities peaked about 2-3 weeks after disconnection between river and floodplain (draining phase). The Foodweb Model (Durand, 2008) notes that dissolved organic carbon (DOC) reaches the estuarine foodweb via bacteria and that this is well understood in this estuary. The model also notes recent studies by Sobczak et al. (2005) that indicates that some zooplankton tend not to use phytoplankton exclusively, supplementing their diets substantially with particulate organic matter or ciliates.

Magnitude = Between 2 and 3
The shift in the longfin smelt-X2 relationships after the introduction of *Corbula* suggest longfin smelt are sensitive to food availability (Kimmerer 2002). Young longfin smelt occur close to Yolo Bypass but the benefit to longfin smelt further downstream may be limited due to the role of *Corbula*.

Certainty = 2
The relative importance of exported floodplain carbon to longfin smelt is unclear, particularly given high densities of the grazer *Corbula* between floodplain and main brackish habitat of longfin smelt.

P4c. Splittail Scenarios 1 and 2

Opperman, 2008 (pg 20) describes the importance of exporting food to downstream foodwebs and the links between carbon produced on floodplains and the downstream foodweb (Sobczak et al. 2005). The use and importance of these food resources has been described for splittail in outcome P3a.

Magnitude = 3
Splittail use Yolo bypass, but the benefit to splittail further downstream may be limited due to role of *Corbula.*

Certainty = 2
The relative importance of exported floodplain carbon to splittail is unclear, particularly given high densities of the grazer *Corbula* between floodplain and downstream habitat of splittail.

P4d. Green/white sturgeon Scenarios 1 and 2

Opperman, 2008 (pg 20) describes the importance of export of food to downstream food webs and the links between carbon produced on floodplains and the downstream foodweb (Sobczak et al. 2005). The use and importance of these food resources has been described for green and white surgeon in outcome P3b.

Magnitude =2
The White Sturgeon Model (Israel et. al., 2009 - pg 11) notes feeding on highly-abundant suspension-feeding bivalves such as *Corbula amurensis.* The Green Sturgeon Model (Israel and Klimley, 2008) notes that invasive *Corbula* has replaced native mollusks and shrimp as food for green sturgeon in recent years. Sturgeon may indirectly benefit from the export of food through the *Corbula* foodweb linkage.

Certainty = 2
Importance of food exported from floodplains for sturgeon directly or indirectly is unclear. Little evidence available.

P4e.1 Steelhead Scenarios 1 and 2

Opperman, 2008 (pg 20) describes the importance of exporting food to downstream foodwebs and the links between carbon produced on floodplains and the downstream foodweb (Sobczak et al. 2005). The use and importance of these food resources has been described for steelhead in outcome P3c.

Magnitude = 2-3
Floodplains produce aquatic insects. Increased flows will export these resources downstream. Steelhead feed mostly on drifting aquatic organisms, terrestrial insects, and bottom dwelling organisms (Moyle et al. 2004).

Certainty = 2
It can be assumed that steelhead are utilizing similar food sources as juvenile salmon given their life-history similarities (see P3d), however there is little documentation.

P4f.1 Chinook Salmon Scenario 1 and 2

Opperman, 2008 (pg 20) describes the importance of exporting food to downstream food webs and the links between carbon produced on floodplains and the downstream foodweb (Sobczak et al. 2005). The availability of these food resources has been described for Chinook salmon in outcome P3d, However the importance of these food resources in downstream habitats is not as well documented.

Magnitude = 2-3
Floodplains produce aquatic insects. Increased flows will export these resources downstream. Steelhead feed mostly on drifting aquatic organisms, terrestrial insects, and bottom dwelling organisms (Moyle et al. 2004).

Certainty = 2
The importance of these food resources in downstream habitats is not as well documented.

Outcome P5: Increase frequency and magnitude of transport of OC and organisms from Cache Slough/Bypass tidal marshes to support Delta foodweb for Delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, and green and white sturgeon

P5a. Delta smelt Scenarios 1 and 2

Marsh production of phytoplankton is high in Liberty Island (Lehman et al. 2007); Phytoplankton supports the delta food web (Sobzack et al. 2002; Mueller-Solger et al. 2002). Production from lower Yolo Bypass including. Liberty and Cache slough marshes stays relatively intact as it moves down the estuary (Monsen 2003). Delta smelt diets are largely comprised of zooplankton (Delta smelt model p. 5), especially larval stages of specific copepods. Food is potentially an important limiting factor for Delta smelt but its effect cannot be readily separated from water temperature (Norbriga and Herbold, 2008 pg. 8).

Magnitude = 3
Magnitude is higher than other species because Delta smelt are planktivorous.

Certainty = 2
It is uncertain whether the increased production associated with the action will be reduced by *Corbicula.*

P5b. Longfin Smelt Scenarios 1 and 2

Marsh production of phytoplankton is high in Liberty Island (Lehman et al. 2007); Phytoplankton supports the delta food web (Sobzack et al. 2002; Mueller-Solger et al. 2002). Production from lower Yolo Bypass, including Liberty and Cache slough marshes, stays relatively intact as it moves down the estuary (Monsen 2003). Longfin Smelt Model (Rosenfield, 2008 - pg 15) notes that early stage longfin smelt juveniles probably rely on *Eurytemora affinis* as a prey item during April and May with other copepods becoming important later in the year. Food limitation is considered a stressor on juveniles and sub adults (Rosenfield, 2008 Figure 4).

Magnitude = 3
Magnitude is higher than other species because longfin smelt are planktivorous.

Certainty = 2
It is uncertain whether the increased production associated with the action will be reduced by *Corbicula.*

P5c. Splittail Scenarios 1 and 2

Marsh production of phytoplankton is high in Liberty Island (Lehman et al. 2007); Phytoplankton supports the delta food web (Sobzack et al. 2002; Mueller-Solger et al. 2002). Production from lower Yolo Bypass, including Liberty and Cache slough marshes, stays relatively intact as it moves down the estuary (Monsen 2003). According to the Splittail Model (Kratville, 2008), larval splittail up to 15mm feed heavily on zooplankton, primarily made up of cladocerans. Chironomid larvae begin to dominate the diet after 15mm in length has been achieved (Feyrer et al. 2007). Moyle et al. (2004)

notes that growth rates, especially in the first year or two of life, may be strongly dependent on availability of high quality food, as suggested by changes in growth rate following the invasion of the overbite clam in the 1980s and by the collapse of *Neomysis* populations upon which splittail historically specialized (Feyrer et al. 2003).

Magnitude = 2
Food availability is not identified as key stressor in the Splittail Model.

Certainty = 2
It is uncertain whether the increased production associated with the action will be reduced by *Corbicula.*

P5d. Green and White Sturgeon Scenario 1 and 2

Marsh production of phytoplankton is high in Liberty Island (Lehman et al. 2007); Phytoplankton supports the delta food web (Sobzack et al. 2002; Mueller-Solger et al. 2002). Production from lower Yolo Bypass, including Liberty and Cache slough marshes, stays relatively intact as it moves down the estuary (Monsen 2003). The Draft White Sturgeon Model (Israel et. al., 2009) indicates nothing is known about the diets of white sturgeon larvae in the wild, although laboratory studies suggested that they consist of benthos, periphyton, and possibly pelagic fry and zooplankton (Brannon et al. 1984, Buddington and Christofferson 1985). Juvenile white sturgeon also may consume tube dwelling amphipods, mysids (*Neomysis spp*), isopods, benthic invertebrates, and fish eggs or fry, including those of other sturgeon (Brannon et al. 1987, PSMFC 1992). The Draft Green Sturgeon Model (Israel and Klimley, 2008 - page 9) indicates that no studies have been undertaken of food resources for larval green sturgeon.

Magnitude =2
There is limited evidence that sturgeon will benefit from this additional food resource.

Certainty = 2
Few studies have been conducted to support juvenile sturgeon feeding. It is uncertain whether the increased production associated with the action will be reduced by *Corbicula.*

P5e. Steelhead Scenario 1 and 2

Marsh production of phytoplankton is high in Liberty Island (Lehman et al. 2007); Phytoplankton supports the delta food web (Sobzack et al. 2002; Mueller-Solger et al. 2002). Production from lower Yolo bypass, including Liberty and Cache slough marshes, stays relatively intact as it moves down the estuary (Monsen 2003). Steelhead feeding strategies and dietary preferences are similar to those of Chinook salmon (Williams and Rosenfield, In preparation p.38). Fish in the wild are expected to be food-limited (Moyle and Cech 2004). Marshes produce aquatic insects; increased flows will export these resources downstream. Steelhead feed mostly on drifting aquatic organisms, terrestrial insects, and bottom dwelling organisms (Moyle et al. 2004).

Magnitude = 2
Marshes produce aquatic insects; increased flows will export these resources downstream. Steelhead feed mostly on drifting aquatic organisms, terrestrial insects, and bottom dwelling organisms.

Certainty = 2
It is uncertain whether the increased production will be consumed by *Cobicula* and thus be unavailable to sturgeon downstream of Yolo.

P5f. Chinook Salmon Scenario 1 and 2

Marsh production of phytoplankton is high in Liberty Island (Lehman et al. 2007); Phytoplankton supports the delta food web (Sobzack et al. 2002; Mueller-Solger et al. 2002). Production from lower Yolo bypass, including Liberty and Cache slough marshes, stays relatively intact as it moves down the estuary (Monsen 2003). Chinook salmon in the wild are expected to be food-limited (Moyle and Cech 2004).

Magnitude = 2
See above

Certainty = 2
It is uncertain whether the increased production will be consumed by *Cobicula* and thus be unavailable to salmon downstream of Yolo.

Outcome P6: Reduce losses due to stranding, illegal harvest and blocked/delayed passage for Chinook salmon, steelhead, green/white sturgeon

P6a. Green and White Sturgeon Scenario 1 and 2

Adult passage of white and green sturgeon is likely constrained in the Yolo Bypass (Harrell and Sommer 2003). Current configuration of Fremont and Sacramento weirs create stranding and poaching problems for white and green sturgeon (Sommer et al. 2005, (Israel et. al., 2009 pg 20), (Israel and Klimley, 2008 page 18); hence efforts to improve passage and redesign weirs will reduce poaching and stranding.

Magnitude = 4
Blocked passage (and resulting legal and illegal harvest) is substantial; loss of spawners is particularly harmful to the populations. Frequent poaching has been well-documented by the Department of Fish and Game.

Certainty = 4
Studies within Yolo have identified the problem (DFG Unpublished Data, Harrell and Sommer 2003; Harrell et al. in prep).

P6b. Steelhead Scenarios 1 and 2

Adult passage of salmon (and steelhead) is likely constrained in the Yolo Bypass (Harrell and Sommer 2003). Current Fremont and Sacramento weirs create stranding problems for salmon (Sommer et al. 2005); hence efforts to improve passage and redesign weirs will reduce poaching and stranding.

Magnitude = 4
Blocked passage is more of a problem than stranding.

Certainty = 3
Studies within Yolo have identified the stranding problem (DFG Unpublished Data, Harrell and Sommer 2003; Harrell et al. in prep). But it is less well documented for steelhead due to relatively low catch of adults.

P6c. All Races Chinook Salmon Scenarios 1 and 2

Adult passage of salmon is likely constrained in the Yolo Bypass (Harrell and Sommer 2003). Current Fremont and Sacramento weirs create stranding problems for salmon (Sommer et al. 2005); hence efforts to improve passage and redesign weirs will reduce poaching and stranding. Williams (2006) indicates that water flowing through the Yolo Bypass attracts migrating adult salmon into this seasonally flooded wetland; however, the Fremont Weir, at the top of the Bypass does not allow salmon passage. This barrier represents either a serious delay to spawning; or a literal "dead end" (Williams and Rosenfield, In preparation page 55).

Magnitude = 4
A serious delay in salmon spawning has been documented. Blocked passage involved an extensive (~100 mile) increase in passage.

Certainty = 3 to 4
Studies within Yolo have identified the problem (DFG Unpublished Data, Harrell and Sommer 2003; Harrell et al. in prep). The certainty is lower for spring and winter-run salmon because of lower numbers and lower catch rates in sampling.

Outcome P7: Increase delivery of readily suspendable sediments to north Delta and improved Delta smelt habitats

<u>Scenario 1:</u>
Sedimentation Model (Schoellhamer et. al., 2007 - page 9) describes Yolo Bypass as the second largest source of sediment for the Delta. Lehman et al. (2008) also found that the concentration of suspended solids were higher in the Yolo Bypass than in the Sacramento River.

The Delta smelt Model (Norbriga and Herbold, 2008 – pages 4-5 and 11) shows that Delta smelt spawn in the Cache Slough region of the northern Delta and that larval Delta smelt have an improved ability to see prey in water with enhanced turbidity. There is an additional hypothesis that Delta smelt use turbidity to conceal themselves from predators (Norbriga and Herbold, 2008 - page 7).

<u>Scenario 2:</u>
Sedimentation Model (Schoellhamer et. al., 2007 - pages 6 and 10) shows that sediment transport is flow dependant, also Floodplain Model (Opperman, 2008 - page 10) states

that floodplain benefits are proportional to the spatial extent of floodplains; however, given the relatively small difference in flow and inundation area between the two scenarios, it seems likely the benefits of enhanced turbidity provided under scenario 1 would be similar to scenario 2.

Magnitude = 3
Increase in quality and quantity of larval/juvenile Delta smelt habitat based on substantial increase in frequency and duration of inundation and sediment delivery over current conditions.

Certainty = 3
There is a high understanding but with many variables.

Outcome P8: Increase survival of out migrating juveniles (steelhead and Chinook salmon) by providing migration route with lower predation and entrainment (at North and South Delta diversions) risk.

Passage through the bypass and reentering the Sacramento River near Rio Vista avoids possible migratory routes into the central delta. As floodwaters recede from the Yolo Bypass, the juveniles exit to the south, ultimately into the toe drain which provides the only means of passage into the delta (Sommer et al. 2001, 2005). Thus Yolo Bypass when inundated during winter/spring months will provide additional migratory paths for emigrating Chinook salmon and steelhead juveniles above the location of the proposed peripheral canal. This would also mitigate entrainment exposure at this new facility

Newman (2008) showed that survival rates were 66% higher for juvenile salmon released in the lower mainstem of Sacramento River (near Ryde) than for those released in central delta (Georgiana Slough). Vogel (2008) conducted an acoustical tag study in 2006 and 2007 which showed there were reach specific characteristics for loss rates on juvenile salmon released in Sacramento River near Old Town. Preliminary results showed that loss in Delta Cross Channel and Georgiana Slough was at least 2 times greater then on main stem or Sutter and Steamboat Slough. This effect is likely similar for steelhead although few specific data are available.

Note: Evaluation assumes that new North Delta facilities would increase predation risks.

Magnitude = 3-4
This action provides an additional migratory route that currently exists but increases the frequency and duration of its availability. The action will benefit upper Sacramento migrating juveniles when functioning properly on a biennial basis. Fish will be able to avoid predators that will likely congregate in the vicinity of the North Deltas diversion as well as being able to benefit from the food resources/habitat provided by the bypass.

Certainty = 3 for Chinook salmon, 2 for Steelhead
Migratory routes for salmon in the north delta have been shown through several studies to have higher survival rates then those in the central Delta (Vogel 2008, Newman 2008) Little data available for steelhead – reduced certainty is based on the assumption that they respond the same as Chinook salmon.

Potential Negative Ecological Outcome(s)

Outcome N1: Increased MeHg and impact on covered species (on floodplain and downstream)

Proximity to mining-related mercury loading sources is an important factor affecting methyl mercury (MeHg) exposure and bioaccumulation in fish in the Bay-Delta (Alpers et al. 2008, page 23). The Yolo Bypass is downstream of mining-related mercury sources in the Cache Creek and Putah Creek watersheds.

Inundation frequency is another important factor affecting MeHg production. Habitats with the highest levels of MeHg production, concentration and exposure to biota are those with periodic flooding events separated by sufficient time to allow complete drying, such as the seasonal floodplains that would be enhanced in this project (Alpers et al. 2008, pages 15 and 17), also cites Marvin-DiPasquale et al. (2007).

The project would result in inundation of larger areas of floodplain, for longer periods of time, and in more years than the baseline weir height condition. These changes from baseline may result in higher MeHg concentrations in the Yolo Bypass aquatic food chain as conditions are improved for development of the phytoplankton and zooplankton communities. The single largest concentration jump in food web MeHg bioaccumulation occurs between aqueous MeHg and algal cells or phytoplankton (Alpers et. al., 2008, page 19). The frequency and magnitude of export of MeHg downstream would increase over baseline, resulting in increased exposure to covered fish species downstream in the Delta.

The linkage of seasonal flooding to MeHg production and subsequent bioaccumulation of MeHg in fish and their prey is well documented. Fish tend to accumulate greater burdens and concentrations of MeHg over time, so older individuals typically have higher body burdens and higher absolute concentrations of MeHg than younger ones (Wiener and Spry 1996). Effects of this bioaccumulation on covered fish species are more uncertain, due to lack of studies of toxicological effects of MeHg on covered species, uncertainty about sensitivity of covered species relative to species that have been studied, and the subtle nature of the behavioral effects that are among the most sensitive endpoints for MeHg toxicity and are difficult to detect. Some of the sub-lethal effects related to Hg in fish include: altered hormone expression, reduced spawning success, reduced reproductive output, reduced gonadosomatic indices and testicular atrophy, liver necrosis, and altered predator avoidance behavior (Alpers et. al., 2008, pg 31).

The Mercury Model (Alpers et. al., 2008, pg 31) indicates that an Hg concentration of 0.20 ppm, (wet-wt) in fish tissue is a threshold for the onset of adverse effects in fish (Beckvar et al. 2005). Concentrations of Hg in some fish from some parts of the Yolo Bypass may currently exceed this effect concentration. For example, Ackerman et al. (2008) found average Hg concentrations of 1.76 ppm, dry-wt (approximately 0.35 ppm wet-wt, assuming wet-weight concentrations are approximately 20% of dry-weight concentrations) in caged mosquitofish placed at the outlets of white rice fields and exposed for 60 days in the Yolo Bypass. Similarly, Hg concentrations in wild mosquitofish and wild silverside were 1.09 ppm, dry-weight (approximately 0.218 ppm, wet-weight) and 1.25 ppm, dry-weight (approximately 0.25 ppm, wet-weight), respectively, at white rice outlets. Mercury concentrations were lower in fish sampled at the inlets to rice fields and in permanent wetlands in the Yolo Bypass (Ackerman et al. 2008). Previous studies focused on canals and permanent ponds in the Yolo Bypass found Hg concentrations in small fish were below effects concentrations (Slotton et al. 2002, Davis et al. 2007). A recent, unpublished study of MeHg bioaccumulation in juvenile Chinook salmon found that the rate of MeHg bioaccumulation was higher in the Yolo Bypass than the mainstream Sacramento River, but the concentrations of MeHg in the juvenile salmon remained below the threshold for toxic effects (Henery et al., in review).

Magnitude = 1-2
The proposed action could result in increases in MeHg production and bioaccumulation that would cause fish tissue Hg concentrations to exceed effects levels for sub-lethal impacts to fish health. The magnitude of this negative outcome would vary depending on species and life-stage due to differences in exposure (a function of distribution and diet) and sensitivity. Acute toxicity (i.e., death from mercury poisoning) would be very unlikely to occur in any covered fish species. Chronic toxicity manifested as adverse behavioral or physiological effects may occur in some individual fish of covered species that spawn in the Yolo Bypass (e.g., splittail), rear in the Bypass (e.g., splittail, salmon and steelhead) or rear immediately downstream in the Cache Slough area (Delta smelt). The risk of chronic toxicity from Hg methylation and bioaccumulation in the Yolo Bypass would be minimal in species that do not use the Yolo Bypass or Cache Slough area for spawning or rearing (e.g., sturgeon and longfin smelt).

Certainty = 2
The linkage of seasonal flooding to MeHg production and subsequent bioaccumulation of MeHg in fish and their prey is well documented. However, potential effects of this bioaccumulation on covered fish species are less clear because of lack of information on the sensitivity of these species to MeHg and uncertainty in predicting the degree to which MeHg concentrations in fish would increase as a result of the action. Two of the most relevant studies of MeHg bioaccumulation in fish in the Yolo Bypass are recent studies that have not yet been published.

Outcome N2: Increased resuspension/mobilization and export of toxic compounds w/impact on covered species

A wide variety of crops are grown in the Yolo Bypass and surrounding areas, and many different pesticides are used on these crops (Smalling et al. 2007) including, but not limited to, pyrethroids (Werner et al. 2008, pg 3). Pesticides were detected in water samples collected in the inflows to the Yolo Bypass and within the Bypass in 2004 (Smalling et al. 2007). Pesticides detected in water samples included herbicides, especially hexazinone and simazine, and insecticides, especially diazinon (Smalling et al. 2007). The concentrations of dissolved pesticides were below levels known to cause acute or chronic toxicity to fish; however, some of the herbicide concentrations (e.g., hexazinone) were high enough to potentially adversely affect primary productivity (Smalling et al. 2007).

Sediments and soils from the Bypass and its inflows contained other pesticides, such as pyrethroids and DDTs (Smalling et al. 2007). The concentrations of pesticides associated with sediments were below levels known to cause acute toxicity to fish; however, the concentration of at least one pyrethroid (lambda-cyhalothrin) in suspended sediment was high enough to adversely affect benthic macroinvertebrates that fish rely on for food (Smalling et al. 2007).

Increased seasonal flooding of agricultural lands may mobilize pyrethroids and other pesticides from soils and increase exposure to covered fish species in the Yolo Bypass and downstream. One of the goals of the project is to facilitate spawning by splittail and rearing by splittail and other species. Pyrethroids can be toxic to fish, especially to early life stages (Werner et al. 2008, pg 16). Teh et al. (2005) showed sub-lethal effects and delayed mortality to larval splittail exposed to orchard storm water runoff that contained a pyrethroid (esfenvalerate) and an organophosphate (diazinon). These fish showed higher mortality rates and slowed growth even after a three month recovery period. Combinations of low concentration toxic chemicals (Pyrethroids, Organophosphates, Organochlorines, etc.) which may have low effects on fish directly can have significant negative impacts on Chironomids (Lydy and Austin 2004), and other invertebrates (Hunt et al. 1999, Hunt et al. 2003, Amweg et al. 2005, Weston et al. 2008). Pyrethroid concentrations would be expected to peak during the winter/spring storm season and after peak agricultural application in the summer and fall (Werner et al. 2008, pg 2). Late-winter and spring are also the times splittail would use the enhanced floodplain habitat to spawn (Kratville**,** 2008, pg 1).

There are critical data gaps on pyrethroids and other pesticides that make it difficult to evaluate risk to covered fish (Werner et al. 2008, pg 32; Werner et. al., 2008, pg 25). In general, little is known about the toxic effects of contaminants known to be present in the Delta on resident Delta species, and even less is known about the sub lethal effects of contaminants (Werner et. al., 2008, pg 25). The potential effects of complex mixtures of low level pesticides, such as those detected in the Yolo Bypass by Smalling et al. (2007) are also poorly understood. Due to additive and synergistic effects, mixtures of pesticides that have been commonly reported in salmon habitats may pose a more important challenge for species recovery than previously anticipated (Laetz et al. 2009).

Magnitude = 1-2
The highest concentrations of dissolved pesticides enter the Bypass as a pulse during the first high-flow event following winter pesticide application (Smalling et al. 2007). Late-winter and spring are also the times splittail would use the enhanced floodplain habitat to spawn (Splittail model, pg 1). The magnitude of potential adverse effects to splittail and other covered fish would vary depending on species and life-stage due to differences in distribution and sensitivity. Species that spawn in the Yolo Bypass (e.g., splittail) or rear in the Bypass (e.g., splittail, salmon and steelhead) or immediately downstream in the Cache Slough area (Delta smelt) would be at greater risk of toxicity than species that do not use these areas for spawning or rearing (e.g., sturgeon and long-fin smelt).

Certainty = 2
There are critical data gaps on pyrethroids and other pesticides that make it difficult to evaluate risk to covered fish (Werner and Oram, 2008 pg 32; Werner et. al., 2008, pg 25). The potential effects of complex mixtures of low level pesticides, such as those detected in the Yolo Bypass by Smalling et al. (2007) are also poorly understood.

Outcome N3: Increased stranding of covered species

N3a.1 & N3a.2 Splittail adult and juvenile Scenarios 1 and 2

Connectivity problems can strand splittail (Opperman, 2008 pg 27 citing Sommer et al. 2005). The approach specified for this action includes grading which may reduce this risk, however the specifics are not known.

Magnitude = 1
Densities of splittail are low in isolated ponds in the Yolo Bypass (DWR unpublished data; Feyrer et al. 2004)

Certainty = 4
Sommer et al (2005) showed that there is relatively little ponded area following floodplain inundation. Low level of ponding reduces stranding.

N3b. Green/white Sturgeon adult/juvenile Scenarios 1 and 2

Current Fremont and Sacramento weirs create stranding and passage problems for white sturgeon and green sturgeon, (Sommer et al. 2005; Harrell and Sommer 2003). Observations indicate substantial legal/illegal harvest resulting from blocked passage.

Poaching may be a major issue for white sturgeon (White Sturgeon model pg 20)

Magnitude = 1
Blocked passage will be minimal behind the modified weir as it will be designed to improve passage, and grading will limit stranding on the floodplain for adults

Certainty = 4
The assumption is that the problem of blocked passage will be resolved by the modifications to the weir.

N3c. Steelhead Scenarios 1 and 2

Adult passage of white sturgeon, green sturgeon, splittail, steelhead and salmon is likely constrained in the Yolo Bypass (Harrell and Sommer 2003). Current Fremont and Sacramento weirs create stranding problems for white sturgeon and green sturgeon (Sommer et al. 2005); hence efforts to improve passage and redesign weirs will reduce stranding (Harrell and Sommer 2003).

Magnitude = 1 (adults), 2 (juveniles)
Blocked passage will be minimal behind the modified weir as it will be designed to improve passage, and grading will limit stranding on the floodplain for adults. Juveniles are more susceptible to stranding thus the effect is greater.

Certainty = 4
Evidence is good that efficient drainage results in low stranding (Sommer et al. 2005); hence additional grading should prevent stranding.

N3d. Chinook Salmon Scenarios 1 and 2

Most juvenile Chinook salmon can exit the existing floodplain configuration (Sommer et al. 2005). Adult passage of salmon is likely constrained in the Yolo Bypass (Harrell and Sommer 2003). Current Fremont and Sacramento weirs create stranding problems for salmonids (Sommer et al. 2005); hence efforts to improve passage and redesign weirs will reduce stranding. (Harrell and Sommer 2003)

Assumption is that is operable gates/ladders would be operable at all times to allow for year-round passage.

Magnitude = 1 (adults), 2 (juveniles)
Stranding is minimal on the Yolo Bypass now. This project will further reduce stranding behind the weir because the new weir design will improve passage and the floodplain will be graded. There is some possibility of reduced passage if migrating salmon encounter the modified structure when it is closed or there is insufficient flow to allow passage.

Certainty = 4
Evidence is good that efficient drainage results in low stranding (Sommer et al. 2005) hence additional grading should prevent stranding.

Outcome N4: Reduced flows in Sacramento River and distributaries to support successful outmigration (Scenarios 1 and 2).

Juvenile salmon survival is dependent on sufficient river flow and water quality (NMFS 2008). Diversions for habitat restoration reduce flow in the mainstem Sacramento River in the same way as diversions for water use. As much as 60 percent of the natural historical inflow to Central Valley watersheds and the Delta have been diverted. Depleted flows have contributed to higher temperatures, lower DO levels, and decreased recruitment of gravel and large woody debris (LWD). More uniform flows year round have resulted in diminished natural channel formation, altered food web processes, and slower regeneration of riparian vegetation (NMFS 2008)

Direct relationships exist between water temperature, water flow, and juvenile salmonid survival (Brandes and McLain 2001).

Elevated water temperatures in the Sacramento River have limited the survival of young salmon in those waters. Juvenile fall-run Chinook salmon survival in the Sacramento River is also directly related to June streamflow and June and July Delta outflow (Dettman et al. 1987).

Magnitude = 2
The effect of this action is limited to the diversion of 2000-4000 cfs at a time when the river flow is approximately 30,000 cfs. It is difficult to evaluate the net negative effect of this action via this outcome as water diverted through the bypass is presumably going to remain in the system to support another migratory route. The action will only affect the Sacramento River between the Fremont Weir and it’s confluence with Cache slough. There is no spawning habitat in this reach and rearing habitat is limited – hence its

primary benefit for emigrating salmonids is as a migration corridor. Since the river is constrained in a well-defined channel by levees, reduction in flow should not affect its' ability to pass fish downstream to any great degree.

Certainty = 3
The relationship between river flow and salmon survival has been well documented (Newman and Rice 2002, Brandes and McLain 2001).

Outcome N5: Increased habitat for predators/competitors to covered species.

N5a. Delta smelt

Evidence from Yolo and Cosumnes of non-natives taking advantage of floodplain (ref Sommer et al 2004, Moyle et al 2006). Opperman (2008 page 10) discusses sources of invasive species.

Delta smelt model (semi final with note – do not cite) – notes that DS are adapted to sustain high mortality during the adult stage (Winemiller and Rose 1992). Predation is one of two primary factors for population dynamics (Figure 7). The most likely ancestral Delta smelt predators would have been piscivorous birds, salmonid fishes, and, secondarily, longfin smelt as a larval predator and predatory freshwater fishes like Sacramento pikeminnow, Sacramento perch, (Moyle 2002). All of the above species could be expected to inhabit the proposed inundated floodplain habitat. Though predation on the floodplain is not specifically addressed in the Delta smelt model, the evaluation team thought predation of Delta smelt on the lower portion of the bypass was significant. Wetlands that flood only in spring and winter (as does the Yolo Bypass) provide substantial benefits for larval and juvenile native fishes, but only limited benefits (as compared to perennially flooded habitats) for non-native larval fish that were spawned later in the year (Grimaldo et al. 2004).

Magnitude = 2
Adaptation to high mortality and the occurrence of many native predators implies that an increased predation rate is not substantial.

Certainty = 3
It is likely the introduction of striped bass (*Morone saxatilis*) in the 1870s greatly increased predation pressure on Delta smelt by placing a resident low-salinity zone predator where there was not one historically (Moyle 2002). Striped bass are likely to inhabit the area downstream of the bypass increasing the certainty of this predation effect.

N5b. Longfin smelt

Predation is a source of direct mortality to eggs and larvae (Rosenfield, 2008). Some fish species (e.g. suckers, splittail, and sturgeon) may feed on longfin smelt eggs. Larval longfin smelt are not strong swimmers and are thus highly vulnerable to predation (Wang 1986). Striped bass and inland silverside are probably major predators on longfin smelt larvae. Terns, gulls, and cormorants may also prey on this life stage. Predation and competition are characterized as medium importance and medium understanding

(Rosenfield, 2008, Figure 5), but floodplain predation and competition are not specifically addressed.

Magnitude = 2
Predation and competition are characterized as medium importance and medium understanding.

Certainty = 3
There is good evidence that predation is an important stressor for juvenile longfin smelt.

N5c. Splittail

Splittail model - Bird predation appears limited until water recedes and floodplains begin to isolate from main channels at which point fish are exposed to wading birds (Moyle 2004). Predation by non native predators in floodplain habitats is characterized as medium with high understanding (Figure 5 and Table 3).

Magnitude = 2
The action will increase the availability of floodplain habitat to splittail but will not influence the presence of the avian predators

Certainty = 4
Good evidence of this predation impact from within the system.

N5d. Green and white sturgeon

The White Sturgeon Model (Israel et. al., 2009, Figure 7) and Green Sturgeon Model (Israel et. al., 2009, Figure 2) both indicate probable distribution of sturgeon in this reach. Due to the benthic nature of green and white sturgeon and the timing of floodplain inundation they are not expected to be found on the floodplain (Josh Israel pers comm.). Juvenile sturgeon are subject to greater predation effects, however, there is no evidence of juvenile sturgeon use of floodplains. Sturgeon caught in Yolo Bypass are adults (Harrell and Sommer 2003).

Magnitude = 1
Juvenile sturgeon are subject to greater predation effects, however, there is no evidence of juvenile sturgeon use of floodplains.

Certainty = 3
Little documentation of effect on juveniles.

N5e. Steelhead and Chinook salmon

The Chinook Salmon Model (Williams and Rosenfield, In preparation) and Steelhead Model (Williams and Rosenfield, In preparation) both indicate non-native predation and competition with invasive species and hatchery produced salmonids is of medium importance in rearing and emigration estuarine habitats, including floodplain (Opperman, 2008, Figure 2a).

Magnitude = 2 (see text above)

Certainty = 4 (see text above)

Important Gaps in Information and/or Understanding

Data Needs

The number of salmonids and sturgeon attracted into the Yolo Bypass and their ultimate fate (death, loss of spawning opportunity, eventual return to the Sacramento River).

Research Needs

- Major gaps – rearing habitat for steelhead? Rearing habitat for juvenile sturgeon?
- Hg accumulation in fish has been documented, but does not indicate there is an effect on fish.
- Degree of contaminants affects on POD.
- Degree of sediment settling on floodplains.
- Degree of predation/competition within floodplains on native covered fish species by non-native fish species.
- Better diet information is needed for floodplain use of steelhead, green and white sturgeon;
- More info is needed about relative importance of food to population level effects for all of the species.
- Transport studies are needed to evaluate the footprint of food transport from floodplains.
- Timing duration of rearing for steelhead, green and white sturgeon.
- Additional information is needed to help quantify the contribution of suspended sediment that Yolo Bypass provides to the north Delta region. Understanding the duration of the suspended sediment benefit would be helpful. Is the increased sediment load only part of a first flush? Can the flows and inundation areas described in scenario 1 and 2 result in the anticipated turbidity benefit?
- Telemetry study of salmonid and sturgeon to study movement of these species in the Yolo Bypass
- Assess Reversibility and Opportunity for Learning
- Better understanding of physiological toxicity affects of in situ native fish

Reversibility

Yes/Easy: As the action includes operable gates the action would not necessarily have to be implemented on the proposed schedule or at all if adverse consequences made its reversal necessary. Grading aspects of the action could theoretically be reversed but this would be more challenging and is less likely to occur.

Opportunity for Learning

High: The operable gates would allow the flooding timing and duration of the bypass to be experimentally manipulated allowing the exploration of specific relationships between floodplain inundation and covered species.

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Appendix A

WOCM 3:
Deep Water Ship Channel Bypass Floodplain

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Action: WOCM 3a/3b: Create new flood bypass east of SDWSC.

Evaluation Team: Floodplain Workgroup

Campbell Ingram (chair), Denise Reed (coach), Carie Battistone (notetaker), Eric Ginney, Ted Sommers, Rosalie Del Rosario, Dennis McEwan, Bill Harrell, Dan Welsh, Yvette Redler, and Vance Russell.

Date of Last Revision: February 21, 2009

Action Description and Clarifying Assumptions

Create a new flood bypass that provides up to 3800 acres (at 3000 cfs) of inundated floodplain habitat adjacent to and east of the Sacramento Deep Water Ship Channel (DWSC) and that inundates in ~50% of years from December 1 to May 15 for 45 consecutive days with a spill intermission of no more than 7 days.

Assume:

1. New bypass empties into Prospect Island with connectivity into Miner's Slough to provide tidal connectivity.
2. Operation is independent of Yolo.
3. Water depth ~1m (possibly though channelization/contouring), low velocity.

Approach

1. Lower 500 linear feet of the west levee on the Sacramento River located upstream of Freeport near the Pocket area (see Attachment) to an elevation of 9 feet (NAVD88).
2. Install an operable bypass diversion structure where the levee was lowered. The new diversion structure would include a fish passage facility designed to effectively allow for the passage of adult salmonids and sturgeon.
3. Construct a new levee adjacent to and east of the DWSC floodplain to confine bypass flows between the DWSC and the new levee. The resulting floodplain would be approximately 2000' wide along the distance of the floodplain.
4. Modify landform to prevent stranding of covered fish species.
5. Remove levees between Miner Slough and Prospect Island to provide for tidal connectivity at the south end of the floodplain.

Intended Outcomes as Stated in Conservation Measure

Positive Outcomes:

P1 (intended): Create new spawning habitat for splittail

P2: Create new juvenile rearing habitat for CS, splittail, steelhead, G/W sturgeon (esp. for American River CS and steelhead)

P3: Increase production of food for rearing of CS, splittail, steelhead, (onsite = seasonal floodplain only)

P4: Increase export of DOM, POM and organisms from seasonal floodplain to provide food in Delta for DS, LS, CS, splittail, steelhead, G/W sturgeon

P5: Increase transport of OC and organisms from Prospect/Miner Slough tidal marshes to support Delta foodweb for DS, LS, CS, splittail, steelhead, G/W sturgeon

P6. Increase in upstream migration opportunity for CS and steelhead

P7: Increase delivery of readily suspendable sediments to Prospect Is and improved DS habitats
P8: Increase survival of out migrating juveniles by providing mitigation route with lower predation and entrainment (at North and South Delta diversions) risk.

Negative Outcomes:
N1: Increased MeHg and impact on covered species (on floodplain and downstream)
N2: Increased resuspension/mobilization and export of toxic compounds w/impact on covered species (consider sensitivity to changes in land use - none stated in assumptions)
N3: Increased stranding of covered species (consider grading proposed in the approach)
N4: Reduced flows in Sacramento River and distributaries to support successful outmigration.
N5: Increased habitat for non-native predators/competitors to covered species
N6: Decrease in turbidity downstream of Yolo and reduction in habitat for Delta smelt and longfin smelt

Conceptual Model Information Regarding Intended Outcomes

The basic drivers and outcomes are described in the DRERIP conceptual models.

Assumptions

Provided in BDCP Conservation Measure
Not provided

Added by Evaluation Team
None identified

Problem(s) with Action as Written:

Needs a map

Scale of Action:

Large

Rationale:
Extent of inundated habitat (3800 acres).

Evaluation Summary

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in Appendix A. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes following this section.

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

YES - Yolo Bypass information is useful.

Nature of Change: None provided.

Potential Positive Ecological Outcome(s)

Outcome P1: Create new spawning habitat for splittail

P1a. Splittail

Floodplain model page 25 and splittail model pages 9 and 12 describe how additional floodplain habitat supports splittail spawning.

Magnitude = 4

Certainty = 4

Outcome P2: Create new juvenile rearing habitat for splittail, green/white sturgeon steelhead and Chinook salmon

P2a Splittail

Same information for flooding for Chinook salmon. Table 1 page 3 in Splittail model indicates juveniles use floodplain Feb-May. Cosumnes publications (Crain et al 2004 conf proc.). Moyle et al 2004. SFEWS. Sommer et al. 1997, 2001, 2007. Moyle et. al. 2004. Feyrer 2006, 2007.

Magnitude = 4

Certainty = 4

P2b. Green/white sturgeon

Same information for flooding for CS. No evidence of juvenile use of floodplains. Adult catch in Yolo are adults (Harrell and Sommer 2003). Mechanism described for Chinook salmon is assumed to apply to White sturgeon (Sommer et al 2005 and Floodplain Model).

Mechanism described for green sturgeon is assumed to apply to white sturgeon (Sommer et al 2005 and Floodplain Model).

Magnitude = 1

Certainty = 2

P2c. Steelhead

Same info for flooding for Chinook salmon. They are there at the time (McEwan 2001) (life stage table – Figure 3). Emigrating Jan-August, peak in Jan-May. Based on Sacramento River information. Mossdale trawl data (Rosalie provided – FWS 2007) shows more fish occur. Floodplain (page 27) says no information on steelhead use of floodplain. Steelhead model (Fig 2 of steelhead section in salmonid model, p155) shows floodplain use. Williams (2006), McEwan (2001) and Moyle (2002) support presence.

Page15-16 of salmon model shows estuarine habitat – may show import for lower reach. Steelhead have been caught on floodplain in Yolo. Some reference in Williams 2006 – chapter 9, page 174. Check Cosumnes.

Magnitude = 3

Certainty = 3

P2d. Chinook salmon

1. Chinook salmon juveniles are present in the area during the proposed floodplain inundation period of late winter and spring.

- Knights Landing data indicates:
  Winter Run Juvenile peaks Nov –Feb
  Fall run peaks Jan – Feb then Apr -May
  Late Fall run peaks on Dec and April
  Spring Run peaks are Dec-Jan and March – April (CDFG rotary screw trap)

2. Chinook salmon juveniles would use the floodplain to rear. The restored floodplain would create rearing habitat for fry/parr that enter the Delta in the winter, coincident with inundation of the floodplain. These fry would be able to feed and grow in the floodplain, and their larger size would increase the likelihood of survival in the ocean.

- "Recent work shows that the bypasses do indeed provide habitat for juvenile Chinook, that they grow well there, and that most avoid stranding". (Williams 2006)
- Juvenile salmon collected from the inundated Yolo Bypass were substantially larger and grew more rapidly than juveniles collected from Sac River (Sommer et al. 2001).

Fall-run Chinook fry (<70mm) rear primarily in the upper fresh-water delta…peak fry rearing is (Feb-March) young fry appear to be most abundant in shallow water/shoreline habitat…rearing occurs for two months or more. (Kjelson et al 1982)

1. Floodplains no longer exist along the lower San Joaquin River, but fall-run Chinook salmon would likely use the restored floodplains, as they have been documented to rear in Yolo Bypass floodplain along the lower Sacramento River.

    - CV Chinook salmon may have relied extensively on floodplain in the past as historically much of the central valley was floodplain habitat (Hunter et al 1999)
    - Williams (2006 article 2) confirmed fall Chinook emigration if Feb-Mar on SJ. Floodplain model (Fig 7 and assoc text) identifies that floodplains provide habitat for CS.
    - Sommer et al (2005) reported extensive use of Yolo and Sutter bypasses by fall-run.
    - Moyle et al (2007) reported use of Cosumnes River floodplain

    Limited data on San Joaquin floodplain (none in Floodplain model). No reason to suggest they should behave different from other systems.

    Magnitude = 3-4
    Creates floodplain habitat and migratory route that is not currently available in this area. Would be accessible once every two years to Sacramento and American river salmon.

    Certainty = 3-4
    There is high certainty that juvenile salmon are in the vicinity, and inference juveniles would rear in restored floodplain based on documented rearing in the Yolo Bypass and the restored Cosumnes River floodplain.

Outcome P3: Increase production of food for rearing of Chinook salmon, green/white sturgeon, splittail, steelhead, (onsite = seasonal floodplain only).

P3a. Splittail

Floodplain Model pages 20-25 describe floodplain food production. Floodplain Model pages 25 and 27 describe utilization and higher survival for splittail on floodplains.

Magnitude = 4
Species is floodplain dependent (Moyle et al. 2004; Sommer et al. 2007)

Certainty = 4

P3b. Green/white sturgeon

Floodplain Model pages 20-25 - a high level of food production on floodplain provides support for magnitude score. No evidence of juvenile use of floodplains. Catch in Yolo are adults (Harrell and Sommer 2003). The mechanism describing CS is assumed to apply to white sturgeon (Sommer et al 2005 and Floodplain Model).

Magnitude = 1

Certainty = 2

P3c. Steelhead

Floodplain Model pages 20-25 - a high level of food production on floodplain provides support for magnitude score. Nothing really in the literature that describes steelhead feeding on floodplains, however, it can be assumed that they are utilizing the same food sources as juvenile salmon, given their life-history similarities. Moyle et al. 2004 states that stream-dwelling RT feed mostly on drifting aquatic organism, terrestrial insects, and bottom dwelling organism which are in abundance on floodplains.

Magnitude =3

Certainty = 2-3

P3d. Chinook Salmon

Floodplain Model pages 20-25 - a high level of food production on floodplain provides support for magnitude score. Floodplain Model pages 27 and 29 describe utilization and higher growth rates for Chinook salmon on floodplains. Chinook salmon likely take advantage of small fishes on the FP (Splittail Model page 8 and Moyle et al. 2004).

Magnitude =3-4

Certainty = -3-4

Outcome P4: Increase export of DOM, POM and organisms from seasonal floodplain to provide food in Delta for Delta smelt, longfin smelt, Chinook salmon, splittail, steelhead, green/white sturgeon.

Floodplain Model page 20 describes the importance of export of food to downstream food webs. All other information under P3 applies to CS, SH, G/W Sturgeon and splittail.

P4a. Delta smelt

DLO Relationship and General Observations:
DS Model page 12 describes the importance of zooplankton; recent studies by Sobzak (2002) indicates that organic carbon can support estuarine food webs: DS rear in area immediately downstream of Yolo Bypass (Sommer et al. in prep – see www.dfg.ca.gov – fall midwater and Kodiak trawl data).

Magnitude = 3
Rear just downstream from Yolo

Certainty = 3

P4b. Longfin Smelt

LF Model page 21 describes the importance of zooplankton: recent studies by Sobzak et al. (2002) indicates that organic carbon can support estuarine food webs.

Magnitude =2
Present in flooding period- but mostly far downstream.

Certainty = -2

P4c. Splittail

Floodplain Model page 20 describes the importance of export of food to downstream food webs. All other information under P3 applies to Chinook salmon, steelhead, green/white sturgeon and splittail.

For CS, SH, G/W Sturgeon and splittail, magnitude and certainty are the same as for P3.

Magnitude =4

Certainty = -4

P4d. Green/white sturgeon

Floodplain Model page 20 describes the importance of export of food to downstream food webs. All other information under P3 applies to Chinook salmon, steelhead, green/white sturgeon and splittail.

For Chinook salmon, steelhead, Green/white sturgeon and splittail, magnitude and certainty are the same as for P3.

Magnitude =1

Certainty = -2

P4e. Steelhead

Floodplain Model page 20 describes the importance of export of food to downstream food webs. All other information under P3 applies to Chinook salmon, steelhead, green/white sturgeon and splittail.

For CS, SH, G/W Sturgeon and splittail, magnitude and certainty are the same as for P3.

Magnitude =2

Certainty = -2

P4f. Chinook salmon

Floodplain Model page 20 describes the importance of export of food to downstream food webs. All other information under P3 applies to Chinook salmon, steelhead, green/white sturgeon and splittail.

For CS, SH, G/W Sturgeon and splittail, magnitude and certainty are the same as for P3.

Magnitude =2

Certainty = -2

Outcome P5: Increase frequency and magnitude of transport of OC and organisms from Cache Slough/Bypass tidal marshes to support Delta foodweb for DS, LS, CS, splittail, steelhead, G/W sturgeon

P5a. Delta smelt

Marsh production of phytoplankton is high in Liberty Island (Lehman et al. 2007); Phytoplankton supports the food web Sobzack et al. 2002; Mueller-Solger et al. 2002). Production from lower Yolo bypass inc. Liberty and Cache slough marshes stays relatively intact as it moves down the estuary (Monsen 2003? PhD thesis, Stanford University). Food is an important limiting factor for all of these species (DS model page 5 and 8;

Magnitude = 3
Higher than others because they are planktivorous

Certainty = 2
Unsure whether the increased production will be eaten by clams**.**

P5b. Longfin Smelt

Marsh production of phytoplankton is high in Liberty Island (Lehman et al. 2007); Phytoplankton supports the food web Sobzack et al. 2002; Mueller-Solger et al. 2002). Production from lower Yolo bypass inc. Liberty and Cache slough marshes stays relatively intact as it moves down the estuary (Monsen 2003? PhD thesis, Stanford University). Food is an important limiting factor for all of these species (DS model page 5 and 8.

Magnitude = 3
Higher than others because they are planktivorous

Certainty = 2
Unsure whether the increased production will be eaten by clams

P5c. Splittail

DLO Relationship and General Observations:
Marsh production of phytoplankton is high in Liberty Island (Lehman et al. 2007); Phytoplankton supports the food web Sobzack et al. 2002; Mueller-Solger et al. 2002). Production from lower Yolo bypass inc. Liberty and Cache slough marshes stays relatively intact as it moves down the estuary (Monsen 2003? PhD thesis, Stanford

University). Food is an important limiting factor for all of these species (Delta Smelt model pages 5 and 8.

Magnitude = 2
Higher than others because they are planktivorous

Certainty = 2
Unsure whether the increased production will be eaten by clams

P5d. Green/white Sturgeon

Marsh production of phytoplankton is high in Liberty Island (Lehman et al. 2007); Phytoplankton supports the food web Sobzack et al. 2002; Mueller-Solger et al. 2002). Production from lower Yolo bypass inc. Liberty and Cache slough marshes stays relatively intact as it moves down the estuary (Monsen 2003? PhD thesis, Stanford University). Food is an important limiting factor for all of these species (DS model page 5 and 8.

Magnitude = 1

Certainty = 2
Unsure whether the increased production will be eaten by clams

P5e. Steelhead

Marsh production of phytoplankton is high in Liberty Island (Lehman et al. 2007); Phytoplankton supports the food web Sobzack et al. 2002; Mueller-Solger et al. 2002). Production from lower Yolo bypass inc. Liberty and Cache slough marshes stays relatively intact as it moves down the estuary (Monsen 2003? PhD thesis, Stanford University). Food is an important limiting factor for all of these species (DS model page 5 and 8.

Magnitude = 2

Certainty = 2
Unsure whether the increased production will be eaten by clams.

P5f. Chinook Salmon

Marsh production of phytoplankton is high in Liberty Island (Lehman et al. 2007); Phytoplankton supports the food web Sobzack et al. 2002; Mueller-Solger et al. 2002). Production from lower Yolo bypass inc. Liberty and Cache slough marshes stays relatively intact as it moves down the estuary (Monsen 2003? PhD thesis, Stanford University). Food is an important limiting factor for all of these species (DS model page 5 and 8.

Magnitude = 2

Certainty = 2
Unsure whether the increased production will be eaten by clams.

Outcome P6: Increase in upstream migration opportunity for CS and steelhead

P6a. Steelhead

Magnitude = 2

Certainty = 2

P6b. Chinook Salmon

Adult Chinook salmon have been observed using the Yolo Bypass as an upstream migration corridor (Harrell and Sommer 2003). However, two passage issues currently exist in Yolo Bypass that make it a risky migratory path for adults:

1. Passage barriers and impediments caused by existing structures that limits access to Sacramento River.
2. False attraction into bypass by tributary

A more natural floodplain environment that coincides with winter flood pulses would benefit the native fish, particularly those with winter and spring spawning and rearing periods. The bypass would provide floodplain-dependent species with an important migration corridor. Seasonal inundation is less important for exotic fishes, which generally use the deeper perennial waters of the bypass and spawn in late spring or summer after the floodplain has drained. (Moyle 2002, Harrell and Sommer 2002).

Magnitude = 2
Blocked passage is more of a problem than stranding

Certainty = 2

Outcome P7: Increase delivery of readily suspendable sediments to north Delta and improved Delta smelt habitats.

Sedimentation model (p. 6 and 10) shows that sediment transport is flow dependant; also Floodplain model (p. 10) states that floodplain benefits are proportional to the spatial extent of floodplains. P. Lehman et al, 2008 also found that the concentration of suspended solids were higher in the Yolo Bypass than in the Sacramento River. Sedimentation model p. 9 describes Yolo Bypass as second largest source of sediment for the Delta. It is logical to assume this bypass would have similar sediment functions as shown in the Yolo Bypass.

The Delta smelt model shows that Delta smelt spawn in the Cache Slough region of the northern Delta (p. 11) and that larval Delta smelt have an improved ability see their prey in water with enhanced turbidity (p. 4 and 5). There is an additional hypothesis that Delta smelt use turbidity to conceal themselves from predators (p. 7 Delta smelt model).

Magnitude = 3
Increase in quality and quantity of larval/juvenile Delta smelt habitat based on substantial increase in inundation over current conditions.

Certainty = 2
High understanding but with many variables.

Outcome P8: Increase survival of out migrating juveniles by providing mitigation route with lower predation and entrainment (at North and South Delta diversions) risk.

This drainage into Prospect by the lower Sacramento River avoids possible migratory routes into the central delta. Newman 2008 showed that Survival rates were 66% higher for salmon juvenile released in the lower mainstem of Sacramento river (Ryde YEAR) then for those released in central delta (Georgiana slough). Will provide additional migratory paths for emigrating Chinook juveniles above the location of proposed peripheral canal, this would mitigate entrainment exposure at this new facility. Vogel 2008 conducted an acoustical tag study in 2006 and 2007 which showed there were reach specific characteristics for loss rates on juvenile salmon released in Sacramento River near Old Town. Preliminary results showed that loss in DCC and Georgiana Slough was at least 2 times greater than on main stem or Sutter and Steamboat Slough. Will provide additional migratory route for American River salmonids that cannot access Yolo Bypass geographically.

Magnitude = 3-4

Certainty = 3
This drainage into Prospect by the lower Sacramento River avoids possible migratory routes into the central delta and proposed intake facility of proposed canal at Hood.

Potential Negative Ecological Outcome(s)

Outcome N1: Increased MeHg and impact on covered species (on floodplain and downstream).

The text and scores provided here are applicable to all covered fish species. Conceptual models: Mercury. An initial spike in MeHg would be expected when the newly created floodplain habitat is inundated for the first time (Hg model, page 15, 18). Although concentrations may attenuate from the initial spike over time, MeHg production would likely remain relatively high compared to other types of habitats. Habitats with the highest levels of MeHg production, concentration, and exposure to biota are those with periodic flooding events separated by sufficient time to allow complete drying, such as the seasonal floodplains that would be created in this project (Hg model, page 15). Covered fish species using the restored habitat would be exposed to MeHg through their food chain, and MeHg would be exported downstream along with organic matter and organisms.

The linkage of seasonal flooding to MeHg production and subsequent bioaccumulation of MeHg in fish and their prey is well documented. Effects of this bioaccumulation on covered fish species are more uncertain, due to lack of studies of toxicological effects of MeHg on covered species, uncertainty about sensitivity of covered species relative to species that have been studied, and the subtle nature of the behavioral effects (e.g., impaired predator avoidance and feeding efficiency) that are among the most sensitive endpoints for MeHg toxicity and are difficult to detect.

Magnitude = 2

Certainty = 3

Outcome N2: Increased resuspension/mobilization and export of toxic compounds w/impact on covered species (consider sensitivity to changes in land use - none stated in assumptions).

The text and scores provided here are applicable to all covered fish species. Drivers and outcomes are generally described in the following DRERIP Conceptual Models: Chemical Stressors, Pyrethroids, and Splittail.

The habitat is being enhanced to facilitate spawning by splittail and rearing by splittail and other species. Current land uses on and adjacent to the project area are agricultural, including orchards and other crops that receive pesticide applications. Pyrethroids, a class of pesticides used as dormant sprays on orchards, can be toxic to fish, especially to early life stages (Pyrethroids model, page 16). Pyrethroid concentrations would be expected to peak during the winter/spring storm season and after peak agricultural application in the summer and fall (Pyrethroids model, page 2). Late-winter and spring are also the times splittail would use the enhanced floodplain habitat to spawn (Splittail model, page 1). Effects of pesticides, if any, would be greatest in the early years of the project and would attenuate over time if the restored habitat is no longer used for farming.

There are critical data gaps on pyrethroids and other pesticides that make it difficult to evaluate risk to covered fish (Pyrethroids model, page 32; Chemical stressors model, page 25). In general, little is known about the toxic effects of contaminants known to be present in the Delta on resident Delta species, and even less is known about the sublethal effects of contaminants (Chemical stressors model, page 25). Clarification is needed on whether the restored floodplain areas would be farmed when they are not inundated, as the amount and type of ongoing farming and pesticide use would affect the magnitude and duration of potential effects of pesticides on covered fish.

External reference: Smalling, K.L., J. Orlando, and K. Kuivila. 2007. Occurrence of pesticides in water, sediment, and soil from the Yolo Bypass, California. San Francisco Estuary and Watershed Science. Vol. 5, Issue 1 (February 2007, Article 2) http://repositories.cdlib.org/jmie/sfews/vol5/iss1/art2

Magnitude = 2
A wide variety of crops are grown in the Yolo Bypass and surrounding areas, and many different pesticides are used on these crops (Smalling et al. 2007). Pesticides were detected in water samples collected in the inflows to the Yolo Bypass and within the Bypass in 2004 (Smalling et al. 2007). Pesticides detected in water samples included herbicides, especially hexazinone and simazine, and insecticides, especially diazinon (Smalling et al. 2007). The concentrations of dissolved pesticides were below levels known to cause acute or chronic toxicity to fish; however, some of the herbicide concentrations (e.g., hexazinone) were high enough to potentially adversely affect primary productivity (Smalling et al. 2007).

Sediments and soils from the Bypass and its inflows contained other pesticides, such as pyrethroids and DDTs (Smalling et al. 2007). The concentrations of pesticides associated with sediments were below levels known to cause acute toxicity to fish; however, the concentration of at least one pyrethroid (lambda-cyhalothrin) in suspended sediment was high enough to adversely affect benthic macroinvertebrates that fish rely on for food (Smalling et al. 2007).

This project involves habitat enhancement to facilitate spawning by splittail and rearing by splittail and other species. The highest concentrations of dissolved pesticides enter the Bypass as a pulse during the first high-flow event following winter pesticide application (Smalling et al. 2007). Late-winter and spring are also the times splittail would use the enhanced floodplain habitat to spawn (Splittail model, page 1).

Certainty = 2
There are critical data gaps on pyrethroids and other pesticides that make it difficult to evaluate risk to covered fish (Pyrethroids model, page 32; Chemical stressors model, page 25). In general, little is known about the toxic effects of contaminants known to be present in the Delta on resident Delta species, and even less is known about the sublethal effects of contaminants (Chemical stressors model, page 25). The potential effects of complex mixtures of low level pesticides, such as those detected in the Yolo Bypass by Smalling et al. (2007) are also poorly understood.

Outcome N3: Increased stranding of covered species (consider grading proposed in the approach)

N3a1: Splittail adults

Connectivity problems can strand splittail (FP model page 27).

Magnitude = 1

Certainty = 4

N3a2: Splittail juveniles

Connectivity problems can strand splittail (Floodplains Model page 27).

Magnitude = 2
Stranding is minimal now.

Certainty = 4

N3b. Green/white Sturgeon adult/juvenile

Adult passage of white sturgeon, green sturgeon, splittail and salmon is likely constrained in the Yolo Bypass (Harrell and Sommer 2003); Current Fremont and Sacramento weirs create stranding problems for white sturgeon, green sturgeon, splittail and salmon (Sommer et al. 2005); hence efforts to improve passage and redesign weirs will reduce poaching and stranding.

Poaching may be a major issue for white sturgeon (white sturgeon model page 20. hence efforts to improve passage and redesign weirs will reduce poaching and stranding.

Magnitude = 1

Certainty = 4

N3c. Steelhead

Adult passage of white sturgeon, green sturgeon, splittail and salmon is likely constrained in the Yolo Bypass (Harrell and Sommer 2003); Current Fremont and Sacramento weirs create stranding problems for white sturgeon, green sturgeon, splittail and salmon (Sommer et al. 2005); hence efforts to improve passage and redesign weirs will reduce poaching and stranding. Efforts to improve passage and redesign weirs will reduce poaching and stranding.

Magnitude = 1 (adults) 2 (juveniles)
Stranding is minimal now.

Certainty = 4

N3d. Chinook Salmon

Most juvenile CS can exit the existing FP configuration (Sommer et al. 2005). Adult passage of white sturgeon, green sturgeon, splittail and salmon is likely constrained in the Yolo Bypass (Harrell and Sommer 2003); Current Fremont and Sacramento weirs create stranding problems for adult white sturgeon, green sturgeon, splittail and salmon (Sommer et al. 2005); hence efforts to improve passage and redesign weirs will reduce poaching and stranding.

Magnitude = 1 (adults) 2 (juveniles)
Stranding is minimal now.

Certainty = 4

Outcome N4: Reduced flows in Sacramento River and distributaries to support successful outmigration.

The text and scores provided here are applicable to all covered fish species. Juvenile salmon survival is dependent on sufficient water flow and quality. Diversions for habitat restoration can have the same impact that diversions for other purposes do. Restoration efforts have to keep a proper balance on water diversions so as to enable the best possible outcome for the system as a whole.

As much as 60 percent of the natural historical inflow to Central Valley watersheds and the Delta have been diverted. Depleted flows have contributed to higher temperatures, lower DO levels, and decreased recruitment of gravel and large woody debris (LWD). More uniform flows year round have resulted in diminished natural channel formation, altered food web processes, and slower regeneration of riparian vegetation (NMFS 2008)

Water withdrawals have reduced river flows and increased temperatures during the critical summer months, and in some cases, have been of a sufficient magnitude to result in reverse flows in the lower San Joaquin River (Reynolds *et al*. 1993). Direct relationships exist between water temperature, water flow, and juvenile salmonid survival (Brands and McLain 2001).

Elevated water temperatures in the Sacramento River have limited the survival of young salmon in those waters. Juvenile fall-run Chinook salmon survival in the Sacramento River is also directly related to June stream flow and June and July Delta outflow (Dustman *et al*. 1987).

Magnitude = 2

Preliminary information indicates a low magnitude. However, this needs more analysis before a more definitive determination can be made. The water diverted is presumably going to remain in the system to support another migratory route.

Certainty = 3

Outcome N5: Increased habitat for non-native predators/competitors to covered species.

The floodplain model does not address non native predation or competition on the floodplain.

N5a. Delta smelt

Evidence from Yolo and Cosumnes about non-natives taking advantage of floodplain (ref Sommer et al 2004, Moyle et al 2006). Floodplain Model: Page 10 talks about sources of invasive species. Foodweb Model is focused on estuarine systems.

Delta smelt model (semi final with note – do not cite) - adapted to sustain high mortality during the adult stage (Winemiller and Rose 1992). Predation is one of two primary factors for population dynamics (Figure 7). The most likely ancestral Delta smelt predators would have been piscivorous birds, salmonid fishes, and, secondarily, longfin smelt as a larval predator and predatory freshwater fishes like Sacramento pikeminnow, Sacramento perch, and striped bass (Moyle 2002). All of the above listed species could be expected to inhabit the proposed inundated floodplain habitat. Though predation on the floodplain is not specifically address in the model the evaluation team thought predation of DS on the lower portion of the bypass was significant.

Magnitude = 1

Certainty = 3

N5b. Longfin smelt

Longfin model - Predation is a source of direct mortality to eggs and larvae. Some fish species (e.g. suckers, splittail, and sturgeon) may feed on LFS eggs. Larval LFS are not strong swimmers (Wang 1986) and are thus highly vulnerable to predation. Striped bass and inland silverside are probably major predators on LFS larvae. Terns, gulls, and cormorants may also prey on this life stage. Predation and competition are characterized as medium importance and medium understanding (Figure 5.) but floodplain predation and competition are not specifically addressed.

Magnitude = 1

Certainty = 3

N5c. Splittail

Splittail model - Bird predation appears limited until water recedes and floodplains begin to isolate from main channels at which point fish are exposed to wading birds (Moyle 2004). Predation by non native predators is characterized as medium with high understanding (Figure 5 and Table 3).

Magnitude = 1

Certainty = 3

N5d. Green and white sturgeon

White sturgeon model indicate probable distribution in this reach (Figure 7), green sturgeon model indicates probable distribution in this reach (Figure 2). Due to the benthic nature of green and white sturgeon and the timing of floodplain inundation they are not expected to be found on the floodplain (personal communication with Josh Israel 2009).

Magnitude = 1

Certainty = 2

N5e. Steelhead and Chinook salmon

The Chinook salmon and steelhead model indicates Non-native predation and competition with invasive species and hatchery produced salmonids is of medium importance in rearing and emigration estuarine habitats, including floodplain (Figure 2a).

Magnitude = 1

Certainty = 3

Outcome N6: Decrease in turbidity downstream of Yolo and reduction in habitat for Delta smelt and longfin smelt.

N6a. Delta and longfin smelt

Sedimentation model (p. 7 and 16) portray floodplains as sediment sinks. Floodplain model (p. 18) states: “Sediment deposition therefore is common at locations where flow velocities decline such as just interior of flooding locations, where internal topography and vegetation reduce velocities, and when spilling onto the floodplain from internal sloughs and channels.” The above statement would seem to be applicable to the Yolo Bypass downstream of the Fremont Weir where heavy bed sediments (sands) may accumulate.

The Delta smelt model shows that Delta smelt spawn in the Cache Slough region of the northern Delta (page 11). Larval Delta smelt have an improved ability see their prey in water with enhanced turbidity (p. 4 and 5) and use turbidity to conceal themselves from predators (page 7).

Longfin smelt model (page 8) shows that increased turbidity helps LS avoid predators but model further states (page 5) that LS are rarely detected above Rio Vista.

Magnitude = 1
Negative outcome could affect a portion of delta smelt habitat if this bypass acts as a 'sink' for suspended sediments in addition to bed sediments.

Certainty = 3
No documentation that Yolo Bypass floodplain is depositional.

Important Gaps in Information and/or Understanding

Research Needs

- Major gaps – rearing habitat for steelhead? Rearing habitat for juvenile sturgeon?
- Hg accumulation in fish has been documented, but does not indicate there is an effect on fish.
- Degree of contaminants affects on POD.
- Degree of sediment settling on floodplains.
- Degree of predation/competition within floodplains on native covered fish species by non-native fish species.
- Better diet information is needed for floodplain use of SH, G/W Sturgeon;
- More information is needed about relative importance of food to population level effects for all of the species.
- Transport studies are needed to evaluate the footprint of food transport from floodplains.
- Timing duration of rearing for SH, green and white sturgeon.
- Additional information is needed to help quantify the contribution of suspended sediment that Yolo Bypass provides to the north Delta region. Understanding the duration of the suspended sediment benefit would be helpful. Is the increased sediment load only part of a first flush? Can the flows and inundation areas described in scenario 1 and 2 result in the anticipated turbidity benefit?

Reversibility

Yes/Easy

Opportunity for Learning

High

Comments (refer to specific sources of information that support the above determination and identify high priority research questions and testable hypotheses).

References Cited

Appendix A

WOCM 8:
Interim Tidal Gates (2-Gates)

Scientific Evaluation Worksheet

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Action

Construct and operate two tidal gates:

1. one installed in Old River on the eastern side of Bacon Island,
2. the second gate would be installed in Connection Slough on the western side of Bacon Island.

Evaluation Team

Water Operations Workgroup – Smelt Team **-** Matt Nobriga, Bruce Herbold, Wim Kimmerer, Steve Detwiler, David Fullerton, John Burke, Kateri Harrison (note-taker), and John Cain (Chair)

Date of Last Revision: May 12, 2009

Action Description and Clarifying Assumptions

Construct and operate two tidal gates – one gate would be installed in Old River on the eastern side of Bacon Island, and the second gate would be installed in Connection Slough on the western side of Bacon Island.

The evaluation team was asked to consider two baseline conditions (D-1640 and OCAP smelt Biological Opinion) and two operational scenarios as follows:

Scenario #1

- Early in the season (December-February) gates would be tidally operated (closed on flood, open on ebb) for 14 days in response to an initial storm event to minimize the movement of preferred smelt habitat (turbidity and salinity) in the south Delta entrainment zone. The gates would be operated December to January to reduce adult delta smelt entrainment risk.

Scenario #2

- Later in the season (March to June), the gates would be closed on flood tides and opened on ebb tides each day to eliminate or reduce movement of larval-juvenile delta smelt towards the pumps (to reduce entrainment) while continuing to allow passage of emigrating salmonids.

The evaluation team considered both operational scenarios together as they are not mutually exclusive. Potential outcomes were only evaluated for delta and longfin smelt.

Approach

Gates would be designed to be easily removed or re-operated, in the event that monitoring results indicate that they are not accomplishing their intended purpose.

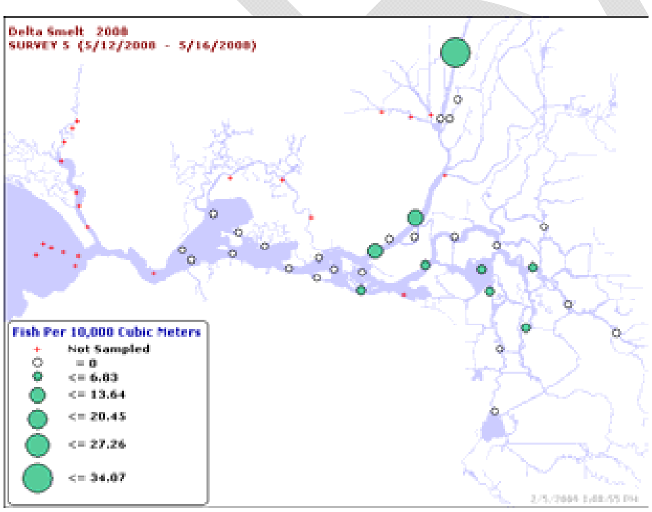
Intended Outcomes as Stated in Conservation Measure

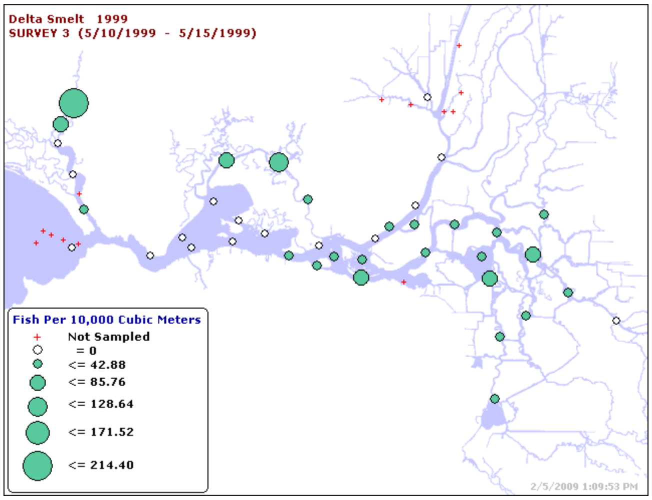
- Reduce entrainment-induced mortality of adult delta smelt from the western Delta.
- Reduce entrainment-induced mortality of adult longfin smelt from the western Delta
- Reduce entrainment-induced mortality of larval delta smelt from the western Delta.
- Reduce entrainment-induced mortality of larval longfin smelt from the western Delta.

General Conceptual Model Support for Intended Outcomes

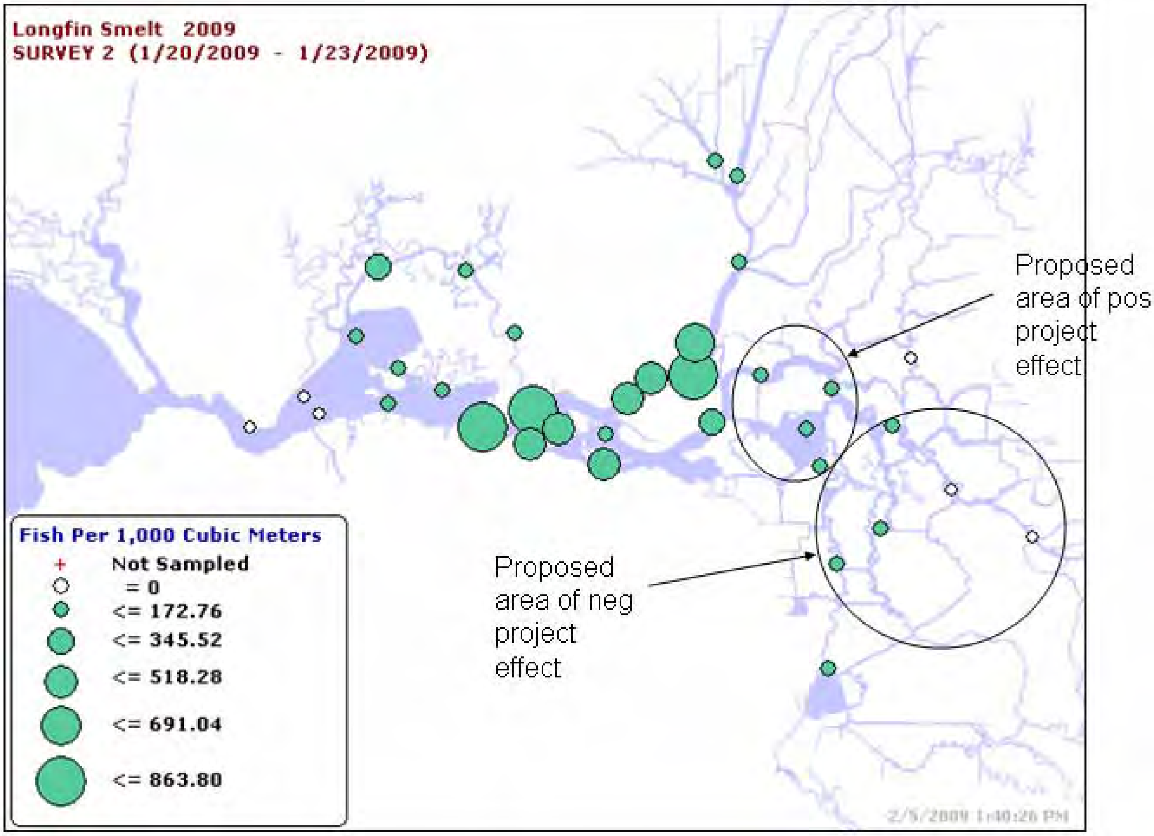
The DRERIP delta smelt and longfin smelt models suggest the cause-effect relationship might apply to the adult migration action because adult smelt would start their migrations from west of the project area. As written, the action is unclear about whether the 14-day operation would potentially occur more than once in a season. This might be necessary to fully ensure a benefit to both species – particularly if the action is used simultaneously to increase exports during winter precipitation events. This is also relevant to larval longfin smelt (see below) because of their earlier spawn timing.

The DRERIP delta smelt model does not provide strong support for the larval cause-effect (e.g., the section on habitat connectivity on pg 14 of the pdf). Further, 20mm data for low outflow springs clearly show delta smelt larvae regularly occur in parts of the central and south Delta where this project would increase their entrainment risk (see attached examples). Any firm decisions about net gains or losses to the population would require quantitative rather than conceptual (qualitative) modeling of larval entrainment risk (a la Kimmerer 2008). Note the OCAP BO intended for OMR restrictions to increase spawning opportunities in the San Joaquin River, not lessen opportunities which this project proposes to do. Therefore, this project proposes to attempt to keep delta smelt out of a portion of the Delta that they have used historically and in the recent past.





The DRERIP longfin smelt model provides qualitative support for the larval cause-effect (e.g., the section of diversions, pgs 12-13 of the pdf), but the timing of the action isn't optimal for longfin larvae (see attached Figure for January 2009 from the smelt larvae survey). Because longfin larvae are already in the water by January, 14 days of operation may make no difference to them given the protracted spawning season described in the DRERIP model. Note also, these surveys provide distribution snapshots. There is no way to determine whether the longfin larvae observed in the central and south Delta were a small fraction that were spawned there, in which case two gates would not improve their fate or a snapshot of the flux rate of the main part of the population into the central and south Delta from the lower Sacramento and confluence regions, which the Interim Tide Gate measure might reduce.



The above is based upon the information contained within the DRERIP: delta smelt and longfin smelt conceptual models. In addition, data and modeling information were obtained from DFG survey data (www.delta.dfg.ca.gov) and CALSIM/DSM2.

Assumptions

Provided in BDCP Conservation Measure

- D1641 is the baseline

Provided by Metropolitan Water District

- OCAP Biological Opinion is the Baseline.

Comments on Action as Written:

1. It is unclear if the early December tidal operations would be done more than once per season if needed.

2. From March to June, DFG would track the distribution of smelt via 20 mm surveys and gate operators would try to keep the fish westward from region of control. Gate closing in conjunction with OMR flow is expected to keep the smelt out of the region. Difficulties arise because the sampling surveys are less reliable at low fish density, and the survey

was not designed for this purpose. It has a two-week sampling interval, but gate ops are proposed daily.

3. In dry years when the gates are needed most to protect water supply, delta smelt also occur in the region where the gates do not provide any hydrodynamic protection. When gates are closed the fish would be stuck between the gates and the pumps, so this increases the risk of entrainment. Operating the gates tidally creates a bit more circulation through the central Delta. Gates would be closed on the flood tide and open on the ebb, tidally pumping water out of Old River. This is balanced by an increased flow towards the pumps from Middle River. Any fish that starts its journey east of Old River has a higher risk of entrainment. Old River carries more flow compared to Middle River (i.e. the flow balance for Old to Middle Rivers may be 60:40).

4. Although a net positive effect on delta smelt is assumed by the project proponents, during the March to June timeframe, there is a trade-off in conditions for smelt vs. salmonids, particularly SJR salmonids.

5. PTM model shows tidally pumping out Old River. If a smelt were located to the north- or southeast of the “control region”, they would see increased entrainment. The fish can get up through the San Joaquin River.

6. Effects on Sacramento salmonids via the Molkulmne River are dependent on what channel the fish enter the SJ River from. Fish come to the pumps from Georgiana Slough. More Sacramento fish could potentially travel to the export pumps.

7. Flows in the model are distributed so that 60% goes to Old River and 40% go to Middle river. If gate operations change such that flow is now directed 100% down Middle River, then a particle located between Old and Middle River or the San Joaquin mainstem east of Old River confluence near Franks Tract would NOT see any benefit.

8. Positive Qwest would likely be maintained. However, assuming an OCAP BO baseline, any incremental benefit of these gates seems more like a tradeoff. The gates prevent entrainment in one direction, but all fish in the other direction will have a higher risk of entrainment. The gates allow exports at the higher end of their approved range (based on new OCAP criteria of -5000 to -1250 cfs). OCAP is designed to achieve a “zero” level of entrainment of adult delta smelt and very low entrainment of larval-juvenile delta smelt. Thus, the benefit of this action at this baseline would be minimal for fisheries. This proposal is an alternative way of implementing OCAP that would deliver more water south of Delta. It is an interim action (near-term) that would be operated before alternative conveyance is complete.

Scale of Action:

Small - Medium

Rationale:

Limited area of proposed project influence; relevance varies with outflow; limited applicability to longfin smelt (as written).

Evaluation Summary Tables

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Relation to Existing Conditions

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

NO. It would not affect boundary conditions. It would affect hydrodynamics in the south and eastern Delta, but not to the point that our current understanding of the system wouldn't hold.

Potential Positive Ecological Outcome(s)

Outcome P1: Reduce entrainment induced mortality of covered fish species from the western Delta.

P1a - X. Delta Smelt – adult (*OCAP BO Baseline*)

General Observations:
Particle-tracking modeling in support of the proposed project purportedly indicates it would limit adult delta smelt's encroachment into the south Delta.

Magnitude = 2 - Low
The OCAP BO has actions intended to greatly limit adult delta smelt entrainment. Thus, the ability of this project to affect greater benefits seems very limited.

Certainty = 3 - Medium
The OCAP actions were developed in response to increased scientific understanding of adult delta smelt entrainment (Kimmerer 2008; Grimaldo et al. in press) that is also reviewed in the delta smelt DRERIP model. The factors that lead to entrainment events are weather-dependent, so they are subject to "variable ecosystem processes" that increase their uncertainty.

P1a - Y. Delta Smelt – adult (D-1641 baseline)

General Observations:
Particle-tracking modeling in support of the proposed project purportedly indicates it would limit adult delta smelt's encroachment into the south Delta.

Magnitude = 3 -4 Medium - High
delta smelt adult entrainment was a median 15% during the D-1641 era (Kimmerer 2008); overall a "sustained minor population effect" though if gates were operated as planned, they could have had a high magnitude effect in a couple of years

Certainty = 2- 3 Low - Medium
Dynamics of adult delta smelt entrainment are conceptually well-understood (Kimmerer 2008; Grimaldo et al. in press) as reviewed in the DRERIP delta smelt model (pg 24 of the pdf)

P1b – X. Delta Smelt - Larval (OCAP BO Baseline)

General Observations
The MWD presentation in support of the project shows a spatial trade-off; possibility for a net positive outcome in some years, no net effect in others, possible net negative effect in others.

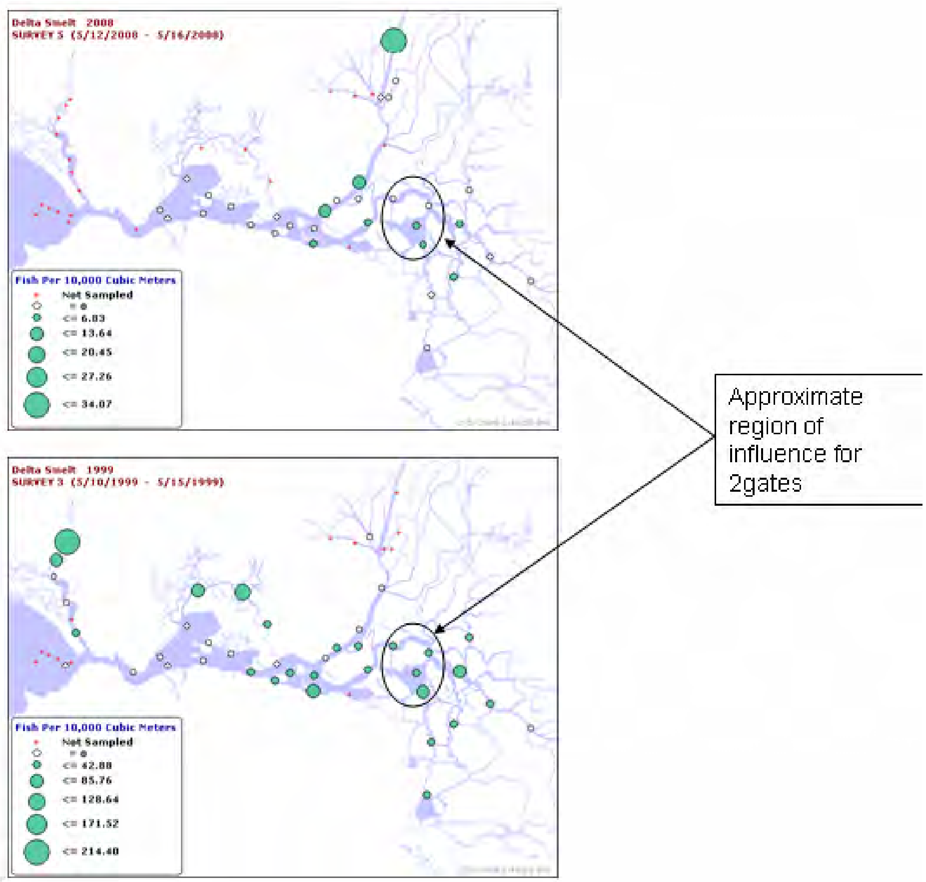
Magnitude = 2 - Low

The OCAP actions were designed to minimize larval-juvenile entrainment; any benefit from this action is therefore minor relative to an OCAP baseline

Certainty = 1 - Minimal

It is not known if OCAP actions will change spawner distributions to more frequently include SJ River, but they are intended to. The 2 gates presentation suggested operations of this project might bisect the fraction of delta smelt larvae rearing in the central Delta in some years – improving survival of some, but decreasing survival of others (see attached figures). The DRERIP delta smelt model does not provide a quantitative breakdown of where larvae have been found. A quantitative assessment of hatch distributions across water year types is needed to fairly evaluate this project.

Assumptions used in Scoring:



P1b – Y: Delta Smelt - Larval *(D-1641 Baseline)*

General Observations

The MWD presentation in support of the project shows a spatial trade-off; possibility for a net positive outcome in some years, no net effect in others, possible net negative effect in others.

Magnitude = 2 - 3 Low - Medium

OMR was often more negative in the D-1641 era than it likely would be under OCAP, so there might be more opportunity for the proposed project to prevent delta smelt entrainment relative to the D-1641 baseline

Certainty = 2 - Low

Uncertainty is high for the utility of this action. The 2 gates presentation suggested operations of this project might bisect the fraction of delta smelt larvae rearing in the central Delta in some years – improving survival of some, but decreasing survival of others (see attached figures). The DRERIP delta smelt model does not provide a quantitative breakdown of where larvae have been found. A quantitative assessment of hatch distributions across water year types is needed to fairly evaluate this project. The utility of the action also depends on outflow: (delta smelt DRERIP model pg 24 of the pdf, which adds weather-related uncertainty.

P1c - X. Longfin Smelt – Adult (*OCAP BO Baseline*)

General Observations:

Particle-tracking modeling in support of the proposed project purportedly indicates it would limit adult delta smelt's encroachment into the south Delta.

Magnitude = 1 - Minimal

The analysis by Kimmerer (shown in Appendix X) for the operation evaluations shows adult longfin entrainment effects are usually less than delta smelt, but the underlying mechanism of adult longfin entrainment is similar to delta smelt (Grimaldo et al. in press).

Certainty = 3 - Medium

There is less certainty about what drives adult longfin smelt entrainment, but it might be similar to delta smelt (Grimaldo et al. in press). Higher certainty that the magnitude of the effect is low because few adult longfin are entrained.

P1c Y. Longfin Smelt – Adult (D-1641 baseline)

General Observations:

Particle-tracking modeling in support of the proposed project purportedly indicates it would limit adult delta smelt's encroachment into the south Delta

Magnitude = 2-3 Low - Medium

longfin smelt entrainment relative to population is usually lower than delta smelt (WK analysis for this evaluation)

Certainty = 2 - Low
There is less certainty about what drives adult longfin smelt entrainment. Higher certainty that the magnitude of the effect is low because few adult longfin are entrained.

P1d - X. Longfin Smelt – Larval (*OCAP BO Baseline*)

General Observations:
The MWD presentation in support of the project shows a spatial trade-off; possibility for a net positive outcome in some years, no net effect in others, possibly net negative effect in others.

Magnitude = 1 – 3 Minimal - Medium
The OCAP Biological Opinion does not provide “full-time” regulation of OMR during peak longfin smelt hatching periods in Jan-Feb. The 2Gates project description (aka write-up) is unclear whether it would either, but it might if the gates were operated consistently Jan-Mar. The 14-d operation that is proposed would be a low magnitude effect. Greater frequency of operation might increase the magnitude of the effect, particularly since larval longfin smelt tend to be located seaward of most delta smelt larvae (Dege and Brown 2004).

The comparatively seaward distribution of longfin smelt might mean the gates could keep distributions out of the south Delta better than for delta smelt larvae.

Certainty = 2 - Low
The spawning distributions of longfin smelt are not well understood; the longfin smelt DRERIP model suggests they might be in or near the LSZ, rather than predominantly in fresh water like delta smelt; larval distributions also depend on X2, so the effect of the project will vary with flow.

P1d - Y. Longfin Smelt – Larval (D-1641 *Baseline*)

General Observations:
The MWD presentation in support of the project shows a spatial trade-off; possibility for a net positive outcome in some years, no net effect in others, possibly net negative effect in others.

Magnitude = 1 – 3 Minimal - Medium
The OCAP does not provide “full-time” regulation of OMR during peak longfin smelt hatching periods in Jan-Feb. The 2Gates project description (write-up) is unclear whether it would either, but it might if the gates were operated consistently Jan-Mar. The 14-d operation that is proposed would be a low magnitude effect. Greater frequency of operation might increase the magnitude of the effect – particularly since larval longfin smelt tend to occur seaward of most delta smelt larvae (Dege and Brown 2004).

The comparatively seaward distribution of longfin smelt might mean the gates could keep distributions out of the south Delta better than for delta smelt larvae.

Certainty = 2 - Low

The spawning distributions of longfin smelt are not well understood; the longfin smelt DRERIP model suggests they might be in or near the LSZ, rather than predominantly in fresh water like delta smelt; larval distributions also depend on X2, so the effect of the project will vary with flow.

Potential Negative Ecological Outcome(s)

Outcome N1: When closed, the gates may block the movement (increase risk of entrainment) of other important fish, including out migrating San Joaquin and Sacramento salmonids and sturgeon.

Outcome identified, but not evaluated.

Outcome N2: When closed, the gates could increase entrainment and mortality of delta smelt in the central and southern Delta.

N2a. Delta Smelt:

General Observations:
20 mm data suggest this will happen in some years (see attached figures).

Magnitude = 2 - Low
These gates will likely bisect larval delta smelt distribution to some degree trapping some fraction of the smelt in the central and south Delta (see attached figures). However, this has historically been a small fraction of the population most of the time. Note this rationale applies to larval longfin smelt too.

Certainty = 2 - Low
There are two kinds of uncertainty regarding this effect. It is uncertain how OCAP OMR flows may influence delta smelt spawning in the SJ River. Additionally, the magnitude of effect depends on the weather and project operations which affect X2.

N2b. Longfin Smelt:

General Observations:
20 mm data suggest this will happen in some years (see attached figures).

Magnitude = 2 - Low
These gates will likely bisect larval longfin smelt distribution to some degree trapping some fraction of the smelt in the central and south Delta (see attached figures). However, this has historically been a small fraction of the population most of the time

Certainty = = 2 - Low
There are two kinds of uncertainty regarding this effect. It is uncertain how OCAP OMR flows may influence longfin smelt spawning in the SJ River. Additionally, the magnitude of effect depends on the weather and project operations which affect X2.

Outcome N3: The gate structure may be conducive to higher predator presence and therefore the risk of predation on covered fish species may increase.

N3a. Delta Smelt

General Observations:
More delta smelt might migrate to the structure than longfin smelt, so there might be some increased loss to predators. However, the DRERIP model notes that delta smelt do not associate strongly with structures in the water (pg 7 of the pdf), so exposure time would likely be limited.

Magnitude = 2 - Low
Kimmerer (2008) estimated adult delta smelt entrainment had a median value of 15% in the past decade. Thus, that fraction of the population might conceivably pass the gate structure and be exposed to hovering predators.

Certainty = 2 - Low
It is known that predators will aggregate around this structure like they do other structures in the Delta. The exposure times and prey fields that the smelts would have, and be part of near the structure are completely unknown.

N3c. Longfin Smelt

General Observations:
The DRERIP longfin model says few longfin smelt migrate past Twitchell Island. That is consistent with the WK analysis for longfin from this eval and suggests this outcome is probably too minor to bother with a full evaluation (for longfin smelt; salmonid folks may conclude differently).
Magnitude = 1 -Minimal
The preliminary analyses for longfin smelt done by Kimmerer for this evaluation (shown in Appendix ___) suggest the effect on longfin smelt would be much lower (as compared to delta smelt above).

Certainty = 2 - Low
It is known that predators will aggregate around this structure like they do other structures in the Delta. The exposure times and prey fields that the smelts would have, and be part of near the structure are completely unknown.

Important Gaps in Information and/or Understanding

Data Needs

1. Smelt spawning micro habitats, (southward flux versus spawn location issue described above for both smelts).
2. Exposure times and prey fields near the gate structures
3. Effects of OCAP Biological Opinion OMR restrictions on smelt spawner distributions
4. Quantitative data to determine particle fates from various locations

Research Needs

Not discussed

Assess Reversibility and Opportunity for Learning

Reversibility

Not discussed

Opportunity for Learning

Not discussed

References Cited

DRERIP Conceptual Models: delta smelt and longfin smelt models.

In addition data and modeling information was obtained from: DFG survey data (www.delta.dfg.ca.gov) and CALSIM/DSM2.

Dege, M, Brown, LR. 2004. Effect of outflow on spring and summertime distribution and abundance of larval and juvenile fishes in the upper San Francisco Estuary. American Fisheries Society Symposium 39:49-66.

Kimmerer, Wim. 2009. Analytical results for BDCP ops study. (Shown in Appendix X)

Grimaldo et al. in press.

Appendix X
Analytical results for BDCP ops study

Wim Kimmerer
January 23, 2009

The results presented here are to support the analysis of BDCP actions involving operations, specifically focused on changing flows in Old and Middle Rivers. These analyses have not been peer reviewed.

Summary

Question 1: Is the impact of export losses likely to be substantial for longfin smelt? The analysis I did suggests not: the ratio of salvage to abundance for longfin smelt is much smaller than that for delta smelt in most years. In dry years it is comparable or even higher.

Question 2: Can we estimate the impact of export losses on longfin as for delta smelt? I did a curtailed version of the analyses in Kimmerer (2008) for longfin smelt, essentially trying to calculated daily losses based on abundance in the south Delta, abundance overall, and Old and Middle River flows. The mean annual loss, compounded over 60 days, was 0.3% of the population. longfin smelt apparently move out of the Delta rather soon after hatching, though, so the 60-day figure may be too long. In contrast, delta smelt remain in freshwater until ~July, resulting in longer exposure to export losses.

Question 3: Can we estimate the impact of export losses on splittail? No.

Question 4. How is salvage of adult delta smelt likely to change with changing Old and Middle River flows? This is still in progress. I have a model to relate salvage to OMR flow, but there are a couple of problems with it. I will work on this some more. I also need the flow scenarios.

Question 1: Is the impact of export losses likely to be substantial for longfin smelt?
Approach: Generally, I compared the ratio of salvage to population size between delta and longfin smelt. Salvage is a poor proxy for export mortality, but probably scales the number of fish that are entrained in the southward-flowing water and thereby toward the pumps. A similar analysis to that of Kimmerer (2008) for delta smelt does not appear feasible, since that analysis relied on the 20mm survey which begins each year well after the spawning peak of longfin smelt.

I calculated total monthly salvage from 1980 through 1995 for each species. I then calculated the total by natal year: for delta smelt all salvage before May was assumed to be from the previous year's cohort, and for longfin smelt I assumed salvage before February was from the previous year (I ignored age of the fish so some 2-year-olds may have been in there). Note that salvage of both species is highest in spring. I took mean catch per trawl from the fall midwater trawl survey and calculated (approximate) population size assuming a volume sampled of 7000 m^3 and a habitat volume of 1.5×10^9 m^3 (these numbers don't really matter for the final result). I then took ratios of total annual salvage to total population size for each year and species. I combined that with estimated export mortality of juvenile delta smelt at the south Delta export facilities from Kimmerer (2008; SFEWS).

Results: Pumping mortality was ~ 1/3 of the salvage:abundance ratio of delta smelt but the two were uncorrelated. The ratio for longfin smelt was always lower than that for delta smelt except during 1989-1991 (Figure 1), which was a drought period when longfin smelt abundance was low. The salvage:abundance ratio for longfin was about 4% of that for delta smelt (median). The salvage:abundance ratio for delta smelt was not a good proxy for the estimate of export mortality; the two were uncorrelated, and the export mortality on average was about 1/3 of the salvage:abundance ratio.

Conclusion: These results show that the magnitude of the export losses to longfin smelt depend on the flow regime. Generally proportional salvage is much lower than that for delta smelt, and usually very near zero. However, during extended periods of low flow, the combination of low abundance and moderate export losses results in rather high ratio of salvage to abundance, so presumably mortality during those periods can be high.

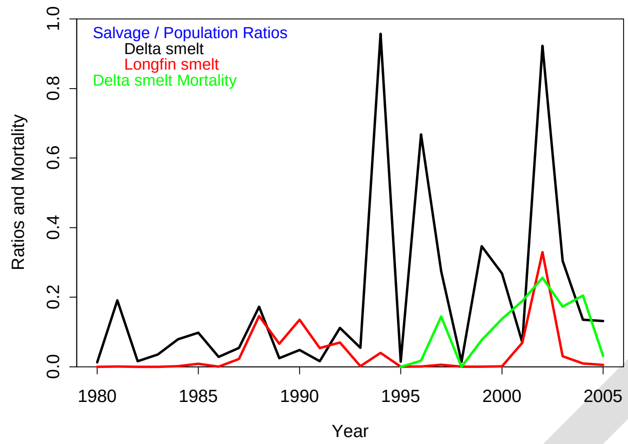


Figure 1. Time course of ratios of annual salvage to population size for delta and longfin smelt, and export-related mortality of delta smelt from Kimmerer (2008)

Question 2: Can we estimate the impact of export losses on longfin as for delta smelt?
Approach: I developed image plots of length by date for longfin smelt from both the 20mm survey and salvage data. The time course of the 20mm survey does not include the entire larval period of longfin smelt, which spawn earlier than delta smelt. The salvage data cover the whole period but do not include fish smaller than 20mm.

I used a similar approach to that applied to determine daily percent mortality of Age-0 delta smelt due to export pumping in Kimmerer (2008). See that paper for assumptions. No correction was made for efficiency of the 20mm net, since similar sizes were assumed to occur in the south Delta and other parts of the system. Mortality was calculated for each 20mm survey from 1995 through 2006. In contrast to the analysis for delta smelt I included stations in San Pablo Bay since longfin smelt are common there, and included the volume of that region (0.9 X 10^9 m^3, Kimmerer 2004) in the calculation of population size.

Results: The image plot from salvage (Figure 2) shows a peak around julian days 90-150 (April – May) in small fish, and a much lower peak earlier in the year of fish that are from previous year classes. Fish below the line in Figure 2 were assumed to be Age-0. The catch in the 20mm survey roughly corroborates the timing of the peak in salvage (Figure 3), although the start of the peak is earlier since the 20mm survey catches smaller fish.

Export mortality was much lower than that for delta smelt (see Kimmerer 2008 Figure 15; daily mortality based on the 20mm survey was as high as 6% d^{-1}). The highest value was a single, somewhat anomalous value of 0.12% d^{-1} in 1996 (Figure 5). The highest mean value was 0.02% d^{-1} in 2002. If this were compounded over a 60-day period of vulnerability, the result would be a loss of 1% of the population. The mean compounded loss was 0.3%. Note that the calculation for delta smelt was much more involved than this, which should be considered only an estimate for range-finding.

Even that estimate may be high. delta smelt remain in the Delta until around July, possibly to avoid high temperature. longfin smelt are larger in samples taken further from the pumps (Figure 6), indicating that they are probably leaving the area within some period after hatching. Therefore individual longfin smelt do not remain vulnerable to pumping for as long a period as delta smelt.

Conclusion: longfin smelt are much less vulnerable to export pumping than delta smelt, although the 20mm survey is somewhat less suitable for making the calculation for longfin than delta smelt. The reasons for the difference are the lower fraction of the longfin smelt population that occurs in the southern Delta, and the earlier movement of longfin smelt to brackish waters out of reach of the pumps.

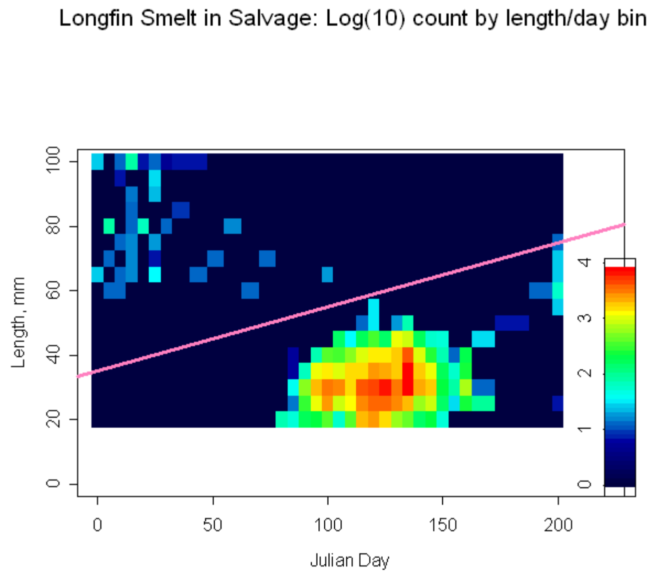


Figure 2. Image plot of catch (log scale) in the salvage facilities by length and day, 1995 – 2006.

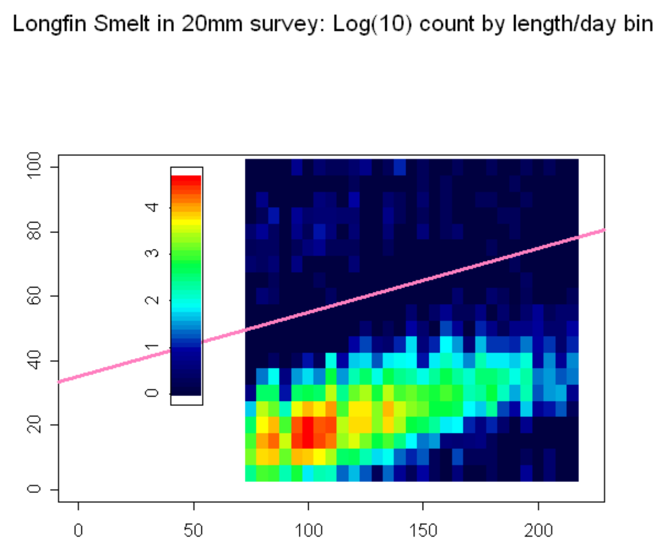


Figure 3. As in Figure 2 for the 20mm survey.

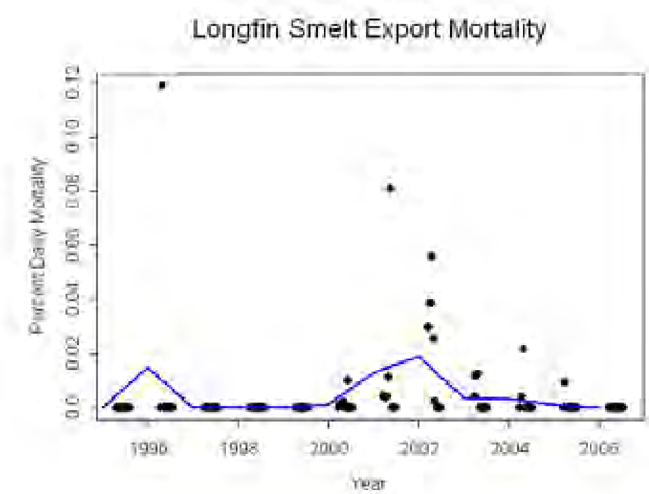


Figure 4. Daily percent mortality due to export pumping and annual mean. Each point represents data from one survey.

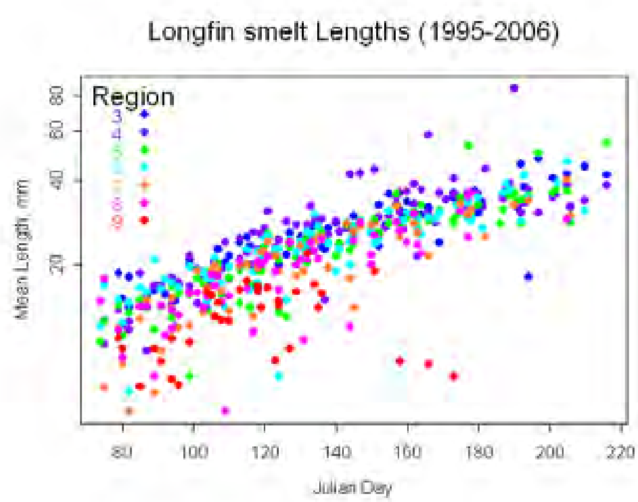


Figure 5. Mean length of longfin smelt from 20mm survey by day and region. The region is the first digit in the station number, and increases generally from San Pablo Bay (3) to the south Delta (9).

Question 3: Can we estimate the impact of export losses on splittail?

Approach: As for delta and longfin smelt except that I did not have the catch per trawl for this species. I therefore used the abundance index from the fall midwater trawl survey, and divided it by 500 (the mean ratio of index to mean catch per trawl for the 4 POD species ranges from 400 to 600). Otherwise the approach was the same.

Results: Salvage was generally higher, sometimes much higher than population size estimated from the MWT (Figure 6)

Conclusion: We can't estimate the impact of export losses on splittail. There is no other sampling program with the right combination of quantitative sampling and seasonal suitability to do this.

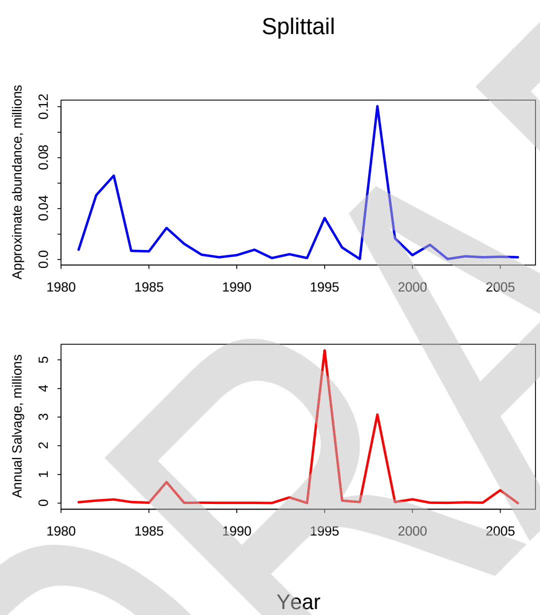


Figure 6. Approximate abundance and annual salvage of Sacramento splittail (millions).

Question 4. How is salvage of adult delta smelt likely to change with changing Old and Middle River flows?

Approach: The basic problem is that the salvage of delta smelt is sometimes high when OMR flows are strongly negative, and sometimes zero. Salvage is usually low when the flows are positive (but not necessarily zero). The question, then, is what benefit accrues from restricting OMR flows in winter.

The general approach was to find a suitable model of the effect of flow on salvage, and then use forecast changes in OMR flow from the 82-year set of scenarios to estimate the change in salvage. If salvage is proportional to export-related mortality, then this should represent the proportional decrease in mortality.

Salvage data from December 12 through March were used in the analysis. A total of 5413 data points were available from 1981 through 2006: 2653 from the state facility and 2760 from the federal facility. The expansion factor to convert counts in the salvage facility to salvage was determined as the ratio of reported salvage to counts for delta smelt, or if that was zero, for all fish. Two cases had zero counts and one had a missing salvage value; these were eliminated. Thirteen cases (February 2006 in the state facility) had missing values for salvage of delta smelt; these were calculated using the expansion factor for all fish. Note that these expansion factors are approximate, in that the actual calculation is done for each of several time periods over the course of a day and summed over the day; however, the expansion factors for delta smelt and all fish were reasonably close so using daily values seemed a useful simplification to avoid having to work with massive amounts of uninformative data.

A suitable model of these relationships must be nonlinear, and allow zero salvage but not negative values; therefore a linear model is unsuitable. However, since the salvage data are based on counts of fish in the two salvage facilities, we can use a model with a Poisson error distribution in which the raw count data are modeled directly. The model is specified separately for the state and federal facilities, since they may have different relationships. The model is specified in steps:

```
 Salvage density  = e^(a + b * OMR)
 Expected Salvage = Salvage density * export flow
Expected count    = Expected salvage / Expansion factor
Observed count ~ Poisson (Expected count)
```

Where a and b are the coefficients to be estimated. Salvage density is the number of fish per unit volume of exported water. This is modeled as a function of OMR flow, since salvage would vary with export flow but salvage density would presumably vary only with OMR flow. Then the expected count is used as the mean of a Poisson distribution, and the raw count data were fit using a Poisson error distribution.

For practical reasons model was fit in a Bayesian analysis using WinBUGS. Uninformative priors for a and b were used, which has the effect that the analysis is similar to a likelihood analysis but is provides more information about the parameters. The prior distributions of the parameters were log normal for **a** (since it can't be less than zero), and normal for **b**, both with means of zero and variances of 10^6. Parameters were estimated from 10,000 iterations after a burn-in of 10,000 iterations to remove the effects of the assumed starting points.

Outcome Code	Covered Spp.	Description	Scenario 1 Magnitude	Scenario 1 Certainty	Scenario 2 Magnitude	Scenario 2 Certainty
Positive Outcomes						
P1a	Delta smelt – adult	Reduce entrainment induced mortality of covered fish species from the western Delta.	2	3	3-4	2-3
P1b	Delta smelt - Larval	Reduce entrainment induced mortality of covered fish species from the western Delta.	2	1	2-3	2
P1c	Longfin smelt – Adult	Reduce entrainment induced mortality of covered fish species from the western Delta.	1	3	2-3	2
P1d	Longfin smelt – Larval	Reduce entrainment induced mortality of covered fish species from the western Delta.	1-3	2	1-3	2
Negative Outcomes						
N3a	Delta smelt	The gate structure may be conducive to higher predator presence and therefore the risk of predation on covered fish species may increase	2	2		
N2a	Delta smelt	When closed, the gates could increase entrainment and mortality of Delta smelt in the central and southern Delta.	2	2		
N3c	Longfin smelt	The gate structure may be conducive to higher predator presence and therefore the risk of predation on covered fish species may increase	1	2		
N2b	Longfin smelt	When closed, the gates could increase entrainment and mortality of Delta smelt in the central and southern Delta.	2	2		

Scenario 1 D-1640 Baseline

Scenario 2 OCAP delta smelt BO

HRCM 1:
San Joaquin ROA (Upstream)

Scientific Evaluation Worksheet

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Action: San Joaquin ROA Floodplain Restoration (upstream of Mossdale)

Evaluation Team: Floodplain and Riparian Workgroup

Campbell Ingram (chair), Denise Reed (coach), Carie Battistone (notetaker), Eric Ginney, Ted Sommers, Rosalie Del Rosario, Dennis McEwan, Bill Harrell, Dan Welsh, Yvette Redler, Vance Russell

Date of Last Revision: February 23, 2009

Action Description and Clarifying Assumptions

Restore floodplain habitat along 7 to 14 miles of the San Joaquin River from Vernalis to Mossdale.

Option #1: 850 acres (7 miles)

Option #2: 1,700 acres (14 miles)

Approach

1. Set back levees along both sides of the channel and remove all or large sections of the existing levees.
2. Contour floodplain area as needed to reduce and avoid the potential for stranding of juvenile and adult fish following inundation events.
3. Modify channel where practicable within the restored floodplain reach to create low velocity habitat areas designed to provide spawning habitat for splittail and rearing habitat for splittail and salmonids.
4. Discontinue farming within setback levee where width will not support floodplain characteristics and farming practices.
5. Allow riparian vegetation to naturally establish.
6. Allow channel to meander between the new levees through the natural processes of erosion and sedimentation.

Intended Outcomes as Stated in Conservation Measure

1. Expand the floodplain to allow flood waters to attenuate, improving access of juvenile fish, such as Chinook salmon and steelhead, to seasonally inundated floodplain habitat.
2. Create additional spawning habitat for Sacramento splittail by expanding floodplain habitat area and providing in-channel spawning habitat by creating backwaters.
3. Create additional rearing habitat for San Joaquin Basin runs of Chinook salmon, Sacramento splittail, and possibly steelhead.
4. Increase the production of food for rearing salmonids, splittail, and other covered species.
5. Increase the availability and production of food in Delta channels downstream of restored floodplain habitat for delta smelt, longfin smelt, and other covered species by exporting organic material and phytoplankton, zooplankton, and other organisms produced from the inundated floodplain into Delta channels.
6. Increase habitat complexity by allowing the natural establishment and growth of woody riparian vegetation that will provide inputs of large woody debris into the river channel and provide overhead cover.

Positive
P1. Improved connectivity of seasonally inundated floodplain habitat for juvenile splittail, green and white sturgeon, Chinook salmon and steelhead
P2. Additional splittail spawning habitat on floodplain
P3. Additional rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment)
P4. Increased production of food for rearing splittail, green and white sturgeon, Chinook salmon and steelhead from inundation and riparian vegetation (local)
P5. Increased availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for splittail, green and white sturgeon, Chinook salmon, steelhead (off site), longfin smelt, and delta smelt
P6. Increased establishment of woody riparian vegetation to export LWD
P7. Increased establishment of woody riparian vegetation to provide shaded channel habitat
P8. Increased downstream turbidity to improve habitat quality for longfin smelt and delta smelt

Negative
N1. Increased MeHg and impact on covered species (direct or indirect)
N2. Increased resuspension/mobilization and export of toxic compounds with impact on covered species (consider time course of effect)
N3. Increased frequency and magnitude of low DO in SDWSC due to an increase in algae/POM and impact on Chinook salmon, steelhead, and green and white sturgeon passage.
N4. Decreased downstream turbidity decreases habitat quality for longfin smelt and delta smelt
N5. Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail
N6. Increased exposure risk to contaminants (including Selenium) due to longer residence time in this area

General Conceptual Model Support for Intended Outcomes

DRERIP models were referenced in evaluations, along with several outside sources.

Models used
Chinook salmon
Splittail
Floodplain
Riparian
Longfin Smelt
Delta Smelt
Boundary Condition
Mercury
Selenium
Sedimentation
Temperature
Chemical Stressors/Pyrethroids
Dissolved Oxygen
Foodweb
Fish Habitat Linkages

Other sources:
T. Sommer pers comm. 2009
McEwan 2001
FWS 2007
Williams 2006
Moyle 2002
Moyle et al 2006, 2007
Baxter sampling (mostly unpublished)
Crain et al 2004 conference proceedings
Henery and Sommer (in press)
Daryl Slotten paper
Sommer et al 2001, 2004, 2005

Harrell and Sommer 2003
Harrell and Sommer (unpub)
Hatton 1940
Healy 1991
Ward et al 2003
Kjelson 1982
SJRG annual reports 2004-2007
Caswell annual report 2004-2007
J. Israel pers comm. 2009
Rosenfield 2007

Assumptions

Provided in BDCP Conservation Measure

1. 500 foot setback on each side.
2. 850 acres for 7 mile option.
3. 1,700 acres for 14 mile option.
4. Approximately half of the acreage would flood for at least 30 days every 7 years; all of the acreage would flood for at least 30 days approximately every 20 years.

Added by Evaluation Team

1. Assumes choke point at Mossdale on river distinguishes between tidal and non-tidal.
2. Assumes no lowering of floodplain to increase inundation
3. Assume all South Delta work will be contingent on significant reduction in south Delta entrainment (need to evaluate some negative outcomes with both 1) Old River isolated and 2) current configuration and reduced pumping (i.e., dual conveyance)).

Problem(s) with Action as Written:

1. Natural recruitment of desirable, native riparian vegetation seems unreasonable given the infrequent inundation of the site (the entire site only floods for a significant duration every 20 years).
2. Took out "(including aquatic, floodplain, and riparian features)" from the original stated action.
3. Contouring needs further explanation – focused on stranding not on connections.
4. Approach 3 and 6 are incompatible.
5. The floodplain inundation target of "half of the acreage would flood for at least 30 days every 7 years; all of the acreage would flood for at least 30 days approximately every 20 years" will likely be hard to reach. Ultimately this assumption affects overall scoring.

Scale of Action:

Option #1 – LARGE SCALE (50% increase in habitat area)
Option #2 – LARGE SCALE (100% increase in habitat area)

Rationale:
Relative magnitude depends on system-wide condition. During flood events you have a large increase in area inundated.

Evaluation Summary Tables

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in Appendix A. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes on the following pages.

Relation to Existing Conditions

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

YES

Nature of Change: Insert short sentence here.

Levees appear to be wide in areas: Mossdale to French Camp is more channelized. Levees are not continuous. This action will create an increased level of inundation/flow. Modeling has been sparse in this area – had to make broad assumptions.

Existing Acreages: 1,866 acres (Vernalis to Mossdale)
Existing Acreages: 233 acres (Mossdale to French Camp)

The effects associated with levee setbacks can be considered within our current understanding of the system.

Note: Would help to describe the relation to historical conditions to help us understand the level of habitat to restore.

Potential Positive Ecological Outcome(s)

Outcome P1: Improve connectivity of seasonally inundated floodplain habitat for juvenile fish (Splittail, G/W sturgeon, Chinook salmon and steelhead).

P1a. Fall-run Chinook salmon

Human-built features reduce connectivity to floodplain habitat for salmon (Floodplain Model - text doesn't specifically state salmon but it cites Ted's paper (Sommer et al. 2005)

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 3-4
Given data on flooding and studies elsewhere.

P1b. Steelhead

Same info for flooding for Chinook Salmon. They are there (McEwan 2001) at the time (life stage table – Figure 3). Emigrating Jan-August, peak in Jan-May based on Sacramento River info. Mossdale trawl data (Rosalie provided – FWS 2007) shows more fish occur. Floodplain (page 27) says no info on steelhead use of floodplain. Steelhead model (Fig 2 of steelhead section in salmonid model, p155) shows floodplain use. Williams (2006), McEwan (2001) and Moyle (2002) support presence. Page15-16 of salmon model shows estuarine habitat – may show import for lower reach.

Steelhead have been caught on floodplain in Yolo (Sommer, T., B. Harrell, M. Nobriga, R. Brown, P. Moyle, W. Kimmerer, and L. Schemel. 2001. California's Yolo Bypass: evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture. Fisheries 26:6-16.). Some reference in Williams 2006 – chapter 9, page 174.

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 2-3
Non-peer reviewed references.

P1c. Splittail

Splittail model, pg 12, describes how loss of connectivity has resulted in habitat loss; Floodplain model pg 18: human-built features such as berms and ditches reduce connectivity to floodplain habitat.

Magnitude = 3
Given longer life span means it can take advantage of more flashy system.

Certainty = 3-4

P1d. White Sturgeon

Same info for flooding for CS. No evidence of juvenile use of floodplains. Adult catch in Yolo are adults (Harrell and Sommer 2003). This mechanism described above is assumed to apply to WS (Sommer et al 2005 and Floodplain Model).

Magnitude = 1-2

Certainty = 1

P1e. Green Sturgeon

Same info for flooding for CS. No evidence of juvenile use of floodplains. Adult catch in Yolo are adults (Harrell and Sommer 2003). This mechanism described above is assumed to apply to WS (Sommer et al 2005 and Floodplain Model).

Magnitude = 1

Certainty = 2

Outcome P2: Create additional splittail spawning habitat on floodplain

P2a. Splittail

Floodplain model pg 25 and Splittail model pgs 9 and 12 describe how additional floodplain habitat supports splittail spawning.

Magnitude = 3
Given longer life span means can take advantage of more flashy system.

Certainty = 3-4

Outcome P3: Create rearing habitat for Chinook salmon, green/white sturgeon, splittail and steelhead. Consider loss to entrainment.

P3a. Fall-run Chinook salmon

Assumption gives duration and frequency. BDCP document shows historic timing is late winter spring. Boundary Condition model (p. 49) shows peaks occur in February period.

Fall-run Chinook salmon juveniles are present in the area during the proposed floodplain inundation period of late winter and spring. San Joaquin fall-run Chinook juveniles enter Delta either as: 1) fry/parr) with high winter flows, typically in January through March (size of 20 to 60 mm fork length, or as 2) smolts after mid March(> 60 mm fork length; (Caswell Annual Report 2007, SJRG 2004, 2005, 2006)

Delta presence of fry confirmed by:

- Presence at Mossdale and Salvage facilities during Jan – March
- San Joaquin River Trawl Dos Reis(RM 51) –Laird(RM 90)
- Salmon < 50mm January through March

- Apparent that much of Tuolumne/Stanislaus River emigrated as fry and pre-smolts with early flood flows in Jan – March…..Early migrants not captured in high numbers at Mossdale/Salvage indicating that juveniles may have remained in the lower San Joaquin above Mossdale….” (SJRG annual report 2006 pg 75, 2007 pg 66).
- Densities of fry may be underrepresented due to both the trawl and salvage being relatively less effective at capturing fry (Salmon less than 50 mm long). (SJRG 2006 Annual Report pg 72)
- Fall run Chinook (Fig 2c) shows juvenile fry/par stage during winter/spring.
- Most Fry enter Delta from tributaries before April (January through March), Smolt enter mid March – June (Based on USFWS/CDFG Mossdale trawl data , SJRG annual reports 2004-2007, Caswell annual report 2007.)

Fall-run Chinook salmon juveniles would use the floodplain to rear. The restored floodplain would create rearing habitat for fry/parr that enter the Delta in the winter, coincident with inundation of the floodplain. These fry would be able to feed and grow in the floodplain, and their larger size would increase the likelihood of survival in the ocean.

- Chinook salmon use the delta inversely proportional to their size (Williams 2006).
- Smolts migrate directly through delta to ocean.
- Fry likely do not migrate out of delta until smolt size. (SJRG annual report 2004 pg 76)
- Shallow water habitats including river floodplains and riparian margin provide rearing habitat. Growth rates for juvenile Salmon are higher and emigration rates are slower when in shallow water rearing habitats. (Kjelson 1982, Sommer 2005)
- “during very high flows, fry simply get swept downstream…because the turbulence is too strong for them to resist” (Williams 2006, pg76)
- “ Fry tend to keep to the margins of large rivers”(Hatton 1940, Healy 1991) meaning fry can move at a slower rate then the river especially if they have access to floodplains where they can find slower moving water.
- Fry that lingered in lower reaches of creek or bypass grew to 70-80mm compared to fry that migrated quickly and averaged 40mm (Ward et all 2003)

Floodplains no longer exist along the lower San Joaquin River, but fall-run Chinook salmon would likely use the restored floodplains, as they have been documented to rear in Yolo Bypass floodplain along the lower Sacramento River.

- CV Chinook salmon may have relied extensively on floodplain in the past as historically much of the central valley was floodplain habitat (Hunter et al 1999)
- Williams (2006 article 2) confirmed fall Chinook emigration if Feb-Mar on SJ. Floodplain model (Fig 7 and assoc text) identifies that floodplains provide habitat for CS.
- “Given the temporal and geographic distribution, (Fall-run juvenile) have more opportunities to use floodplain habitats than do other Central Valley runs” (Rosenfield 2007).
- Sommer et al (2005) reported extensive use of Yolo and Sutter bypasses by fall-run.
- Moyle et al (2007) reported use of Cosumnes River floodplain

Limited data on SJ floodplain (none in Floodplain model) No reason to suggest they should behave different from other systems.

Magnitude = 2
Given limited temporal effect in frequency. Availability of floodplain is infrequent, with partial inundation every 7 years. This floodplain would be unavailable for at least 2 generations of San Joaquin fall run, of which the majority are 3 year old spawners, with some 2 year old spawners (Myers et al. 1998, p. 61). There is high certainty that juvenile salmon are in the vicinity, and inference juveniles would rear in restored floodplain based on documented rearing in the Yolo Bypass and the restored Cosumnes River floodplain.

Certainty = 3-4
Given data on flooding and studies elsewhere.

P3b. Steelhead

Same info for flooding for Chinook salmon. They are there at the time (McEwan 2001 life stage table – Figure 3 - emigrating Jan-August, peak in Jan-May -based on Sacramento River info). Mossdale trawl data (Rosalie provided – FWS 2007) shows more fish occur. Floodplain Model (page 27) says no info on steelhead use of floodplain. Steelhead model (Fig 2 of steelhead section in salmonid model, p155) shows floodplain use. Williams (2006), McEwan (2001) and Moyle (2002) supports presence.

Page15-16 of salmon model shows estuarine habitat – may show import for lower reach.

Steelhead have been caught on floodplain in Yolo (Sommer, T., B. Harrell, M. Nobriga, R. Brown, P. Moyle, W. Kimmerer, and L. Schemel. 2001. California's Yolo Bypass: evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture. Fisheries 26:6-16.). Some reference in Williams 2006 – chapter 9, page 174.

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 2
Non–peer reviewed references.

P3c. Splittail

DLO Relationship and General Observations:
Same info for flooding for CS. Table 1 page 3 in Splittail model indicates juveniles use floodplain Feb-May, distribution shows they are in SJ. based on Baxter sampling (mostly unpublished). Cosumnes publications (Crain et al 2004 conf proc.), Moyle et al 2004. SFEWS. Still not much info from SJ – same inference, no reason to believe they would behave differently.

Magnitude = 3
Given longer life span means can take advantage of more flashy system.

Certainty = 3-4
Given data on flooding and studies elsewhere.

P3d. White Sturgeon

DLO Relationship and General Observations:
Same info for flooding for Chinook salmon. No evidence of juvenile use of floodplains. Adult catch in Yolo are adults (Harrell and Sommer 2003). This mechanism described above is assumed to apply to WS (Sommer et al 2005 and Floodplain Model).

Magnitude = 1-2

Certainty = 1

P3e. Green sturgeon

DLO Relationship and General Observations:
Same info for flooding for Chinook salmon. No evidence of juvenile use of floodplains. Adult catch in Yolo are adults (Harrell and Sommer 2003). This mechanism described above is assumed to apply to WS (Sommer et al 2005 and Floodplain Model).

Magnitude = 1

Certainty = 2

Outcome P4: Increase production of food for rearing Chinook salmon, steelhead, green/white sturgeon, splittail from inundation and riparian vegetation (local).

P4a. Fall-run Chinook salmon

Floodplain Model pgs 20-25 - high levels of food production on floodplain provides support for magnitude score. Floodplain Model pgs 27 and 29 describe utilization and higher growth rates for Chinook salmon on floodplains. Chinook salmon likely take advantage of small fishes on the floodplain (Splittail Model pg 8 and Moyle et al. 2004).

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 3-4
Given data on flooding and studies elsewhere.

P4b. Steelhead

Floodplain Model pgs 20-25 - high levels of food production on floodplain provides support for magnitude score. Nothing in the literature that describes steelhead feeding on floodplains, however, it can be assumed that they are utilizing the same food sources as juvenile salmon, given their life-history similarities. Moyle 2002 states that stream-dwelling rainbow trout feed mostly on drifting aquatic orgs, terrestrial insects, and bottom dwelling orgs which are in abundance on floodplains.

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 2
Non-peer reviewed.

P4c. Splittail

Floodplain Model pgs 20-25 - high levels of food production on floodplain provides support for magnitude score. Floodplain Model pgs 25 and 27 describes utilization and higher survival for splittail on floodplains.

Magnitude = 3
Given longer life span means can take advantage of more flashy system.

Certainty = 3-4

P4d. White sturgeon

Floodplain Model pgs 20-25 - high levels of food production on floodplain provides support for magnitude score. This mechanism described Chinook salmon is assumed to apply to WS (Sommer et al 2005 and Floodplain Model).

Magnitude = 1
No evidence of juvenile use of floodplains. Catch in Yolo are adults (Harrell and Sommer 2003).

Certainty = 1
Understanding of sturgeon on floodplain is low and needs further study, e.g., could have higher worth if better understood, group had difficulty determining whether to eliminate sturgeon based on understanding of their use of floodplains.

P4e. Green sturgeon

DLO Relationship and General Observations:
Floodplain Model pgs 20-25 - high levels of food production on floodplain provides support for magnitude score. This mechanism described for Chinook salmon is assumed to apply to GS (Sommer et al 2005 and Floodplain Model).

Magnitude = 1
No evidence of juvenile use of floodplains. Catch in Yolo are adults (Harrell and Sommer 2003).

Certainty = 2
Understanding of sturgeon on floodplain is low and needs further study, e.g., could have higher worth if better understood, group had difficulty determining whether to eliminate sturgeon based on understanding of their use of floodplains.

Outcome P5: Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt.

P5a. Fall-run Chinook salmon

Floodplain Model pgs 20-25 - high levels of food production on floodplain provides support for magnitude score. Floodplain Model pgs 27 and 29 describe utilization and higher growth rates for Chinook salmon on floodplains.

Chinook salmon likely take advantage of small fishes on the floodplain (Splittail Model pg 8 and Moyle et al. 2004).

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 3-4
Given data on flooding and studies elsewhere.

P5b. Steelhead

Floodplain Model pgs 20-25 - high levels of food production on floodplain provides support for magnitude score.

Nothing really in the literature that describes steelhead feeding on floodplains, however, it can be assumed that they are utilizing the same food sources as juvenile salmon, given their life-history similarities. Moyle 2002 states that stream-dwelling rainbow trout feed mostly on drifting aquatic orgs, terrestrial insects, and bottom dwelling orgs which are in abundance on floodplains.

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 2
Non-peer reviewed.

P5c. Splittail

Floodplain Model pgs 20-25 - high levels of food production on floodplain provides support for magnitude score. Floodplain Model pgs 25 and 27 describes utilization and higher survival for splittail on floodplains.

Magnitude = 3
Given longer life span means can take advantage of more flashy system.

Certainty = 3-4

P5d. White sturgeon

Floodplain Model pgs 20-25 - high levels of food production on floodplain provides support for magnitude score.

This mechanism described Chinook salmon is assumed to apply to WS (Sommer et al 2005 and Floodplain Model).

Magnitude = 1
No evidence of juvenile use of floodplains. Catch in Yolo are adults (Harrell and Sommer 2003).

Certainty = 1
Understanding of sturgeon on floodplain is low and needs further study, e.g., could have higher worth if better understood, group had difficulty determining whether to eliminate sturgeon based on understanding of their use of floodplains.

P5e. Green sturgeon

Floodplain Model pgs 20-25 - high levels of food production on floodplain provides support for magnitude score.

This mechanism described for Chinook salmon is assumed to apply to GS (Sommer et al 2005 and Floodplain Model).

Magnitude = 1
No evidence of juvenile use of floodplains. Catch in Yolo are adults (Harrell and Sommer 2003).

Certainty = 2
Understanding of sturgeon on floodplain is low and needs further study, e.g., could have higher worth if better understood, group had difficulty determining whether to eliminate sturgeon based on understanding of their use of floodplains.

P5f. Longfin smelt

Longfin smelt Model pg 21 describes the importance of zooplankton.

Magnitude = 2
Given limited temporal effect in frequency; occur under extreme high flow events when food is less likely a constraint.

Certainty = 3

P5g. Delta smelt

Delta smelt Model pg 12 describes the importance of zooplankton.

Magnitude = 2
Given limited temporal effect in frequency; occur under extreme high flow events when food is less likely a constraint.

Certainty = 3

Outcome P6: Increase establishment of woody riparian veg to export LWD.

P6. Not evaluated by species

Assumption for action HRCM1 gives duration and frequency of inundation of the floodplain. Note that highway and railroad bridges, existing developments and homes will make it difficult to actually implement this action in many areas of the action area.

Many factors and processes influence natural recruitment of woody riparian vegetation, and are summarized in the DRERIP Riparian Vegetation Model. Figures 5, 6, & 7 of that model demonstrate how levees disrupt the setting of the “physical template” (the surface hydrology and floodplain scouring processes necessary for that template) that is necessary for natural recruitment to occur. Actions in HRCM1 would result in reduction of that stressor (setting back the levee), which would allow for increased establishment of woody riparian vegetation. The altered flow regime of the San Joaquin River system would not be modified by this action, and would therefore remain as a stressor and (in combination with altered channel and floodplain morphology) this would still limit inundation frequency and duration of the site.

While natural riparian vegetation recruitment in the setback area would be possible, infrequent natural flooding may encourage invasive species recruitment (DRERIP Riparian Model, page 20) because surface water and groundwater hydrology drive the recruitment and establishment parameters of vegetation somewhat independently of the physical template. Specifically, this includes recruitment parameters for necessary seedling survival and changes in biotic competition and anoxia that may favor invasive species over native species that are flood-tolerant or require flooding to establish. Infrequent inundation also translates to infrequent LWD export from the area of increased vegetation.

Chinook salmon likely take advantage of small fishes on the floodplain (Splittail Model pg 8 and Moyle et al. 2004).

Magnitude = 2
Magnitude score is based on effect being local (e.g., 7 or 14 mile reach) to regional (LWD would move downstream) in scale. However, because new floodplain areas would not be inundated very frequently (and hence the increase in LWD recruitment would be sporadic), the temporal effect is low. The DRERIP Floodplain Model (pages 5, 6, & 7) describes how flood flows modify the floodplain and interact with riparian vegetation to recruit LWD. The approach to Action HRCM1 will set back levees allowing vegetation recruitment (and flooding) where it is currently precluded; however, the action will not modify the floodplain morphology or increase flood hydrology in terms of frequency or duration. Thus, while riparian vegetation may be increased by the action, because of the morphology of the site and other stressors (specifically, impaired flood hydrology), the inundation frequency—and hence the LWD export—is likely to be infrequent (e.g., every 7 years for half the new floodplain; every 20 years for the entire floodplain). Therefore, while this outcome is positive, the actual increase in LWD export is likely to be relatively infrequent and thus of low magnitude.

Certainty = 3
Certainty score is based on dependence of outcome on variable ecosystem processes (i.e., flooding needed to cause LWD input is highly variable—e.g., every 7 to 20 years based on modeling).

Outcome P7: Increase establishment of woody riparian vegetation to provide shaded channel habitat.

P7a. 7-mile reach option

The DRERIP Riparian Model (interactions with floodplains as shown in Figure 5, and specifically the Riparian Vegetation Sub-model; green box in Figure 5) produces a conceptual framework for illustrating the creation of the physical “shaded riverine aquatic habitat” that would be provided by action HRCM1. Removing levees or eliminating vegetation clearing at the river’s edge would allow for increased establishment of woody riparian vegetation.

Based on assumptions and approach to HRCM1, “modifications” to the channel will be made to benefit splittail spawning and provide splittail and salmonid rearing habitat. Ostensibly, this would include addition of instream LWD, but because riparian vegetation is assumed to come from "natural recruitment", any increase in woody riparian vegetation establishment (and hence increased shade) along the banks would be expected to occur only in areas where current levees (without vegetation) are located immediately adjacent to the river, or vegetation along the river is cleared all the way up to the edge of the river.

Benefit to covered species would be dependant on water temperature effects. Shade would reduce the amount of shortwave radiation striking the water (see Figure 1, DRERIP Temperature model); however, at this fine habitat-level scale, while shading is important, its influence is difficult to prescribe quantitatively (DRERIP Temperature model, page 6). Predicting the magnitude of the shading effect is beyond the level of the conceptual models.

Magnitude = 2
Currently, compared to the upstream reach (the other 7 mile section that comprises the 14-mile action area), more levee is adjacent to the river channel, and hence the opportunity for levee setback to increase woody riparian vegetation (and hence shade the channel) immediately adjacent to the channel is greater relative to that in the upstream 7 miles (Google Earth satellite imagery; DRERIP-BDCP maps). Only about 1 mile of floodplain along the river is cleared right up to the river's edge. However, highway and railroad bridges, existing developments and homes in the downstream portion of this reach will make it difficult to actually implement this action at the scale and extent assumed for this area. SUMMARY: Compared to upstream 7 miles, potential magnitude of increase is larger for this segment of the action area (more sections of bank would gain shade); however, the likelihood of actual implementation is lower than upstream because of constraints.

Certainty = 3
Certainty score is based on dependence on external factors and the lack of predictability in the outcome directly supporting covered species.

P7b. 14-mile reach option

The DRERIP Riparian Model (interactions with floodplains as shown in Figure 5, and specifically the Riparian Vegetation Sub-model; green box in Figure 5) produces a conceptual framework for illustrating the creation of the physical "shaded riverine aquatic habitat" that would be provided by action HRCM1. Removing levees or eliminating vegetation clearing at the river's edge would allow for increased establishment of woody riparian vegetation.

Based on assumptions and approach to HRCM1, "modifications" to the channel will be made to benefit splittail spawning and provide splittail and salmonid rearing habitat. Ostensibly, this would include addition of instream LWD, but because riparian vegetation is assumed to come from "natural recruitment", any increase in woody riparian vegetation establishment (and hence increased shade) along the banks would be expected to occur only in areas where current levees (without vegetation) are located immediately adjacent to the river, or vegetation along the river is cleared all the way up to the edge of the river.

Benefit to covered species would be dependant on water temperature effects. Shade would reduce the amount of shortwave radiation striking the water (see Figure 1, DRERIP Temperature model); however, at this fine habitat-level scale, while shading is important, its influence is difficult to prescribe quantitatively (DRERIP Temperature model, page 6). Predicting the magnitude of the shading effect is beyond the level of the conceptual models.

Magnitude = 3
This version of the action would include another 7 miles located upstream. Currently, compared to the downstream reach (the lower 7 mile section that comprises the 14-mile action area), the levees are relatively far back from the channel (Google Earth satellite imagery; DRERIP-BDCP maps) and vegetation exists along most of the river channel. Hence, the relative opportunity for levee setback to increase woody riparian vegetation (and hence shade the channel) immediately adjacent to the channel is lower than in the downstream 7 miles. However, existing developments and homes in this reach are located in areas with relatively large areas between them and the river, so the opportunity to actually implement this action at the scale and extent assumed for this upstream reach is greater than in the downstream. SUMMARY: Compared to downstream 7 miles, potential magnitude of increase is less for this segment of the action area (because existing conditions are currently better), but likelihood of actual implementation is higher than downstream. Would affect multiple patches of habitat.

Certainty = 3
Certainty score is based on dependence on external factors and the lack of predictability in the outcome directly supporting covered species.

Outcome P8: Increased downstream turbidity improves habitat quality for delta smelt and longfin smelt.

P8a. Delta smelt

Positive link between delta smelt and turbidity throughout life-history is well documented in both lab and field studies. Longfin smelt abundance appears to be positively linked with turbidity, although less research is available.

Action assumes relatively infrequent inundation events. Inundation will suspend and mobilize sediment from the restored floodplain, increasing turbidity in the water column downstream. Floodplain model: Sediment on floodplains can be resuspended by flows or turbulence such as wind-generated waves (pg. 18). Sediment model: The Yolo Bypass floodplain, when inundated, can be a large source of sediment to the Sacramento River (pg. 9). A restored floodplain on the San Joaquin River could be a source for suspended sediment downstream, assuming it functions similarly to the Yolo Bypass. Delta smelt model: Turbidity increases larval feeding success (pg. 4-5); turbidity conceals juvenile delta smelt from predation (pg. 7); and juveniles are most abundant in areas with low water transparency (pg. 11). Longfin smelt model: Longfin smelt occurring in turbid water have reduced exposure to predation (pgs. 7, 8, 13). Although less information is available for longfin, they likely benefit from higher levels of turbidity in similar ways to delta smelt.
Magnitude = 2
Limited temporal and population level effect due to low frequency of inundation (given in assumptions).

Certainty = 3-4

P8b. Longfin smelt

Same as delta smelt above.

Magnitude = 2
Limited temporal and population level effect due to low frequency of inundation (given in assumptions).

Certainty = 3

Potential Negative Ecological Outcome(s)

Outcome N1: Increased MeHg and impact on covered species (direct or indirect).

N1a. Same for all species

Figure 2 in Hg model – shows seasonally flooded links. Page 10 – Hg formation relation to habitat (episodic wetting/drying). Hg is less of a factor in SJR system compared to northern Delta (Yolo). Seasonal affects on fish in different locations (Fig 6) – with existing system. No major of minor population affects (regional or local). Isn't very much info showing an affect, especially in Delta. Refer to Henery and Sommer (in press). Certainty of methylation high, affects on covered species low (unknown but likely). Species models do not address Hg directly (little known) but need to check. Floodplain Model: Figure 4 links to Hg model – no other references found Daryl Slotten paper: Hg accumulation in fish, but does not indicate affect on fish. Sites that are inundated less frequently have higher methyl rates then those that inundate more frequently – apply differently based on tidal influence in areas.

Magnitude = 1
Details described here.

Certainty = 3
Based on level understanding of affects on fish species.

Outcome N2: Increased resuspension/mobilization and export of toxic compounds w/impact on covered species (consider time course of effect).

N2a. Same for all species:

Time scale considerations: depends on the specific chemical (some compounds are short lived in the system, some stay longer). Outcome worded very generally. Look at worse case scenario and what is most likely. Chemical Stressors Models: generally speaks to transport (more transport with more inundation) and supports as negative outcomes. Sedimentation model: Figure 2 – river mobilizes toxics from hydraulic mining (pg 6). Temperature model: may affect some of the processes related to toxics. Not applicable here – more applies to WQ. Pyrethroids Model: general - more runoff during rainy season. Is there an ammonia or nitrogen model? How do they relate? May not be applicable here, more from wastewater point sources.

Magnitude = 1
Not much sediment to mobilize.

Certainty = 2

Outcome N3: Increased freq. and magnitude of Low DO in SDWSC due to inc in algae/POM and impact on salmon/steelhead/G&W sturgeon passage.

N3a. Same for all species

Plus presence of fish species needs to be considered. Page 33 salmon model talks about DO as migration barrier and timing issue (juvenile not migrating when DO is an issue) Also see page 60 re adults. More of an issue for adult and juvenile salmon.

Magnitude = 1

Certainty = 4
Would not cause affects on species based on seasonality (more of a late summer fall issue

Outcome N4: Decreased downstream turbidity decreases habitat quality for delta smelt and longfin smelt.

N4. Same for delta and longfin smelt

Water moving out on the floodplain and settling out of sediment. Sediment Model: has a section on floodplain but does not specifically say it traps sediment. Figure 8 in sediment model makes link. Floodplain Model: no information found in model. We expect it would increase turbidity with export of phyto/zooplankton. May be a seasonality issue again – less phytoplankton in winter. Delta Smelt Model: Pg 2, 10, and 11 talk about turbidity as important habitat factor. Longfin Smelt Model: link to turbidity is poor (pg 7), they tend to hang out in turbid water.

(For potential addition to existing rationale) Floodplain model: Reduced water velocities on floodplains, due to topography and vegetation, results in the deposition of sediment, potentially decreasing turbidity (pg. 18).

Magnitude = 1

Certainty = 4

Outcome N5: Increased habitat for non-native predators/competitors to native fishes (Chinook salmon, steelhead, green and white sturgeon, and splittail).

N5a. Chinook salmon

Evidence from Yolo and Cosumnes about non-natives taking advantage of floodplain (ref Sommer et al 2004, Moyle et al 2006). Floodplain Model: Page 10 talks about sources of invasive species. Foodweb Model is focused on estuarine systems.

Chinook salmon and steelhead. The CS and steelhead model indicates Non-native predation and competition with invasive species and hatchery produced salmonids is of medium importance in rearing and emigration estuarine habitats, including floodplain (Figure 2a). There is limited data on CS and steelhead use of SJ floodplain (no mention in Rosenfield 2007) but the evaluation team thought there is no reason why they would not utilize this habitat in the same way they utilize similar Delta systems (Yolo Bypass).

Magnitude = 2
Based on perennial inundated benches, but not floodplains; benches may support more non-native predators.

Certainty = 4
Based on understanding high concentrations of non-natives in perennially shallow water areas of the San Joaquin (Grimaldo et al. 2003, Feyrer 2003).

N5b. Steelhead

Evidence from Yolo and Cosumnes about non-natives taking advantage of floodplain (ref Sommer et al 2004, Moyle et al 2006). Floodplain Model: Page 10 talks about sources of invasive species. Foodweb Model is focused on estuarine systems.

Chinook salmon and steelhead. The CS and steelhead model indicates Non-native predation and competition with invasive species and hatchery produced salmonids is of medium importance in rearing and emigration estuarine habitats, including floodplain (Figure 2a). There is limited data on CS and steelhead use of SJ floodplain (no mention in Rosenfield 2007) but the evaluation team thought there is no reason why they would not utilize this habitat in the same way they utilize similar Delta systems (Yolo Bypass).

Magnitude = 2
Based on perennial inundated benches, but not floodplains; benches may support more non-native predators.

Certainty = 4
Based on understanding high concentrations of non-natives in perennially shallow water areas of the San Joaquin (Grimaldo et al. 2003, Feyrer 2003).

N5c. Green and white sturgeon

DLO Relationship and General Observations:
Evidence from Yolo and Cosumnes about non-natives taking advantage of floodplain (ref Sommer et al 2004, Moyle et al 2006). Floodplain Model: Page 10 talks about sources of invasive species. Foodweb Model is focused on estuarine systems.

White sturgeon – model indicate probable distribution in this reach (Figure 7), green sturgeon model indicates uncertain distribution in this reach (Figure 2). Due to the benthic nature of green and white sturgeon and the timing of floodplain inundation they are not expected to be found on the floodplain (personal communication with Josh Israel 2009).

Magnitude = 1

Certainty = 2

N5d. Splittail

Evidence from Yolo and Cosumnes about non-natives taking advantage of floodplain (ref Sommer et al 2004, Moyle et al 2006). Floodplain Model: Page 10 talks about sources of invasive species. Foodweb Model is focused on estuarine systems.

Splittail model - Predation by non native fish is characterized as low with high understanding for juveniles and as medium with medium understanding for adults (Figures 5, 6 and 7.) Bird predation appears limited until water recedes and floodplains begin to isolate from main channels at which point fish are exposed to wading birds. [Moyle 2004].

Magnitude = 2

Certainty = 4

Outcome N6: Increased exposure risk to contaminants (including Selenium) due to longer residence time in this area.

N6a. Not evaluated by species.

Selenium (Se) loading of the Bay-Delta ecosystem is driven mainly by loads entering the Delta from the San Joaquin River (SJR), which in turn receives most of its Se input from agricultural drainwater entering the river through Mud Slough (Se model, Fig. 1). This project is along the mainstem SJR downstream of these Se inputs.

The proposed action involves habitat modification that creates more extensive floodplain and low velocity, shallow water habitats. These types of habitats create a better environment for Se partitioning in food chains than would occur in bed sediment of the river channel. Exposure of covered fish to Se might increase due to higher bioaccumulation of Se in invertebrate prey and longer residence time of the fish in the enhanced habitat.

Salmonids are relatively sensitive to Se compared to other fish (Se model, pg 19). Beckon (2008 abstract from CALFED science conference; manuscript in prep) evaluated Se data from the SJR and concluded that, although discharges of Se to the SJR have been reduced over the last 15 years, Se will pose a substantial risk to salmon that are reintroduced to restored middle reaches of the river unless Se loads are further reduced and/or sufficient dilution flows are provided. The magnitude of potential effects of Se from this project between Vernalis and Mossdale may be lower than would occur at projects along the middle reaches of the SJR mainstem (i.e., sites in the vicinity of Mud Slough) because this project occurs downstream of dilution sources from the Merced, Tuolumne and Stanislaus Rivers. However, this spatial difference does not provide strong protection because Se bioaccumulates in food chains, is recycled in the ecosystem, and can have significant lag times between when loading occurs and when effects are seen.

The seasonal use of the habitat may also reduce the potential magnitude of Se impacts to covered fish species, especially juvenile salmonids. Seasonal use of the Delta by juvenile salmonids occurs mainly during high flow periods (January-June)(salmon model, pg 11); whereas highest concentrations of Se occur during low flow periods (Se model, pg 6). However, this seasonal difference does not provide strong protection because Se bioaccumulates in food chains, is recycled in the ecosystem, and can have significant lag times between when loading occurs and when effects are seen.

The invertebrate prey of juvenile salmonids are water-column-feeding or detritus-feeding species that are less contaminated than certain suspension or deposit-feeding bivalves

(Se model, Table 5 and Fig. 1). Adult splittail and sturgeon feed on bivalves and would be expected to have greater exposure to Se in their diet than salmonids. This project is intended to provide rearing habitat for juvenile sturgeon and splittail rather than habitat for adults, but may also result in increased residence time by spawning and foraging adults. However, the bivalve species present at this freshwater location would be Corbicula fluminea rather than Corbula amurensis (Corbula and Corbicula models). C. fluminea is less efficient at bioaccumulating Se than C. amurensis (Se model, pg. 14).

Se dynamics in the Bay-Delta system are fairly well understood, but there is uncertainty about how changes in management of SJR flows, water exports, and potential future actions to solve the drainage problem on the west side of the San Joaquin Valley could affect Se loading and cycling in the Delta (Se model, pp. 3 and 4). A quantitative analysis of the increased risk of Se toxicity resulting from this project would require estimates of the increase in the amount of time covered fish spend at this location relative to the baseline condition, as well as estimates of future river flows, water exports, and Se loads. Such an analysis is beyond the scope of this worksheet exercise, but should be considered if the project is recommended for evaluation in the NEPA process.

Magnitude = 2

Certainty = 3

Important Gaps in Information and/or Understanding

Research Needs

- The basis of the assumption for the flooding frequency could be refined (Table 2, BDCP doc).
- Major gaps – rearing habitat for steelhead? Rearing habitat for juvenile sturgeon?
- Hg accumulation in fish has been documented, but does not indicate affect on fish.
- Degree of contaminants affects on POD.
- Degree of sediment settling on floodplains.
- Degree of predation/competition within floodplains on native covered fish species by non-native fish species.
- Better diet information is needed for floodplain use of SH, G/W Sturgeon;
- More info is needed about relative importance of food to population level effects for all of the species.
- Transport studies are needed to evaluate the footprint of food transport from floodplains.
- Timing duration of rearing for SH, G/W Sturgeon.
- The turbidity linkage for longfin smelt is not as well documented in the research as it is for delta smelt. Further studies positively linking turbidity and longfin smelt would be helpful.

Assess Reversibility and Opportunity for Learning

Reversibility

No/Hard

Comments:

- Would be monumental effort/cost to reconstruct levees
- Low reversibility with high resources associated with structural investments in setback levees. Land acquisition and jurisdiction also constraints.
- Implementation of this action would not provide a suitable opportunity to address critical unknowns or uncertainties. If action were implemented at a larger scale and with more-frequent inundation, this score may change.
- The change from existing conditions to as-built conditions is not strong for this action. Existing vegetation and channel shade already exist in many parts of the action area.

Opportunity for Learning

Low

Comments

Opportunity for learning associated with habitat improvements for San Joaquin Basin Chinook juveniles is scored low based on infrequency of inundation .An increase of habitat would not create monitoring ops that we would not be gained form other areas. Score would be higher if inundation was more frequent. Monitoring juvenile use of San Joaquin floodplains would advance understanding of juvenile Chinook in the San Joaquin basin. However we cannot conduct research on area that floods so infrequently. The 30 day inundation period (as written) is a high standard to meet.

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Chinook salmon
Splittail
Floodplain
Riparian
Longfin Smelt
Delta Smelt
Boundary Condition
Mercury
Selenium
Sedimentation
Temperature
Chemical Stressors/Pyrethroids
Dissolved Oxygen
Foodweb
Fish Habitat Linkages
T. Sommer pers comm. 2009
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SJRG annual reports 2004-2007
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J. Israel pers comm. 2009
Rosenfield 2007

Appendix A

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P6	All	Increased establishment of woody riparian vegetation to export LWD	2	3
P7a/b	Chinook salmon-San Joaquin	Increase establishment of woody riparian vegetation to provide shaded channel habitat	2	3
P8a	Delta smelt	Increased downstream turbidity improves habitat quality for delta smelt and longfin smelt	2	3-4
P5g	Delta smelt	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	2	3
P5a	Fall-run Chinook Salmon	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	2	3-4
P4a	Fall-run Chinook Salmon	Increase production of food for rearing Chinook salmon, steelhead, green/white sturgeon, splittail from inundation and riparian vegetation (local)	2	3-4
P3a	Fall-run Chinook Salmon	Create rearing habitat for Chinook salmon, green/white sturgeon, splittail and steelhead. Consider loss to entrainment.	2	3-4
P1a	Fall-run Chinook Salmon	Improve connectivity of seasonally inundated floodplain habitat for juvenile fish (Splittail, G/W sturgeon, Chinook salmon and steelhead)	2	3-4
P5e	Green Sturgeon	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	1	2
P4e	Green Sturgeon	Increase production of food for rearing Chinook salmon, steelhead, green/white sturgeon, splittail from inundation and riparian vegetation (local)	1	2
P3e	Green Sturgeon	Create rearing habitat for Chinook salmon, green/white sturgeon, splittail and steelhead. Consider loss to entrainment.	1	2
P1e	Green Sturgeon	Improve connectivity of seasonally inundated floodplain habitat for juvenile fish (Splittail, G/W sturgeon, Chinook salmon and steelhead)	1	2
P8b	Longfin smelt	Increased downstream turbidity improves habitat quality for delta smelt and longfin smelt	2	3
P5f	Longfin smelt	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	2	3

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes (contd.)				
P5c	Splittail	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	3	3-4
P4c	Splittail	Increase production of food for rearing Chinook salmon, steelhead, green/white sturgeon, splittail from inundation and riparian vegetation (local)	3	3-4
P3c	Splittail	Create rearing habitat for Chinook salmon, green/white sturgeon, splittail and steelhead. Consider loss to entrainment.	3	3-4
P2a	Splittail	Create additional splittail spawning habitat on floodplain	3	3-4
P1c	Splittail	Improve connectivity of seasonally inundated floodplain habitat for juvenile fish (Splittail, G/W sturgeon, Chinook salmon and steelhead)	3	3-4
P5b	Steelhead	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	2	2
P4b	Steelhead	Increase production of food for rearing Chinook salmon, steelhead, green/white sturgeon, splittail from inundation and riparian vegetation (local)	2	2
P3b	Steelhead	Create rearing habitat for Chinook salmon, green/white sturgeon, splittail and steelhead. Consider loss to entrainment.	2	2
P1b	Steelhead	Improve connectivity of seasonally inundated floodplain habitat for juvenile fish (Splittail, G/W sturgeon, Chinook salmon and steelhead)	2	2-3
P5d	White Sturgeon	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt	1	1
P4d	White Sturgeon	Increase production of food for rearing Chinook salmon, steelhead, green/white sturgeon, splittail from inundation and riparian vegetation (local)	1	1
P3d	White Sturgeon	Create rearing habitat for Chinook salmon, green/white sturgeon, splittail and steelhead. Consider loss to entrainment.	1-2	1
P1d	White Sturgeon	Improve connectivity of seasonally inundated floodplain habitat for juvenile fish (Splittail, G/W sturgeon, Chinook salmon and steelhead)	1-2	1

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Negative Outcomes				
N6a	All	Increased exposure risk to contaminants (including Selinium) due to longer residence time in this area	2	3
N3a	All	Increased frequency and magnitude of low DO in SDWSC due to an increase in algae/POM and impact on Chinook salmon, steelhead, and green and white sturgeon passage.	1	4
N2a	All	Increased resuspension/mobilization and export of toxic compounds with impact on covered species (consider time course of effect)	1	2
N1a	All	Increased MeHg and impact on covered species (direct or indirect)	1	3
N5a	Chinook salmon	Increased habitat for non-native predators/competitors to native fishes (Chinook salmon, steelhead, green and white sturgeon, and splittail)	2	4
N4	Delta smelt & Longfin smelt	Decreased downstream turbidity decreases habitat quality for longfin smelt and delta smelt	1	4
N5c	Green & White Sturgeon	Increased habitat for non-native predators/competitors to native fishes (Chinook salmon, steelhead, green and white sturgeon, and splittail)	1	2
N5d	Splittail	Increased habitat for non-native predators/competitors to native fishes (Chinook salmon, steelhead, green and white sturgeon, and splittail)	2	4
N5b	Steelhead	Increased habitat for non-native predators/competitors to native fishes (Chinook salmon, steelhead, green and white sturgeon, and splittail)	2	4

HRCM 2:
San Joaquin ROA (Downstream)

Scientific Evaluation Worksheet

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APPENDIX A **23**

Action: San Joaquin ROA Floodplain Restoration (downstream of Mossdale)

Evaluation Team: Floodplain and Riparian Workgroup
Campbell Ingram (chair), Denise Reed (coach), Carie Battistone (notetaker), Eric Ginney, Ted Sommers, Rosalie Del Rosario, Dennis McEwan, Bill Harrell, Dan Welsh, Yvette Redler, and Vance Russell.

Date of Last Revision: February 23, 2009

Action Description and Clarifying Assumptions

HRCM 2: Restore floodplain habitat along 6 to 12 miles of the San Joaquin River from Mossdale to French Camp Slough.

- **Option #1:** 363 acres (6 miles)
- **Option #2:** 725 acres (12 miles)

Approach

1. Set back levees along one side of the channel and remove all or large sections of the existing levees.
2. Contour floodplain area as needed to reduce and avoid the potential for stranding of juvenile and adult fish following inundation events.
3. Contour surface elevations along tidal reaches to allow natural establishment of tidal freshwater wetland and riparian habitat.
4. Modify channel where practicable within the restored floodplain reach to create low velocity habitat areas designed to provide spawning habitat for splittail and rearing habitat for splittail and salmonids.
5. Discontinue farming within setback levee where width will not support floodplain characteristics and farming practices.
6. Allow riparian vegetation to naturally establish
7. Allow channel to meander between the new levees through the natural processes of erosion and sedimentation.

Intended Outcomes as Stated in Conservation Measure

1. Expand the floodplain to allow flood waters to attenuate, improving access of juvenile fish, such as Chinook salmon and steelhead, to seasonally inundated floodplain habitat, and reducing flood risk to properties upstream and downstream.
2. Create additional spawning habitat for Sacramento splittail by expanding floodplain habitat area and providing in-channel spawning habitat by creating backwaters.
3. Create additional rearing habitat for San Joaquin Basin runs of Chinook salmon, Sacramento splittail, and possibly steelhead.
4. Increase the production of food for rearing salmonids, splittail, and other covered species.
5. Increase the availability and production of food in Delta channels downstream of restored floodplain habitat for delta smelt, longfin smelt, and other covered species by exporting organic material and phytoplankton, zooplankton, and other organisms produced from the inundated floodplain into Delta channels.

6. Increase habitat complexity by allowing the natural establishment and growth of woody riparian vegetation that will provide inputs of large woody debris into the river channel and provide overhead cover.

Positive

P1. Improved connectivity of seasonally inundated floodplain habitat for juvenile splittail, green and white sturgeon, Chinook salmon and steelhead.
P2. Additional splittail spawning habitat on floodplain.
P3. Additional rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment).
P4. Increased production of food for rearing splittail, green and white sturgeon, Chinook salmon and steelhead from inundation and riparian vegetation (local).
P5. Increased availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for splittail, green and white sturgeon, Chinook salmon, steelhead (off site), longfin smelt, and delta smelt.
P6. Increased establishment of woody riparian vegetation to export LWD.
P7. Increased establishment of woody riparian vegetation to provide shaded channel habitat.
P8. Increased downstream turbidity to improve habitat quality for longfin smelt and delta smelt.

Negative

N1. Increased MeHg and impact on covered species (direct or indirect).
N2. Increased resuspension/mobilization and export of toxic compounds with impact on covered species (consider time course of effect).
N3. Increased frequency and magnitude of low DO in SDWSC due to an increase in algae/POM and impact on Chinook salmon, steelhead, and green and white sturgeon passage.
N4. Decreased downstream turbidity decreases habitat quality for longfin smelt and delta smelt.
N5. Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail.
N6. Increased exposure risk to contaminants (including Selenium) due to longer residence time in this area.

General Conceptual Model Support for Intended Outcomes

DRERIP models were referenced in evaluations, along with several outside sources.

Models used:
Salmon (Williams/Rosenfield 2007)
Splittail
Floodplain
Riparian
Longfin Smelt
Delta Smelt
Boundary Condition
Mercury
Selenium
Sedimentation
Temperature
Chemical Stressors/Pyrethroids
Dissolved Oxygen
Foodweb
Fish Habitat Linkages

Other sources:
T. Sommer pers comm. 2009
McEwan 2001

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Hatton 1940
Healy 1991
Ward et al 2003
Kjelson 1982
SJRG annual reports 2004-2007
Caswell annual report 2004-2007
J. Israel pers comm. 2009
Rosenfield 2007

Assumptions

Provided in BDCP Conservation Measure

1. 500 foot setback on one side.
2. 363 acres for 6 mile option.
3. 725 acres for 12 mile option.
4. Approximately half of the acreage would flood for at least 30 days every 7 years; all of the acreage would flood for at least 30 days approximately every 20 years.

Added by Evaluation Team

1. Assumes choke point at Mossdale on river distinguishes between tidal and non-tidal.
2. Assumes no lowering of floodplain to increase inundation
3. Assume all South Delta work will be contingent on significant reduction in south Delta entrainment (need to evaluate some negative outcomes with both 1) Old River isolated and 2) current configuration and reduced pumping (i.e., dual conveyance)).

Problem(s) with Action as Written:

1. Natural recruitment of desirable, native riparian vegetation seems unreasonable given the infrequent inundation of the site (the entire site only floods for a significant duration every 20 years).
2. Took out "(including aquatic, floodplain, intertidal marsh, and riparian features)" from the original stated action.
3. Contouring needs further explanation – focused on stranding not on connections.
4. The floodplain inundation target of "half of the acreage would flood for at least 30 days every 7 years; all of the acreage would flood for at least 30 days approximately every 20 years" will likely be hard to reach. Ultimately this assumption affects overall scoring.

Scale of Action:

Option #1 – LARGE SCALE (50% increase in habitat area)
Option #2 – LARGE SCALE (100% increase in habitat area)

Rationale:
Relative magnitude depends on system-wide condition. During flood events you have a large increase in area inundated.

Evaluation Summary Tables

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in Appendix A. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes on the following pages.

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

YES

Nature of Change:

Levees appear to be more channelized. Levees are not continuous. The level of inundation/flow this action will create increases. Modeling has been sparse in this area – had to make broad assumptions.

Existing Acreages: 233 acres (Moss-French)

The effects associated with levee setbacks can be considered within our current understanding of the system.

Note: Would help to describe the relation to historical conditions to help us understand the level of habitat to restore.

Potential Positive Ecological Outcome(s)

Outcome P1: Improve connectivity of seasonally inundated floodplain habitat for juvenile fish (splittail, green and white sturgeon, Chinook salmon and steelhead).

P1a. Fall-run Chinook salmon

Human-built features reduce connectivity to floodplain habitat for salmon (Floodplain Model. Text doesn't specifically state salmon but it cites Ted's paper (Sommer et al. 2005, which does).

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 3-4
Given data on flooding and studies elsewhere

P1b. Steelhead

Same information for flooding for Chinook Salmon. They are there (McEwan 2001) at the time (life stage table – Figure 3). Emigrating Jan-August, peak in Jan-May (based on Sacramento River information). Mossdale trawl data (Rosalie provided – FWS 2007) shows more fish occur. Floodplain (page 27) says no information on steelhead use of floodplain. Steelhead model (Fig 2 of steelhead section in salmonid model, p155) shows floodplain use. Williams (2006), McEwan (2001) and Moyle (2002) support presence.

Page15-16 of salmon model shows estuarine habitat – may show import for lower reach.

Steelhead have been caught on floodplain in Yolo (Sommer, T., B. Harrell, M. Nobriga, R. Brown, P. Moyle, W. Kimmerer, and L. Schemel. 2001. California's Yolo Bypass: evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture. Fisheries 26:6-16.). Some reference in Williams 2006 – chapter 9, page 174.

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 2
Non-peer reviewed references.

P1c. Splittail

Splittail model page 12 describes how loss of connectivity has resulted in habitat loss; Floodplain model page 18: human-built features such as berms, ditches, etc. reduce connectivity to floodplain habitat.

Magnitude = 3
Given longer life span means it can take advantage of more flashy system.

Certainty = 3-4

P1d. White Sturgeon

Same information for flooding for Chinook salmon. No evidence of juvenile use of floodplains. Adult catch in Yolo are adults (Harrell and Sommer 2003). This mechanism described above is assumed to apply to white sturgeon (Sommer et al 2005 and Floodplain Model).

Magnitude = 1-2

Certainty = 1
Understanding of sturgeon on floodplain is low and needs further study, e.g., could have higher worth if better understood. It is difficult to determine whether to eliminate sturgeon based on understanding of their use of floodplains.

P1e. Green Sturgeon

Same information for flooding for Chinook salmon. No evidence of juvenile use of floodplains. Adult catch in Yolo are adults (Harrell and Sommer 2003). This mechanism described above is assumed to apply to WS (Sommer et al 2005 and Floodplain Model).

Magnitude = 1

Certainty = 2
Understanding of sturgeon on floodplain is low and needs further study, e.g., could have higher worth if better understood. It is difficult to determine whether to eliminate sturgeon based on understanding of their use of floodplains.

Outcome P2: Create additional spawning habitat (splittail) on floodplain.

P2. Splittail

Floodplain model page 25 and Splittail model pages 9 and 12 describe how additional floodplain habitat supports splittail spawning.

Magnitude = 3
Given longer life span means can take advantage of more flashy system.

Certainty = 3-4

Outcome P3: Create rearing habitat for Chinook salmon, green and white sturgeon, splittail and steelhead. Consider loss to entrainment.

P3a. Fall-run Chinook salmon

Assumption gives duration and frequency. BDCP document shows historic timing is late winter spring. Boundary Condition model (p. 49) shows peaks occur in February period.

Fall-run Chinook salmon juveniles are present in the area during the proposed floodplain inundation period of late winter and spring. San Joaquin fall-run Chinook juveniles enter Delta either as: 1) fry/parr) with high winter flows, typically in January through March (size of 20 to 60 mm fork length, or as 2) smolts after mid March(> 60 mm fork length; (Caswell Annual Report 2007, SJRG 2004, 2005, 2006)

Delta presence of fry confirmed by:

- Presence at Mossdale and Salvage facilities during Jan – March
- San Joaquin River Trawl Dos Reis(RM 51) –Laird(RM 90)
- Salmon < 50mm January through March
- Apparent that much of Tuolumne/Stanislaus River emigrated as fry and pre-smolts with early flood flows in Jan – March…..Early migrants not captured in high numbers at Mossdale/Salvage indicating that juveniles may have remained in the lower San Joaquin above Mossdale….” (SJRG annual report 2006 page 75, 2007 page 66).
- Densities of fry may be underrepresented due to both the trawl and salvage being relatively less effective at capturing fry (Salmon less than 50 mm long). (SJRG 2006 Annual Report page 72)
- Fall run Chinook (Fig 2c) shows juvenile fry/par stage during winter/spring.
- Most Fry enter Delta from tributaries before April (January through March), Smolt enter mid March – June (Based on USFWS/CDFG Mossdale trawl data , SJRG annual reports 2004-2007, Caswell annual report 2007.)

Fall-run Chinook salmon juveniles would use the floodplain to rear. The restored floodplain would create rearing habitat for fry/parr that enter the Delta in the winter, coincident with inundation of the floodplain. These fry would be able to feed and grow in the floodplain, and their larger size would increase the likelihood of survival in the ocean.

- Chinook salmon use the delta inversely proportional to their size (Williams 2006).
- Smolts migrate directly through delta to ocean.
- Fry likely do not migrate out of delta until smolt size. (SJRG annual report 2004 page 76)
- Shallow water habitats including river floodplains and riparian margin provide rearing habitat. Growth rates for juvenile Salmon are higher and emigration rates are slower when in shallow water rearing habitats. (Kjelson 1982, Sommer 2005)
- “during very high flows, fry simply get swept downstream…because the turbulence is too strong for them to resist” (Williams 2006, page76)
- “ Fry tend to keep to the margins of large rivers”(Hatton 1940, Healy 1991) meaning fry can move at a slower rate then the river especially if they have access to floodplains where they can find slower moving water.
- Fry that lingered in lower reaches of creek or bypass grew to 70-80mm compared to fry that migrated quickly and averaged 40mm (Ward et all 2003)

Floodplains no longer exist along the lower San Joaquin River, but fall-run Chinook salmon would likely use the restored floodplains, as they have been documented to rear in Yolo Bypass floodplain along the lower Sacramento River.

- CV Chinook salmon may have relied extensively on floodplain in the past as historically much of the central valley was floodplain habitat (Hunter et al 1999)
- Williams (2006 article 2) confirmed fall Chinook emigration if Feb-Mar on SJ. Floodplain model (Fig 7 and assoc text) identifies that floodplains provide habitat for CS.
- "Given the temporal and geographic distribution, (Fall-run juvenile) have more opportunities to use floodplain habitats then do other Central Valley runs" (Rosenfield 2007).
- Sommer et al (2005) reported extensive use of Yolo and Sutter bypasses by fall-run.
- Moyle et al (2007) reported use of Cosumnes River floodplain

Limited data on SJ floodplain (none in Floodplain model) No reason to suggest they should behave different from other systems.

Magnitude = 2
Given limited temporal effect in frequency. Availability of floodplain is infrequent, with partial inundation every 7 years. This floodplain would be unavailable for least 2 generations of San Joaquin fall run, of which the majority are 3 year old spawners, with some 2 year old spawners (Myers et al. 1998, p. 61).

Certainty = 3-4
Given data on flooding and studies elsewhere. There is high certainty that juvenile salmon are in the vicinity, and inference juveniles would rear in restored floodplain based on documented rearing in the Yolo Bypass and the restored Cosumnes River floodplain.

P3b. Steelhead

Same information for flooding for Chinook salmon. They are there at the time (McEwan 2001 life stage table – Figure 3 - emigrating Jan-August, peak in Jan-May -based on Sacramento River information). Mossdale trawl data (Rosalie provided – FWS 2007) shows more fish occur. Floodplain Model (page 27) says no information on steelhead use of floodplain. Steelhead model (Fig 2 of steelhead section in salmonid model, p155) shows floodplain use. Williams (2006), McEwan (2001) and Moyle (2002) supports presence.

Page15-16 of salmon model shows estuarine habitat – may show import for lower reach.

Steelhead have been caught on floodplain in Yolo (Sommer, T., B. Harrell, M. Nobriga, R. Brown, P. Moyle, W. Kimmerer, and L. Schemel. 2001. California's Yolo Bypass: evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture. Fisheries 26:6-16.). Some reference in Williams 2006 – chapter 9, page 174.

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 2-3
Non–peer reviewed references.

P3c. Splittail

Same information for flooding for Chinook salmon. Table 1 page 3 in Splittail Model indicates juveniles use floodplain Feb-May, distribution shows they are in SJ. based on Baxter sampling (mostly unpublished). Cosumnes publications (Crain et al 2004 conf proc.), Moyle et al 2004. SFEWS. Still not much information from SJ – same inference, no reason to believe they would behave differently.

Magnitude = 3
Given longer life span means can take advantage of more flashy system.

Certainty = 3-4
Given data on flooding and studies elsewhere.

P3d. White Sturgeon

Same information for flooding for Chinook salmon. No evidence of juvenile use of floodplains. Adult catch in Yolo are adults (Harrell and Sommer 2003).

This mechanism described above is assumed to apply to WS (Sommer et al 2005 and Floodplain Model).

Magnitude = 1-2

Certainty = 1
Understanding of sturgeon on floodplain is low and needs further study, e.g., could have higher worth if better understood. It is difficult to determine whether to eliminate sturgeon based on understanding of their use of floodplains.

P3e. Green sturgeon

Same information for flooding for Chinook salmon. No evidence of juvenile use of floodplains. Adult catch in Yolo are adults (Harrell and Sommer 2003).

This mechanism described above is assumed to apply to WS (Sommer et al 2005 and Floodplain Model).

Magnitude = 1

Certainty = 2
Understanding of sturgeon on floodplain is low and needs further study, e.g., could have higher worth if better understood. It is difficult to determine whether to eliminate sturgeon based on understanding of their use of floodplains.

Outcome P4: Increase production of food for rearing Chinook salmon, steelhead, green and white sturgeon, and splittail from inundation and riparian vegetation (local).

P4a. Fall-run Chinook salmon

Floodplain Model pages 20-25 - high levels of food production on floodplain provides support for magnitude score. Floodplain Model pages 27 and 29 describe utilization and higher growth rates for Chinook salmon on floodplains. Chinook salmon likely take advantage of small fishes on the floodplain (Splittail Model page 8 and Moyle et al. 2004).

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 3-4
Given data on flooding and studies elsewhere.

P4b. Steelhead

Floodplain Model pages 20-25 - high levels of food production on floodplain provides support for magnitude score. Steelhead feeding on floodplains is not described in the literature. However, it can be assumed that they are utilizing the same food sources as juvenile salmon, given their life-history similarities. Moyle 2002 states that stream-dwelling rainbow trout feed mostly on drifting aquatic orgs, terrestrial insects, and bottom dwelling orgs which are in abundance on floodplains.

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 2
Non-peer reviewed.

P4c. Splittail

Floodplain Model pages 20-25 - high levels of food production on floodplain provides support for magnitude score. Floodplain Model pages 25 and 27 describes utilization and higher survival for splittail on floodplains.

Magnitude = 3
Given longer life span means can take advantage of more flashy system.

Certainty = 3-4

P4d. White sturgeon

Floodplain Model pages 20-25 - high levels of food production on floodplain provides support for magnitude score.

This mechanism described Chinook salmon is assumed to apply to white sturgeon (Sommer et al 2005 and Floodplain Model).

Magnitude = 1
No evidence of juvenile use of floodplains. Catch in Yolo are adults (Harrell and Sommer 2003).

Certainty = 1
Understanding of sturgeon on floodplain is low and needs further study, e.g., could have higher worth if better understood, group had difficulty determining whether to eliminate sturgeon based on understanding of their use of floodplains.

P4e. Green sturgeon

Floodplain Model pages 20-25 - high levels of food production on floodplain provides support for magnitude score. This mechanism described for Chinook salmon is assumed to apply to green sturgeon (Sommer et al 2005 and Floodplain Model).

Magnitude = 1
No evidence of juvenile use of floodplains. Catch in Yolo are adults (Harrell and Sommer 2003).

Certainty = 2
Understanding of sturgeon on floodplain is low and needs further study, e.g., could have higher worth if better understood, group had difficulty determining whether to eliminate sturgeon based on understanding of their use of floodplains.

Outcome P5: Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt.

P5a. Fall-run Chinook salmon

Floodplain Model pages 20-25 - high levels of food production on floodplain provides support for magnitude score. Floodplain Model pages 27 and 29 describe utilization and higher growth rates for Chinook salmon on floodplains. Chinook salmon likely take advantage of small fishes on the floodplain (Splittail Model page 8 and Moyle et al. 2004).

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 3-4
Given data on flooding and studies elsewhere.

P5b. Steelhead

Floodplain Model pages 20-25 - high levels of food production on floodplain provides support for magnitude score.

Steelhead feeding on floodplains is not described in the literature. However, it can be assumed that they are utilizing the same food sources as juvenile salmon, given their life-history similarities. Moyle 2002 states that stream-dwelling rainbow trout feed mostly on drifting aquatic orgs, terrestrial insects, and bottom dwelling organisms which are in abundance on floodplains.

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 2
Non-peer reviewed.

P5c. Splittail

Floodplain Model pages 20-25 - high levels of food production on floodplain provides support for magnitude score. Floodplain Model pages 25 and 27 describes utilization and higher survival for splittail on floodplains.

Magnitude = 3
Given longer life span means can take advantage of more flashy system.

Certainty = 3-4

P5d. White sturgeon

Floodplain Model pages 20-25 - high levels of food production on floodplain provides support for magnitude score. This mechanism described Chinook salmon is assumed to apply to white sturgeon (Sommer et al 2005 and Floodplain Model).

Magnitude = 1
No evidence of juvenile use of floodplains. Catch in Yolo are adults (Harrell and Sommer 2003).

Certainty = 1
Understanding of sturgeon on floodplain is low and needs further study, e.g., could have higher worth if better understood, group had difficulty determining whether to eliminate sturgeon based on understanding of their use of floodplains.

P5e. Green sturgeon

Floodplain Model pages 20-25 - high levels of food production on floodplain provides support for magnitude score. This mechanism described for Chinook salmon is assumed to apply to green sturgeon (Sommer et al 2005 and Floodplain Model).

Magnitude = 1

No evidence of juvenile use of floodplains. Catch in Yolo are adults (Harrell and Sommer 2003).

Certainty = 2
Understanding of sturgeon on floodplain is low and needs further study, e.g., could have higher worth if better understood, group had difficulty determining whether to eliminate sturgeon based on understanding of their use of floodplains.

P5f. Longfin smelt

Longfin smelt Model page 21 describes the importance of zooplankton.

Magnitude = 2
Given limited temporal effect in frequency; occur under extreme high flow events when food is less likely a constraint.

Certainty = 3

P5g. Delta smelt

Delta smelt Model page 12 describes the importance of zooplankton.

Magnitude = 2
Given limited temporal effect in frequency; occur under extreme high flow events when food is less likely a constraint.

Certainty = 3

Outcome P6: Increase establishment of woody riparian vegetation to export LWD.

This evaluation applies to all covered species (i.e. species were not evaluated individually. Scores apply to both options. Assumption for action HRCM2 gives duration and frequency of inundation of the floodplain.

Many factors and processes influence natural recruitment of woody riparian vegetation, and are summarized in the DRERIP Riparian Vegetation Model. Figures 5, 6, & 7 of that model demonstrate how levees disrupt the setting of the "physical template" (the surface hydrology and floodplain scouring processes necessary for that template) that is necessary for natural recruitment to occur. Actions in HRCM1 would result in reduction of that stressor (setting back the levee), which would allow for increased establishment of woody riparian vegetation. The altered flow regime of the San Joaquin River system would not be modified by this action, and would therefore remain as a stressor and (in combination with altered channel and floodplain morphology) this would still limit inundation frequency and duration of the site. Thus, while natural riparian vegetation recruitment in the setback area would be possible, infrequent natural flooding may encourage invasive species recruitment (DRERIP Riparian Model, page 20) because surface water and groundwater hydrology drive the recruitment and establishment parameters of vegetation somewhat independently of the physical template. Specifically, this includes recruitment parameters for necessary seedling survival and changes in biotic competition and anoxia that may favor invasive species over native species that are flood-tolerant or require flooding to establish. Infrequent inundation also translates to infrequent LWD export from the area of increased vegetation.

Chinook salmon likely take advantage of small fishes on the floodplain (Splittail Model page 8 and Moyle et al. 2004).

Magnitude = 2
Magnitude score is based on effect being local (e.g., 7 or 14 mile reach) to regional (LWD would move downstream) in scale. However, because new floodplain areas would not be inundated very frequently (and hence the increase in LWD recruitment would be sporadic), the temporal effect is low. The DRERIP Floodplain Model (pages 5, 6, & 7) describes how flood flows modify the floodplain and interact with riparian vegetation to recruit LWD. The approach to Action HRCM1 will set back levees allowing vegetation recruitment (and flooding) where it is currently precluded; however, the action will not modify the floodplain morphology or increase flood hydrology in terms of frequency or duration. Thus, while riparian vegetation may be increased by the action, because of the morphology of the site and other stressors (specifically, impaired flood hydrology), the inundation frequency—and hence the LWD export—is likely to be infrequent (e.g., every 7 years for half the new floodplain; every 20 years for the entire floodplain). Therefore, while this outcome is positive, the actual increase in LWD export is likely to be relatively infrequent and thus of low magnitude.

Certainty = 3
Certainty score is based on dependence of outcome on variable ecosystem processes (i.e., flooding needed to cause LWD input is highly variable—e.g., every 7 to 20 years based on modeling).

Outcome P7: Increase establishment of woody riparian vegetation to provide shaded channel habitat.

P7a. 6-mile reach option

The DRERIP Riparian Model (interactions with floodplains as shown in Figure 5, and specifically the Riparian Vegetation Sub-model; green box in Figure 5) produces a conceptual framework for illustrating the creation of the physical “shaded riverine aquatic habitat” that would be provided by action HRCM1. Removing levees or eliminating vegetation clearing at the river’s edge would allow for increased establishment of woody riparian vegetation.

Based on assumptions and approach to HRCM1, “modifications” to the channel will be made to benefit splittail spawning and provide splittail and salmonid rearing habitat. Ostensibly, this would include addition of instream LWD, but because riparian vegetation is assumed to come from “natural recruitment”, any increase in woody riparian vegetation establishment (and hence increased shade) along the banks would be expected to occur only in areas where current levees (without vegetation) are located immediately adjacent to the river, or vegetation along the river is cleared all the way up to the edge of the river.

Benefit to covered species would be dependant on water temperature effects. Shade would reduce the amount of shortwave radiation striking the water (see Figure 1, DRERIP Temperature model); however, at this fine habitat-level scale, while shading is important, its influence is difficult to prescribe quantitatively (DRERIP Temperature model, page 6). Predicting the magnitude of the shading effect is beyond the level of the conceptual models.

Magnitude = 3
Currently, in the action area for both 6 & 12 mile versions of the action, the levees along the river are immediately adjacent to the channel for the vast majority of the reach (Google Earth satellite imagery; DRERIP-BDCP maps). The levees in this reach are almost entirely devoid of woody riparian vegetation. The action would allow for a substantial change in vegetation and shading within the local reach. Compared to the HRCM1 action [7 or 14 mile versions] the relative opportunity for levee setback, even on only one bank, as in HRCM2, to increase woody riparian vegetation, and hence shade the channel, immediately adjacent to the channel is higher.

Certainty = 2
Certainty score is based on dependence on external factors and the lack of predictability in the outcome directly supporting covered species.

P7b. 12-mile reach option

The DRERIP Riparian Model (interactions with floodplains as shown in Figure 5, and specifically the Riparian Vegetation Sub-model; green box in Figure 5) produces a conceptual framework for illustrating the creation of the physical "shaded riverine aquatic habitat" that would be provided by action HRCM1. Removing levees or eliminating vegetation clearing at the river's edge would allow for increased establishment of woody riparian vegetation.

Based on assumptions and approach to HRCM1, "modifications" to the channel will be made to benefit splittail spawning and provide splittail and salmonid rearing habitat. Ostensibly, this would include addition of instream LWD, but because riparian vegetation is assumed to come from "natural recruitment", any increase in woody riparian vegetation establishment (and hence increased shade) along the banks would be expected to occur only in areas where current levees (without vegetation) are located immediately adjacent to the river, or vegetation along the river is cleared all the way up to the edge of the river.

Benefit to covered species would be dependant on water temperature effects. Shade would reduce the amount of shortwave radiation striking the water (see Figure 1, DRERIP Temperature model); however, at this fine habitat-level scale, while shading is important, its influence is difficult to prescribe quantitatively (DRERIP Temperature model, page 6). Predicting the magnitude of the shading effect is beyond the level of the conceptual models.

Magnitude = 3
Currently, in the action area for both 6 & 12 mile versions of the action, the levees along the river are immediately adjacent to the channel for the vast majority of the reach (Google Earth satellite imagery; DRERIP-BDCP maps). The levees in this reach are

almost entirely devoid of woody riparian vegetation. The action would allow for a substantial change in vegetation and shading within the local reach. Compared to the HRCM1 action [7 or 14 mile versions] the relative opportunity for levee setback, even on only one bank, as in HRCM2, to increase woody riparian vegetation, and hence shade the channel, immediately adjacent to the channel is higher.

Certainty = 2
Certainty score is based on dependence on external factors and the lack of predictability in the outcome directly supporting covered species.

Outcome P8: Increased downstream turbidity improves habitat quality for delta smelt and longfin smelt.

P8a. Delta smelt

Positive link between delta smelt and turbidity throughout life-history is well documented in both lab and field studies. Longfin smelt abundance appears to be positively linked with turbidity, although less research is available.

Action assumes relatively infrequent inundation events. Inundation will suspend and mobilize sediment from the restored floodplain, increasing turbidity in the water column downstream. Floodplain model: Sediment on floodplains can be resuspended by flows or turbulence such as wind-generated waves (page. 18). Sediment model: The Yolo Bypass floodplain, when inundated, can be a large source of sediment to the Sacramento River (page. 9). A restored floodplain on the San Joaquin River could be a source for suspended sediment downstream, assuming it functions similarly to the Yolo Bypass. Delta smelt model: Turbidity increases larval feeding success (page. 4-5); turbidity conceals juvenile delta smelt from predation (page. 7); and juveniles are most abundant in areas with low water transparency (page. 11). Longfin smelt model: Longfin smelt occurring in turbid water have reduced exposure to predation (pages. 7, 8, 13). Although less information is available for longfin, they likely benefit from higher levels of turbidity in similar ways to delta smelt.

Channel migration and bank erosion could be considered as an intermediate outcome.

Magnitude = 2
Limited temporal and population level effect due to low frequency of inundation (given in assumptions).

Certainty = 3-4

P8b. Longfin smelt

The discussion provided for delta smelt in the above paragraphs is also applicable here.

Magnitude = 2
Limited temporal and population level effect due to low frequency of inundation (given in assumptions).

Certainty = 3

Potential Negative Ecological Outcome(s)

Outcome N1: Increased MeHg and impact on covered species (direct or indirect).

N1a. Same for all species

An initial spike in MeHg would be expected when the newly created floodplain habitat in areas where levees are being set back is inundated for the first time (Hg model, page 15, 18). Although concentrations may attenuate from the initial spike over time, MeHg production would likely remain relatively high compared to other types of habitats. Habitats with the highest levels of MeHg production, concentration, and exposure to biota are those with periodic flooding events separated by sufficient time to allow complete drying, such as the seasonal floodplains that would be created in this project (Hg model, page 15). Covered fish species using the restored habitat would be exposed to MeHg through their food chain, and MeHg would be exported downstream along with organic matter and organisms. The effects on fish, if any, would be minimal in most years due to the infrequency of inundation (inundated >30 days once every 7 to 20 years).

The linkage of seasonal flooding to MeHg production and subsequent bioaccumulation of MeHg in fish and their prey is well documented. Effects of this bioaccumulation on covered fish species are more uncertain, due to lack of studies of toxicological effects of MeHg on covered species, uncertainty about sensitivity of covered species relative to species that have been studied, and the subtle nature of the behavioral effects (e.g., impaired predator avoidance and feeding efficiency) that are among the most sensitive endpoints for MeHg toxicity and are difficult to detect.

Magnitude = 1

Certainty = 3
Based on level understanding of affects on fish species.

Outcome N2: Increased resuspension/mobilization and export of toxic compounds w/impact on covered species (consider time course of effect).

The information provided here (including scores) is applicable to all covered fish species. The habitat is being enhanced to facilitate spawning by splittail and rearing by splittail and other species. Current land uses on and adjacent to the project area are agricultural, including orchards and other crops that receive pesticide applications. Pyrethroids, a class of pesticides used as dormant sprays on orchards, can be toxic to fish, especially to early life stages (Pyrethroids model, page 16). Pyrethroid concentrations would be expected to peak during the winter/spring storm season and after peak agricultural application in the summer and fall (Pyrethroids model, page 2). Late-winter and spring are also the times splittail would use the enhanced floodplain habitat to spawn (Splittail model, page 1). Effects of pesticides, if any, would be greatest in the early years of the project as pesticides that have accumulated in agricultural soils are mobilized. Potential for pesticide effects would decrease over time in the restored areas where farming will be discontinued, but may continue in areas that continue to be farmed or are affected by runoff from adjacent agricultural areas.

There are critical data gaps on pyrethroids and other pesticides that make it difficult to evaluate risk to covered fish (Pyrethroids model, page 32; Chemical stressors model, page 25). In general, little is known about the toxic effects of contaminants known to be present in the Delta on resident Delta species, and even less is known about the sublethal effects of contaminants (Chemical stressors model, page 25). Clarification is needed on how much of the restored floodplain areas would be farmed when they are not inundated, as the amount and type of ongoing farming and pesticide use would affect the magnitude and duration of potential effects of pesticides on covered fish.

Magnitude = 1
Not much sediment to mobilize.

Certainty = 2

Outcome N3: Increased frequency and magnitude of low DO in SDWSC due to increase in algae/POM and impact on salmon, steelhead, and green and white sturgeon passage.

The information provided here (including scores) is applicable to all covered fish species. Plus presence of fish species needs to be considered. Page 33 salmon model talks about DO as migration barrier and timing issue (juvenile not migrating when DO is an issue). Also see page 60 regarding adults. More of an issue for adult and juvenile salmon.

Magnitude = 1

Certainty = 4
Would not cause affects on species based on seasonality (more of a late summer fall issue

Outcome N4: Decreased downstream turbidity decreases habitat quality for delta smelt and longfin smelt.

The information provided here (including scores) is applicable to all covered fish species. Water moving out on the floodplain and settling out of sediment. Sediment Model: has a section on floodplain but does not specifically say it traps sediment. Figure 8 in sediment model makes link. Floodplain Model: no information found in model. We expect it would increase turbidity with export of phyto/zooplankton. May be a seasonality issue again – less phytoplankton in winter. Delta Smelt Model: pages 2, 10, and 11 talk about turbidity as important habitat factor. Longfin Smelt Model: link to turbidity is poor (page 7), they tend to hang out in turbid water.

Floodplain model: Reduced water velocities on floodplains, due to topography and vegetation, results in the deposition of sediment, potentially decreasing turbidity (page. 18).

Channel migration and bank erosion may be considered as an intermediate outcome.

Magnitude = 1

Certainty = 4

Outcome N5: Increased habitat for non-native predators/competitors to native fishes (Chinook salmon, steelhead, green and white sturgeon, and splittail).

Delta and longfin smelt, all life stages are typically not present in this part of the Delta (Delta smelt model and longfin smelt model), therefore no competition or predation would be expected.

N5a. Chinook salmon

The floodplain model does not address non native predation or competition on the floodplain. Evidence from Yolo and Cosumnes about non-natives taking advantage of floodplain (ref Sommer et al 2004, Moyle et al 2006). Floodplain Model: Page 10 talks about sources of invasive species. Foodweb Model is focused on estuarine systems.

The Chinook salmon and steelhead model indicates Non-native predation and competition with invasive species and hatchery produced salmonids is of medium importance in rearing and emigration estuarine habitats, including floodplain (Figure 2a). There is limited data on CS and steelhead use of SJ floodplain (no mention in Rosenfield 2007) but the evaluation team thought there is no reason why they would not utilize this habitat in the same way they utilize similar Delta systems (Yolo Bypass).

Magnitude = 2
Based on perennial inundated benches, but not floodplains; benches may support more non-native predators.

Certainty = 4
Based on understanding high concentrations of non-natives in perennially shallow water areas of the San Joaquin (Grimaldo et al. 2003, Feyrer 2003).

Risk = Low

N5b. Steelhead

The floodplain model does not address non native predation or competition on the floodplain. Evidence from Yolo and Cosumnes about non-natives taking advantage of floodplain (ref Sommer et al 2004, Moyle et al 2006). Floodplain Model: Page 10 talks about sources of invasive species. Foodweb Model is focused on estuarine systems.

The Chinook salmon and steelhead model indicates Non-native predation and competition with invasive species and hatchery produced salmonids is of medium importance in rearing and emigration estuarine habitats, including floodplain (Figure 2a). There is limited data on CS and steelhead use of SJ floodplain (no mention in Rosenfield

2007) but the evaluation team thought there is no reason why they would not utilize this habitat in the same way they utilize similar Delta systems (Yolo Bypass).

Magnitude = 2
Based on perennial inundated benches, but not floodplains; benches may support more non-native predators.

Certainty = 4
Based on understanding high concentrations of non-natives in perennially shallow water areas of the San Joaquin (Grimaldo et al. 2003, Feyrer 2003).

N5c. Green and white sturgeon

The floodplain model does not address non native predation or competition on the floodplain. Evidence from Yolo and Cosumnes about non-natives taking advantage of floodplain (ref Sommer et al 2004, Moyle et al 2006). Floodplain Model: Page 10 talks about sources of invasive species. Foodweb Model is focused on estuarine systems.

White sturgeon – model indicate probable distribution in this reach (Figure 7), green sturgeon model indicates uncertain distribution in this reach (Figure 2). Due to the benthic nature of green and white sturgeon and the timing of floodplain inundation they are not expected to be found on the floodplain (personal communication with Josh Israel 2009).

Magnitude = 1

Certainty = 2

N5d. Splittail

The floodplain model does not address non native predation or competition on the floodplain. Evidence from Yolo and Cosumnes about non-natives taking advantage of floodplain (ref Sommer et al 2004, Moyle et al 2006). Floodplain Model: Page 10 talks about sources of invasive species. Foodweb Model is focused on estuarine systems.

Splittail model - Predation by non native fish is characterized as low with high understanding for juveniles and as medium with medium understanding for adults (Figures 5, 6 and 7.) Bird predation appears limited until water recedes and floodplains begin to isolate from main channels at which point fish are exposed to wading birds. [Moyle 2004].

Magnitude = 2

Certainty = 4

Outcome N6: Increased exposure risk to contaminants (including Selenium) due to longer residence time in this area.

The information presented here (including scores) is applicable to all covered fish species. Selenium (Se) loading of the Bay-Delta ecosystem is driven mainly by loads entering the Delta from the San Joaquin River (SJR), which in turn receives most of its Se input from agricultural drainwater entering the river through Mud Slough (Se model, Fig. 1). This project is along the mainstem SJR downstream of these Se inputs.

The proposed action involves habitat modification that creates more extensive floodplain and low velocity, shallow water habitats. These types of habitats create a better environment for Se partitioning in food chains than would occur in bed sediment of the river channel. Exposure of covered fish to Se might increase due to higher bioaccumulation of Se in invertebrate prey and longer residence time of the fish in the restored habitat. The effect would be minimal due to the infrequency of inundation (inundated >30 days once every 7 to 20 years).

Se dynamics in the Bay-Delta system are fairly well understood, but there is uncertainty about how changes in management of SJR flows, water exports, and potential future actions to solve the drainage problem on the west side of the San Joaquin Valley could affect Se loading and cycling in the Delta (Se model, pp 3 and 4). A quantitative analysis of the increased risk of Se toxicity resulting from this project would require estimates of the increase in the amount of time covered fish spend at this location relative to the baseline condition, as well as estimates of future river flows, water exports, and Se loads. Such an analysis is beyond the scope of this worksheet exercise, but should be considered if the project is recommended for evaluation in the NEPA process.

Magnitude = 2

Certainty = 3

Important Gaps in Information and/or Understanding

Research Needs

- The basis of the assumption for the flooding frequency could be refined (Table 2, BDCP doc).
- Major gaps – rearing habitat for steelhead? Rearing habitat for juvenile sturgeon?
- Hg accumulation in fish has been documented, but does not indicate affect on fish.
- Degree of contaminants affects on POD.
- Degree of sediment settling on floodplains.
- Degree of predation/competition within floodplains on native covered fish species by non-native fish species.
- Better diet information is needed for floodplain use of SH, green sturgeon and white sturgeon.
- More information is needed about relative importance of food to population level effects for all of the species.
- Transport studies are needed to evaluate the footprint of food transport from floodplains.
- Timing duration of rearing for SH, green sturgeon and white sturgeon.
- The turbidity linkage for longfin smelt is not as well documented in the research as it is for delta smelt. Further studies positively linking turbidity and longfin smelt would be helpful.

Assess Reversibility and Opportunity for Learning

Reversibility

No/Hard

Comments:

- Would be monumental effort/cost to reconstruct levees
- Low reversibility with high resources associated with structural investments in setback levees.
- Land acquisition and jurisdiction also constraints.
- Implementation of this action would not provide a suitable opportunity to address critical unknowns or uncertainties. If action were implemented at a larger scale and with more-frequent inundation, this score may change.

Opportunity for Learning

Low

Comments

Opportunity for learning associated with habitat improvements for San Joaquin Basin Chinook juveniles is scored low based on infrequency of inundation .An increase of habitat would not create monitoring ops that we would not be gained form other areas. Score would be higher if inundation was more frequent. Monitoring juvenile use of San Joaquin floodplains would advance understanding of juvenile Chinook in the San Joaquin basin. However we cannot conduct research on area that floods so infrequently. The 30 day inundation period (as written) is a high standard to meet.

References Cited

Salmon (Williams/Rosenfield 2007)
Splittail
Floodplain
Riparian
Longfin Smelt
Delta Smelt
Boundary Condition
Mercury
Selenium
Sedimentation
Temperature
Chemical Stressors/Pyrethroids
Dissolved Oxygen
Foodweb
Fish Habitat Linkages
T. Sommer pers comm. 2009
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Moyle 2002
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Caswell annual report 2004-2007
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Rosenfield 2007

Appendix A

HRCM 3:
South Delta ROA

Scientific Evaluation Worksheet

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Action: HRCM 3 - South Delta ROA Floodplain Restoration

Evaluation Team: Floodplain and Riparian Workgroup
Campbell Ingram (chair), Denise Reed (coach), Carie Battistone (notetaker), Eric Ginney, Ted Sommers, Rosalie Del Rosario, Dennis McEwan, Bill Harrell, Dan Welsh, Yvette Redler, and Vance Russell.

Date of Last Revision: February 23, 2009

Action Description and Clarifying Assumptions

Restore between 800 and 1,600 acres of floodplain habitat (including aquatic, intertidal marsh, floodplain and riparian features) along Old River at Fabian Tract

Option #1: 800 acres (6.5 miles with 500 foot setback on each side)

Option #2: 1,600 acres (13.2 miles with 500 foot setback on each side)

Approach

1. Set back levees along both sides of the channel and remove all or large sections of the existing levees
2. Discontinue farming within the setback levees and allowing riparian vegetation to naturally establish on the floodplain.
3. Re-contour the restored floodplain surface, if needed, to avoid potential for stranding of juvenile and adult fish following inundation events.
4. Contour surface elevations along tidal reaches to allow natural establishment of tidal freshwater wetland and riparian habitat.
5. Allow riparian vegetation to naturally establish.
6. Allow channel to meander between the new levees through the natural processes of erosion and sedimentation.

Intended Outcomes as Stated in Conservation Measure

1. Expand the floodplain to allow flood waters to attenuate, improving access of juvenile fish, such as Chinook salmon and steelhead, to seasonally inundated floodplain habitat, and reducing flood risk to properties upstream and downstream.
2. Create additional spawning habitat for Sacramento splittail by expanding floodplain habitat area.
3. Create additional rearing habitat for Sacramento splittail, runs of Chinook salmon from the San Joaquin River and other eastside tributaries, and possibly steelhead.
4. Increase the production of food for rearing salmonids, splittail, and other covered species.
5. Increase the availability and production of food in the Delta downstream of restored floodplain habitat for delta smelt, longfin smelt, and other covered species by exporting organic material and phytoplankton, zooplankton, and other organisms produced from the inundated floodplain into the Delta.
6. Increase the load of organic carbon, phytoplankton, zooplankton, and macroinvertebrates exported into aquatic habitat in the Delta.
7. Increase the hydrodynamic and structural complexity within the channel by allowing the natural establishment and growth of woody riparian vegetation that would provide inputs of large woody debris into the river channel and provide overhead cover.

8. Improve in-channel habitat complexity along the Old River corridor would be expected to reduce the predation risk to covered fish species.
9. Improve connectivity between San Joaquin River habitats and Delta habitats for passage of juvenile salmonids outmigrating from the San Joaquin River and eastside tributaries.
10. Increase habitat complexity by allowing the natural establishment and growth of woody riparian vegetation that will provide inputs of large woody debris into the river channel and provide overhead cover.

Positive

P1: Improve connectivity of seasonally inundated floodplain habitat for juvenile splittail, green and white sturgeon, Chinook salmon and steelhead.
P2: Create additional spawning habitat for splittail on floodplain.
P3: Create rearing habitat for Chinook salmon, green and white sturgeon, splittail and steelhead (consider loss to entrainment).
P4: Increase production of food for rearing Chinook salmon, steelhead, green and white sturgeon, and splittail from inundation and riparian vegetation (local).
P5: Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (offsite), longfin smelt, and delta smelt (consider loss to entrainment).
P6: Increase establishment of woody riparian vegetation to export LWD.
P7: Increase establishment of woody riparian vegetation to provide shaded channel habitat.
P8: Increased downstream turbidity improves habitat quality for delta smelt and longfin smelt.

Negative

N1: Increased MeHg and impact on covered species (direct or indirect)
N2: Increased resuspension/mobilization and export of toxic compounds with impact on covered species (consider time course of effect).
N3: Decreased downstream turbidity decreases habitat quality for delta smelt and longfin smelt.
N4: Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail.
N5: Increased exposure risk to contaminants (inc. Se) due to longer residence time in this area.

General Conceptual Model Support for Intended Outcomes

DRERIP models were referenced in evaluations, along with several outside sources.

Models used:
Salmon model (Williams/Rosenfield 2007)
Steelhead
Splittail
Green and white sturgeon
Longfin smelt
Delta smelt
Floodplain
Boundary conditions
Riparian vegetation
Temperature
Mercury
Pyrethroids
Chemical stressors
Selenium

Other sources:
Hatton 1940
Healy 1991
Ward et al 2003
Sommer 2005
Sommer et al 2001, 2004, 2005
Harrell and Sommer 2003
Harrell and Sommer unpub
Williams 2006
SJRG annual reports 2004-2007
FWS 2007
Myers et al. 1998
San Joaquin Technical Annual Report 2004
Caswell Annual Report 2007
Kjelson 1982
McEwan 2001
Moyle 2002
Moyle et al 2006, 2007
Hunter et al 1999
Rosenfield 2007
Beckon 2008

Assumptions

Provided in BDCP Conservation Measure

1. Restoration would be focused on Old River corridor, with Middle River serving as a water conveyance channel.
2. 800 acres = 6.5 miles with 500 foot setback on each side.
3. 1,600 acres = 13.2 miles with 500 foot setback on each side.
4. Approximately half of the acreage would flood for at least 30 days every 7 years; all of the acreage would flood for at least 30 days approximately every 20 years.

Added by Evaluation Team

1. All South Delta work will be contingent on significant reduction in south Delta entrainment (need to evaluate some negative outcomes with both 1) Old River isolated and 2) current configuration and reduced pumping (i.e., dual conveyance).
2. The improvements occur west of the confluence between Old and San Joaquin Rivers and east of the point of intertidal elevation.
3. Reduced entrainment risk considering alternate conveyance.
4. Flooding based on existing hydrology (Feb/March).
5. There is a 1 meter depth in floodplain.

Problem(s) with Action as Written:

1. Natural recruitment of desirable, native riparian vegetation seems unreasonable given the infrequent inundation of the site (the entire site only floods for a significant duration every 20 years).
2. Took out language in action specifying sub-habitats within floodplain habitat – "including aquatic, intertidal marsh, floodplain and riparian features".
3. Contouring needs further explanation – focused on stranding not on connections.
4. The floodplain inundation target of "half of the acreage would flood for at least 30 days every 7 years; all of the acreage would flood for at least 30 days approximately every 20 years" will likely be hard to reach. Ultimately this assumption affects overall scoring.
5. Possible limited production of phytoplankton and zooplankton during floods (intended outcome #5).
6. Some question about steelhead (outcomes #1 and #3). Does rearing habitat and food matter during steelhead migration?

Scale of Action:

Option #1 – SMALL SCALE
Option #2 – SMALL SCALE

Rationale:
Frequency of inundation is low for both, some floodplain habitat already (may need to modify if data available).

Evaluation Summary Tables

Summary tables listing magnitude and certainty scores for each outcome, by species, are provided in Appendix A. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes on the following pages.

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

YES

Potential Positive Ecological Outcome(s)

Outcome P1: Improve connectivity of seasonally inundated floodplain habitat for juvenile fish (splittail, green and white sturgeon, Chinook salmon and steelhead).

P1a. Fall-run Chinook salmon

Human-built features reduce connectivity to floodplain habitat for salmon (Floodplain Model. Text doesn't specifically state salmon but it cites Ted's paper (Sommer et al. 2005, which does).

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 3-4
Given data on flooding and studies elsewhere.

P1b. Steelhead

Same information for flooding for Chinook salmon. Fish are present (McEwan 2001) at the time (life stage table – Figure 3). Emigrating Jan-August, peak in Jan-May (based on Sacramento River information). Mossdale trawl data (Rosalie provided – FWS 2007) shows more fish occur. Floodplain (page 27) says no information on steelhead use of floodplain. Steelhead model (Figure 2 of steelhead section in salmonid model, page 155) shows floodplain use. Williams (2006), McEwan (2001) and Moyle (2002) support presence.

Page15-16 of salmon model shows estuarine habitat – may show import for lower reach.

Steelhead have been caught on floodplain in Yolo (Sommer, T., B. Harrell, M. Nobriga, R. Brown, P. Moyle, W. Kimmerer, and L. Schemel. 2001. California's Yolo Bypass: evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture. Fisheries 26:6-16.). Some reference in Williams 2006 – chapter 9, page 174.

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 2-3
Non-peer reviewed references.

P1c. Splittail

Splittail model page 12 describes how loss of connectivity has resulted in habitat loss; Floodplain model page 18: human built features such as berms, ditches, etc. reduce connectivity to floodplain habitat.

Magnitude = 3
Given longer life span means it can take advantage of more flashy system.

Certainty = 3-4

P1d. White Sturgeon

Same information for flooding for Chinook salmon. No evidence of juvenile use of floodplains. Adult catch in Yolo are adults (Harrell and Sommer 2003). This mechanism described above is assumed to apply to white sturgeon (Sommer et al 2005 and Floodplain Model).

Magnitude = 1-2

Certainty = 1

P1e. Green Sturgeon

DLO Relationship and General Observations
Same information for flooding for Chinook salmon. No evidence of juvenile use of floodplains. Adult catch in Yolo are adults (Harrell and Sommer 2003). This mechanism described above is assumed to apply to white sturgeon (Sommer et al 2005 and Floodplain Model).

Magnitude = 1

Certainty = 2

Understanding of sturgeon on floodplain is low and needs further study, e.g., could have higher worth if better understood, group had difficulty determining whether to eliminate sturgeon based on understanding of their use of floodplains.

Outcome P2: Create additional spawning habitat (splittail) on floodplain.

P2. Splittail

Floodplain model page 25 and Splittail model pages 9 and 12 describe how additional floodplain habitat supports splittail spawning.

Magnitude = 3
Given longer life span means can take advantage of more flashy system.

Certainty = 3-4

Outcome P3: Create rearing habitat for Chinook salmon, green and white sturgeon, splittail and steelhead. Consider loss to entrainment.

P3a. Fall-run Chinook salmon

Assumption gives duration and frequency. BDCP document shows historic timing is late winter spring. Boundary Condition model (p. 49) shows peaks occur in February period.

Fall-run Chinook salmon juveniles are present in the area during the proposed floodplain inundation period of late winter and spring. San Joaquin fall-run Chinook juveniles enter Delta either as: 1) fry/parr) with high winter flows, typically in January through March (size of 20 to 60 mm fork length, or as 2) smolts after mid March(> 60 mm fork length; (Caswell Annual Report 2007, SJRG 2004, 2005, 2006)

Delta presence of fry confirmed by:

- Presence at Mossdale and Salvage facilities during Jan – March
- San Joaquin River Trawl Dos Reis(RM 51) –Laird(RM 90)
- Salmon < 50mm January through March
- Apparent that much of Tuolumne/Stanislaus River emigrated as fry and pre-smolts with early flood flows in Jan – March…..Early migrants not captured in high numbers at Mossdale/Salvage indicating that juveniles may have remained in the lower San Joaquin above Mossdale…." (SJRG annual report 2006 page 75, 2007 page 66).
- Densities of fry may be underrepresented due to both the trawl and salvage being relatively less effective at capturing fry (Salmon less than 50 mm long). (SJRG 2006 Annual Report page 72)
- Fall run Chinook (Fig 2c) shows juvenile fry/par stage during winter/spring.
- Most Fry enter Delta from tributaries before April (January through March), Smolt enter mid March – June (Based on USFWS/CDFG Mossdale trawl data , SJRG annual reports 2004-2007, Caswell annual report 2007.)

Fall-run Chinook salmon juveniles would use the floodplain to rear. The restored floodplain would create rearing habitat for fry/parr that enter the Delta in the winter, coincident with inundation of the floodplain. These fry would be able to feed and grow in the floodplain, and their larger size would increase the likelihood of survival in the ocean.

- Chinook salmon use the delta inversely proportional to their size (Williams 2006).
- Smolts migrate directly through delta to ocean.
- Fry likely do not migrate out of delta until smolt size. (SJRG annual report 2004 page 76)
- Shallow water habitats including river floodplains and riparian margin provide rearing habitat. Growth rates for juvenile Salmon are higher and emigration rates are slower when in shallow water rearing habitats. (Kjelson 1982, Sommer 2005)
- "during very high flows, fry simply get swept downstream…because the turbulence is too strong for them to resist" (Williams 2006, page76)
- " Fry tend to keep to the margins of large rivers"(Hatton 1940, Healy 1991) meaning fry can move at a slower rate then the river especially if they have access to floodplains where they can find slower moving water.
- Fry that lingered in lower reaches of creek or bypass grew to 70-80mm compared to fry that migrated quickly and averaged 40mm (Ward et all 2003)

Floodplains no longer exist along the lower San Joaquin River, but fall-run Chinook salmon would likely use the restored floodplains, as they have been documented to rear in Yolo Bypass floodplain along the lower Sacramento River.

- CV Chinook salmon may have relied extensively on floodplain in the past as historically much of the central valley was floodplain habitat (Hunter et al 1999)
- Williams (2006 article 2) confirmed fall Chinook emigration if Feb-Mar on San Joaquin. Floodplain model (Fig 7 and assoc text) identifies that floodplains provide habitat for Chinook salmon.
- "Given the temporal and geographic distribution, (Fall-run juvenile) have more opportunities to use floodplain habitats then do other Central Valley runs" (Rosenfield 2007).
- Sommer et al (2005) reported extensive use of Yolo and Sutter bypasses by fall-run.
- Moyle et al (2007) reported use of Cosumnes River floodplain

Limited data on San Joaquin floodplain (none in Floodplain model) No reason to suggest they should behave different from other systems.

Magnitude = 2
Given limited temporal effect in frequency. Availability of floodplain is infrequent, with partial inundation every 7 years. This floodplain would be unavailable for least 2 generations of San Joaquin fall run, of which the majority are 3 year old spawners, with some 2 year old spawners (Myers et al. 1998, p. 61).

Certainty = 3-4
Given data on flooding and studies elsewhere. There is high certainty that juvenile salmon are in the vicinity, and inference juveniles would rear in restored floodplain based on documented rearing in the Yolo Bypass and the restored Cosumnes River floodplain.

P3b. Steelhead

Same information for flooding for Chinook salmon. Fish are present at the time (McEwan 2001 life stage table – Figure 3 - emigrating Jan-August, peak in Jan-May - based on Sacramento River information). Mossdale trawl data (Rosalie provided – FWS 2007) shows more fish occur. Floodplain Model (page 27) says no information on steelhead use of floodplain. Steelhead model (Fig 2 of steelhead section in salmonid model, p155) shows floodplain use. Williams (2006), McEwan (2001) and Moyle (2002) supports presence.

Page15-16 of salmon model shows estuarine habitat – may show import for lower reach.

Steelhead have been caught on floodplain in Yolo (Sommer, T., B. Harrell, M. Nobriga, R. Brown, P. Moyle, W. Kimmerer, and L. Schemel. 2001. California's Yolo Bypass: evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture. Fisheries 26:6-16.). Some reference in Williams 2006 – chapter 9, page 174.

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 2-3
Non–peer reviewed references.

P3c. Splittail

Same information for flooding for Chinook salmon. Table 1 page 3 in Splittail Model indicates juveniles use floodplain Feb-May, distribution shows they are in San Joaquin. based on Baxter sampling (mostly unpublished). Cosumnes publications (Crain et al 2004 conf proc.), Moyle et al 2004. SFEWS. Still not much information from San Joaquin – same inference, no reason to believe they would behave differently.

Magnitude = 3
Longer life span means can take advantage of more flashy system.

Certainty = 3-4
Given data on flooding and studies elsewhere.

P3d. White Sturgeon

Same information for flooding for Chinook salmon. No evidence of juvenile use of floodplains. Adult catch in Yolo are adults (Harrell and Sommer 2003).

This mechanism described above is assumed to apply to white sturgeon (Sommer et al 2005 and Floodplain Model).

Magnitude = 1-2

Certainty = 1
Understanding of sturgeon on floodplain is low and needs further study, e.g., could have higher worth if better understood, group had difficulty determining whether to eliminate sturgeon based on understanding of their use of floodplains.

P3e. Green sturgeon

Same information for flooding for Chinook salmon. No evidence of juvenile use of floodplains. Adult catch in Yolo are adults (Harrell and Sommer 2003).

This mechanism described above is assumed to apply to green sturgeon also (Sommer et al 2005 and Floodplain Model).

Magnitude = 1

Certainty = 2
Understanding of sturgeon on floodplain is low and needs further study, e.g., could have higher worth if better understood, group had difficulty determining whether to eliminate sturgeon based on understanding of their use of floodplains.

Outcome P4: Increase production of food for rearing Chinook salmon, steelhead, green and white sturgeon, and splittail from inundation and riparian vegetation (local).

P4a. Fall-run Chinook salmon

Floodplain Model pages 20-25 - a high level of food production on floodplain provides support for magnitude score. Floodplain Model pages 27 and 29 describe utilization and higher growth rates for Chinook salmon on floodplains. Chinook salmon likely take advantage of small fishes on the floodplain (Splittail Model page 8 and Moyle et al. 2004).

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 3-4
Given data on flooding and studies elsewhere.

P4b. Steelhead

Floodplain Model pages 20-25 - a high level of food production on floodplain provides support for magnitude score.

Nothing really in the literature that describes steelhead feeding on floodplains, however, it can be assumed that they are utilizing the same food sources as juvenile salmon, given their life-history similarities. Moyle 2002 states that stream-dwelling rainbow trout feed mostly on drifting aquatic organisms, terrestrial insects, and bottom dwelling organisms which are in abundance on floodplains.

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 2
Non-peer reviewed.

P4c. Splittail

Floodplain Model pages 20-25 - a high level of food production on floodplain provides support for magnitude score. Floodplain Model pages 25 and 27 describes utilization and higher survival for splittail on floodplains.

Magnitude = 3
Given longer life span means can take advantage of more flashy system.

Certainty = 3-4

P4d. White sturgeon

Floodplain Model pages 20-25 - a high level of food production on floodplain provides support for magnitude score. This mechanism described Chinook salmon is assumed to apply to white sturgeon (Sommer et al 2005 and Floodplain Model).

Magnitude = 1
No evidence of juvenile use of floodplains. Catch in Yolo are adults (Harrell and Sommer 2003).

Certainty = 1
Understanding of sturgeon on floodplain is low and needs further study, e.g., could have higher worth if better understood, group had difficulty determining whether to eliminate sturgeon based on understanding of their use of floodplains.

P4e. Green sturgeon

Floodplain Model pages 20-25 - a high level of food production on floodplain provides support for magnitude score.

This mechanism described for Chinook salmon is assumed to apply to green sturgeon (Sommer et al 2005 and Floodplain Model).

Magnitude = 1
No evidence of juvenile use of floodplains. Catch in Yolo are adults (Harrell and Sommer 2003).

Certainty = 2
Understanding of sturgeon on floodplain is low and needs further study, e.g., could have higher worth if better understood. Group had difficulty determining whether to eliminate sturgeon based on understanding of their use of floodplains.

Outcome P5: Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (off site), longfin smelt, and delta smelt.

P5a. Fall-run Chinook salmon

Floodplain Model pages 20-25 - a high level of food production on floodplain provides support for magnitude score. Floodplain Model pages 27 and 29 describe utilization and higher growth rates for Chinook salmon on floodplains.

Chinook salmon likely take advantage of small fishes on the floodplain (Splittail Model page 8 and Moyle et al. 2004).

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 3-4
Given data on flooding and studies elsewhere.

P5b. Steelhead

Floodplain Model pages 20-25 - a high level of food production on floodplain provides support for magnitude score.

Steelhead feeding on floodplains is not described in the literature. However, it can be assumed that they are utilizing the same food sources as juvenile salmon, given their life-history similarities. Moyle 2002 states that stream-dwelling rainbow trout feed mostly on drifting aquatic organisms, terrestrial insects, and bottom dwelling organisms which are in abundance on floodplains.

Magnitude = 2
Given limited temporal effect in frequency.

Certainty = 2
Non-peer reviewed.

P5c. Splittail

Floodplain Model pages 20-25 - high levels of food production on floodplain provides support for magnitude score. Floodplain Model pages 25 and 27 describes utilization and higher survival for splittail on floodplains.

Magnitude = 3
Longer life span means can take advantage of more flashy system.

Certainty = 3-4

P5d. White sturgeon

Floodplain Model pages 20-25 - high levels of food production on floodplain provides support for magnitude score.

This mechanism described Chinook salmon is assumed to apply to white sturgeon (Sommer et al 2005 and Floodplain Model).

Magnitude = 1
No evidence of juvenile use of floodplains. Catch in Yolo are adults (Harrell and Sommer 2003).

Certainty = 1
Understanding of sturgeon on floodplain is low and needs further study, e.g., could have higher worth if better understood. Group had difficulty determining whether to eliminate sturgeon based on understanding of their use of floodplains.

P5e. Green sturgeon

Floodplain Model pages 20-25 - a high level of food production on floodplain provides support for magnitude score. This mechanism described for Chinook salmon is assumed to apply to green sturgeon (Sommer et al 2005 and Floodplain Model).

Magnitude = 1
No evidence of juvenile use of floodplains. Catch in Yolo are adults (Harrell and Sommer 2003).

Certainty = 2
Understanding of sturgeon on floodplain is low and needs further study, e.g., could have higher worth if better understood, group had difficulty determining whether to eliminate sturgeon based on understanding of their use of floodplains.

P5f. Longfin smelt

Longfin smelt Model page 21 describes the importance of zooplankton.

Magnitude = 2
Given limited temporal effect in frequency; occur under extreme high flow events when food is less likely a constraint.

P5g. Delta smelt

Delta Smelt Model page 12 describes the importance of zooplankton.

Magnitude = 2
Given limited temporal effect in frequency; occur under extreme high flow events when food is less likely a constraint.

Certainty = 3

Outcome P6: Increase establishment of woody riparian vegetation to export LWD.

The following paragraphs are applicable to all covered fish species. Options #`1 and #2 are discussed below.

P6a. Option #1 800 acres.

Assumption for action HRCM3 gives duration and frequency of inundation of the floodplain. Many factors and processes influence natural recruitment of woody riparian vegetation, and are summarized in the DRERIP Riparian Vegetation Model. Figures 5, 6, & 7 of that model demonstrate how levees disrupt the setting of the "physical template" (the surface hydrology and floodplain scouring processes necessary for that template) that is necessary for natural recruitment to occur. Actions in HRCM1 would result in reduction of that stressor (setting back the levee), which would allow for increased establishment of woody riparian vegetation. The altered flow regime of the San Joaquin River system would not be modified by this action, and would therefore remain as a stressor and (in combination with altered channel and floodplain morphology) this would still limit inundation frequency and duration of the site. Thus, while natural riparian vegetation recruitment in the setback area would be possible, infrequent natural flooding may encourage invasive species recruitment (DRERIP Riparian Model, page 20) because surface water and groundwater hydrology drive the recruitment and establishment parameters of vegetation somewhat independently of the physical template. Specifically, this includes recruitment parameters for necessary seedling survival and changes in biotic competition and anoxia that may favor invasive species over native species that are flood-tolerant or require flooding to establish. Infrequent inundation also translates to infrequent LWD export from the area of increased vegetation.

Magnitude = 2
Score is based on effect being local (e.g., 6.5 mile reach) to regional (LWD would move downstream) in scale. However, because new floodplain areas would not be inundated very frequently (and hence the increase in LWD recruitment would be sporadic), the temporal effect is low.

The DRERIP Floodplain Model (pages 5, 6, & 7) describes how flood flows modify the floodplain and interact with riparian vegetation to recruit LWD. The approach to Action HRCM1 will set back levees allowing vegetation recruitment (and flooding) where it is currently precluded; however, the action will not modify the floodplain morphology or increase flood hydrology in terms of frequency or duration. Thus, while riparian vegetation may be increased by the action, because of the morphology of the site and other stressors (specifically, impaired flood hydrology), the inundation frequency—and hence the LWD export—is likely to be infrequent (e.g., every 7 years for half the new floodplain; every 20 years for the entire floodplain). Therefore, because most of this 6-mile reach already includes some water's edge riparian vegetation (DRERIP-BDCP maps & Google Earth satellite imagery), the only additional LWD input would come from the new floodplain areas (which would be flooded relatively infrequently). While this outcome is positive, the actual increase in LWD export is likely to be relatively infrequent and thus of low magnitude.

Certainty = 3
Certainty score is based on dependence of outcome on variable ecosystem processes (i.e., flooding needed to cause LWD input is highly variable—e.g., every 7 to 20 years based on modeling).

P6b. Option #2 1,600 acres. Not evaluated by species.

Assumption for action HRCM3 gives duration and frequency of inundation of the floodplain. Many factors and processes influence natural recruitment of woody riparian vegetation, and are summarized in the DRERIP Riparian Vegetation Model. Figures 5, 6, & 7 of that model demonstrate how levees disrupt the setting of the "physical template" (the surface hydrology and floodplain scouring processes necessary for that template) that is necessary for natural recruitment to occur. Actions in HRCM1 would result in reduction of that stressor (setting back the levee), which would allow for increased establishment of woody riparian vegetation. The altered flow regime of the San Joaquin River system would not be modified by this action, and would therefore remain as a stressor and (in combination with altered channel and floodplain morphology) this would still limit inundation frequency and duration of the site. Thus, while natural riparian vegetation recruitment in the setback area would be possible, infrequent natural flooding may encourage invasive species recruitment (DRERIP Riparian Model, page 20) because surface water and groundwater hydrology drive the recruitment and establishment parameters of vegetation somewhat independently of the physical template. Specifically, this includes recruitment parameters for necessary seedling survival and changes in biotic competition and anoxia that may favor invasive species over native species that are flood-tolerant or require flooding to establish. Infrequent inundation also translates to infrequent LWD export from the area of increased vegetation.

Magnitude = 3
Score is based on effect being local (e.g., 13-mile reach) to regional (LWD would move downstream) in scale. Inundation and LWD export have the same frequencies as the 6.5-mile/downstream version of the action; however, the upper 6-mile reach of the action area includes very little (if any) existing water's edge riparian vegetation (DRERIP-BDCP maps & Google Earth satellite imagery). Thus, under existing conditions, there is little if any LWD input from this upper end of the reach. Though the new floodplain area would be flooded relatively infrequently, water's edge riparian would increase. Flood flows that may not inundate the floodplain may still be capable of eroding banks and recruiting LWD. This represents an increased magnitude from the 6.5-mile/downstream reach version of this action, and results in a slightly higher magnitude.

Certainty = 3
Certainty score is based on dependence of outcome on variable ecosystem processes (i.e., flooding needed to cause LWD input is highly variable—e.g., every 7 to 20 years based on modeling).

Outcome P7: Increase establishment of woody riparian vegetation to provide shaded channel habitat.

P7a. Option #1 800acres

The DRERIP Riparian Model (interactions with floodplains as shown in Figure 5, and specifically the Riparian Vegetation Sub-model; green box in Figure 5) produces a conceptual framework for illustrating the creation of the physical "shaded riverine aquatic habitat" that would be provided by action HRCM1. Removing levees or eliminating vegetation clearing at the river's edge would allow for increased establishment of woody riparian vegetation.

Based on assumptions and approach to HRCM1, "modifications" to the channel will be made to benefit splittail spawning and provide splittail and salmonid rearing habitat. Ostensibly, this would include addition of instream LWD, but because riparian vegetation is assumed to come from "natural recruitment", any increase in woody riparian vegetation establishment (and hence increased shade) along the banks would be expected to occur only in areas where current levees (without vegetation) are located immediately adjacent to the river, or vegetation along the river is cleared all the way up to the edge of the river.

Benefit to covered species would be dependant on water temperature effects. Shade would reduce the amount of shortwave radiation striking the water (see Figure 1, DRERIP Temperature model); however, at this fine habitat-level scale, while shading is important, its influence is difficult to prescribe quantitatively (DRERIP Temperature model, page 6). Predicting the magnitude of the shading effect is beyond the level of the conceptual models.

Magnitude = 2
Currently, compared to the upstream reach (the other 6.5-mile section that completes the 13-mile action area); there is a relatively-substantial amount of riparian vegetation on the levees immediately adjacent to the river channel (Google Earth satellite imagery; DRERIP-BDCP maps). Thus the opportunity for levee setback to increase woody riparian vegetation (and hence shade the channel) immediately adjacent to the channel is lower relative to that in the upstream 6.5 miles. SUMMARY: Compared to upstream 6.5 miles, potential magnitude of increase is lower for this segment of the action area (i.e., relatively-less bank would gain shade).

Certainty = 3
Certainty score is based on dependence on external factors and the lack of predictability in the outcome directly supporting covered species.

P7b. Option #2 1600 acres

The DRERIP Riparian Model (interactions with floodplains as shown in Figure 5, and specifically the Riparian Vegetation Sub-model; green box in Figure 5) produces a conceptual framework for illustrating the creation of the physical "shaded riverine aquatic habitat" that would be provided by action HRCM1. Removing levees or eliminating vegetation clearing at the river's edge would allow for increased establishment of woody riparian vegetation.

Based on assumptions and approach to HRCM1, "modifications" to the channel will be made to benefit splittail spawning and provide splittail and salmonid rearing habitat. Ostensibly, this would include addition of instream LWD, but because riparian vegetation is assumed to come from "natural recruitment", any increase in woody riparian vegetation establishment (and hence increased shade) along the banks would be expected to occur only in areas where current levees (without vegetation) are located immediately adjacent to the river, or vegetation along the river is cleared all the way up to the edge of the river.

Benefit to covered species would be dependant on water temperature effects. Shade would reduce the amount of shortwave radiation striking the water (see Figure 1, DRERIP Temperature model); however, at this fine habitat-level scale, while shading is important, its influence is difficult to prescribe quantitatively (DRERIP Temperature model, page 6). Predicting the magnitude of the shading effect is beyond the level of the conceptual models.

Magnitude = 2
This reach currently has little if any riparian along the water's edge (Google Earth satellite imagery; DRERIP-BDCP maps). Thus the relative increase is greater for this version of the action.

Certainty = 3
Certainty score is based on dependence on external factors and the lack of predictability in the outcome directly supporting covered species.

Outcome P8: Increased downstream turbidity improves habitat quality for delta smelt and longfin smelt.

P8a. Delta smelt

Positive link between delta smelt and turbidity throughout life-history is well documented in both lab and field studies. Longfin smelt abundance appears to be positively linked with turbidity, although less research is available.

Action assumes relatively infrequent inundation events. Inundation will suspend and mobilize sediment from the restored floodplain, increasing turbidity in the water column downstream. Floodplain model: Sediment on floodplains can be resuspended by flows or turbulence such as wind-generated waves (page. 18). Sediment model: The Yolo Bypass floodplain, when inundated, can be a large source of sediment to the Sacramento River (page. 9). A restored floodplain on the San Joaquin River could be a source for suspended sediment downstream, assuming it functions similarly to the Yolo Bypass. Delta smelt model: Turbidity increases larval feeding success (page. 4-5); turbidity conceals juvenile delta smelt from predation (page. 7); and juveniles are most abundant in areas with low water transparency (page. 11). Longfin smelt model: Longfin smelt occurring in turbid water have reduced exposure to predation (pages. 7, 8, 13). Although less information is available for longfin, they likely benefit from higher levels of turbidity in similar ways to delta smelt.

Channel migration and bank erosion could be considered as an intermediate outcome.

Magnitude = 2
Limited temporal and population level effect due to low frequency of inundation (given in assumptions).

Certainty = 3-4
Positive link between delta smelt and turbidity throughout life-history is well documented in both lab and field studies. Longfin smelt abundance appears to be positively linked with turbidity, although less research is available.

P8b. Longfin smelt

The text provided above in Outcome P8a is also applicable here.

Magnitude = 2
Limited temporal and population level effect due to low frequency of inundation (given in assumptions).

Certainty = 3
Positive link between delta smelt and turbidity throughout life-history is well documented in both lab and field studies. Longfin smelt abundance appears to be positively linked with turbidity, although less research is available.

Potential Negative Ecological Outcome(s)

Outcome N1: Increased MeHg and impact on covered species (direct or indirect).

N1. Same for all species

An initial spike in MeHg would be expected when the newly created floodplain habitat in areas where levees are being set back is inundated for the first time (Hg model, page 15, 18). Although concentrations may attenuate from the initial spike over time, MeHg production would likely remain relatively high compared to other types of habitats. Habitats with the highest levels of MeHg production, concentration, and exposure to biota are those with periodic flooding events separated by sufficient time to allow complete drying, such as the seasonal floodplains that would be created in this project (Hg model, page 15). Covered fish species using the restored habitat would be exposed to MeHg through their food chain, and MeHg would be exported downstream along with organic matter and organisms. The effects on fish, if any, would be minimal in most years due to the infrequency of inundation (inundated >30 days once every 7 to 20 years).

The linkage of seasonal flooding to MeHg production and subsequent bioaccumulation of MeHg in fish and their prey is well documented. Effects of this bioaccumulation on covered fish species are more uncertain, due to lack of studies of toxicological effects of MeHg on covered species, uncertainty about sensitivity of covered species relative to species that have been studied, and the subtle nature of the behavioral effects (e.g., impaired predator avoidance and feeding efficiency) that are among the most sensitive endpoints for MeHg toxicity and are difficult to detect.

Magnitude = 1

Certainty = 3
Based on level understanding of affects on fish species.

Outcome N2: Increased resuspension/mobilization and export of toxic compounds w/impact on covered species (consider time course of effect).

N2a. Same for all species:

The habitat is being enhanced to facilitate spawning by splittail and rearing by splittail and other species. Current land uses on and adjacent to the project area are agricultural crops that receive pesticide applications, including pyrethroids. Pyrethroids can be toxic to fish, especially to early life stages (Pyrethroids model, page 16). Pyrethroid concentrations would be expected to peak during the winter/spring storm season and after peak agricultural application in the summer and fall (Pyrethroids model, page 2). Late-winter and spring are also the times splittail would use the enhanced floodplain habitat to spawn (Splittail model, page 1). Effects of pesticides, if any, would be greatest in the early years of the project as pesticides that have accumulated in agricultural soils are mobilized. Potential for pesticide effects would decrease over time in the restored areas where farming will be discontinued. This elimination of farming between the setback levees may actually result in an improvement above baseline with regards to risks of pesticides to fish.

There are critical data gaps on pyrethroids and other pesticides that make it difficult to evaluate risk to covered fish (Pyrethroids model, page 32; Chemical stressors model, page 25). In general, little is known about the toxic effects of contaminants known to be present in the Delta on resident Delta species, and even less is known about the sublethal effects of contaminants (Chemical stressors model, page 25). However, elimination of farming and associated pesticide use between the setback levees would almost certainly minimize the magnitude and duration of potential effects of pesticides on covered fish.

Magnitude = 1
Not much sediment to mobilize.

Certainty = 4

Outcome N3: Decreased downstream turbidity decreases habitat quality for delta smelt and longfin smelt.

N3a. Same for delta and longfin smelt

Water moving out on the floodplain and settling out of sediment. Sediment Model: has a section on floodplain but does not specifically say it traps sediment. Figure 8 in sediment model makes link. Floodplain Model: no information found in model. We expect it would increase turbidity with export of phyto/zooplankton. May be a seasonality issue again – less phytoplankton in winter. Delta Smelt Model: Page 2, 10, and 11 talk about turbidity as important habitat factor. Longfin Smelt Model: link to turbidity is poor (page 7), they tend to hang out in turbid water.

(For potential addition to existing rationale) Floodplain model: Reduced water velocities on floodplains, due to topography and vegetation, results in the deposition of sediment, potentially decreasing turbidity (page. 18).

Channel migration and bank erosion may be considered as an intermediate outcome.

Magnitude = 1

Certainty = 4

Outcome N4: Increased habitat for non-native predators/competitors to native fishes (Chinook salmon, steelhead, green and white sturgeon, and splittail).

Delta and longfin smelt, all life stages are typically not present in this part of the Delta (Delta smelt model and longfin smelt model); therefore no competition or predation would be expected.

N4a. Chinook salmon

The floodplain model does not address non native predation or competition on the floodplain. Evidence from Yolo and Cosumnes about non-natives taking advantage of floodplain (ref Sommer et al 2004, Moyle et al 2006). Floodplain Model: Page 10 talks about sources of invasive species. Foodweb Model is focused on estuarine systems.

The Chinook salmon and steelhead model indicates Non-native predation and competition with invasive species and hatchery produced salmonids is of medium importance in rearing and emigration estuarine habitats, including floodplain (Figure 2a). There is limited data on Chinook salmon and steelhead use of San Joaquin floodplain (no mention in Rosenfield 2007) but the evaluation team thought there is no reason why they would not utilize this habitat in the same way they utilize similar Delta systems (Yolo Bypass).

Magnitude = 2
Based on perennial inundated benches, but not floodplains; benches may support more non-native predators.

Certainty = 4
Based on understanding high concentrations of non-natives in perennially shallow water areas of the San Joaquin (Grimaldo et al. 2003, Feyrer 2003).

N4b. Steelhead

The floodplain model does not address non native predation or competition on the floodplain. Evidence from Yolo and Cosumnes about non-natives taking advantage of floodplain (ref Sommer et al 2004, Moyle et al 2006). Floodplain Model: Page 10 talks about sources of invasive species. Foodweb Model is focused on estuarine systems.

The Chinook salmon and steelhead model indicates Non-native predation and competition with invasive species and hatchery produced salmonids is of medium importance in rearing and emigration estuarine habitats, including floodplain (Figure 2a). There is limited data on Chinook salmon and steelhead use of San Joaquin floodplain (no mention in Rosenfield 2007) but the evaluation team thought there is no reason why they would not utilize this habitat in the same way they utilize similar Delta systems (Yolo Bypass).

Magnitude = 2
Based on perennial inundated benches, but not floodplains; benches may support more non-native predators.

Certainty = 4

Based on understanding high concentrations of non-natives in perennially shallow water areas of the San Joaquin (Grimaldo et al. 2003, Feyrer 2003).

N4c. Green and white sturgeon

The floodplain model does not address non native predation or competition on the floodplain. Evidence from Yolo and Cosumnes about non-natives taking advantage of floodplain (ref Sommer et al 2004, Moyle et al 2006). Floodplain Model: Page 10 talks about sources of invasive species. Foodweb Model is focused on estuarine systems.

White sturgeon – model indicate probable distribution in this reach (Figure 7), green sturgeon model indicates uncertain distribution in this reach (Figure 2). Due to the benthic nature of green and white sturgeon and the timing of floodplain inundation they are not expected to be found on the floodplain (personal communication with Josh Israel 2009).

Magnitude = 1

Certainty = 2
Sturgeon have a lower risk because they are uncommon in this area.

N4d. Splittail

The floodplain model does not address non native predation or competition on the floodplain. Evidence from Yolo and Cosumnes about non-natives taking advantage of floodplain (ref Sommer et al 2004, Moyle et al 2006). Floodplain Model: Page 10 talks about sources of invasive species. Foodweb Model is focused on estuarine systems.

Splittail model - Predation by non native fish is characterized as low with high understanding for juveniles and as medium with medium understanding for adults (Figures 5, 6 and 7.) Bird predation appears limited until water recedes and floodplains begin to isolate from main channels at which point fish are exposed to wading birds. [Moyle 2004].

Magnitude = 2

Certainty = 4

Outcome N5: Increased exposure risk to contaminants (incl. Se) due to longer residence time in this area.

The following text and scores are applicable to all covered fish species (i.e. species were not evaluated separately). Selenium (Se) loading of the Bay-Delta ecosystem is driven mainly by loads entering the Delta from the San Joaquin River (SJR), which in turn receives most of its Se input from agricultural drainwater entering the river through Mud Slough (Se model, Fig. 1). The location of this project along Old River is in the South Delta in proximity to Se inputs from the SJR. Despite this location, the magnitude of potential effects of Se on covered fish species from this project relative to baseline is minimal.

The proposed action involves habitat modification that creates more extensive floodplain and low velocity, shallow water habitats. These types of habitats create a better environment for Se partitioning in food chains than would occur in bed sediment of the river channel. Exposure of covered fish to Se might increase due to higher bioaccumulation of Se in invertebrate prey and longer residence time of the fish in the restored habitat. The effect would be minimal due to the infrequency of inundation (inundated >30 days once every 7 to 20 years).

Salmonids are relatively sensitive to Se compared to other fish species (Se model, page 19). Beckon (2008 abstract from CALFED science conference; manuscript in prep) evaluated Se data from the SJR and concluded that, although discharges of Se to the SJR have been reduced over the last 15 years, Se will pose a substantial risk to salmon that are reintroduced to restored middle reaches of the river unless Se loads are further reduced and/or sufficient dilution flows are provided. The magnitude of potential effects of Se from this project may be lower than would occur at projects along the middle reaches of the SJR (i.e., sites in the vicinity of Mud Slough) because this project occurs in the South Delta, downstream of dilution sources from the Merced, Tuolumne and Stanislaus Rivers. However, this spatial difference does not provide strong protection because Se bioaccumulates in food chains, is recycled in the ecosystem, and can have significant lag times between when loading occurs and when effects are seen.

The seasonal use of the habitat may also reduce the potential magnitude of Se impacts to covered fish species, especially juvenile salmonids. Seasonal use of the Delta by juvenile salmonids occurs mainly during high flow periods (January-June) (salmon model, page 11); whereas highest concentrations of Se occur during low flow periods (Se model, page 6). However, this seasonal difference does not provide strong protection because Se bioaccumulates in food chains, is recycled in the ecosystem, and can have significant lag times between when loading occurs and when effects are seen.

The invertebrate prey of juvenile salmonids are water-column-feeding or detritus-feeding species that are relatively less contaminated than certain suspension or deposit-feeding bivalves (Se model, Table 5 and Fig. 1). Adult splittail and sturgeon feed on bivalves and would be expected to have greater exposure to Se in their diet than salmonids. This project is intended to provide rearing habitat for juvenile sturgeon and splittail rather than habitat for adults, but may also result in increased residence time by spawning and foraging adults. However, the bivalve species present at this freshwater location would be Corbicula fluminea rather than Corbula amurensis (Corbula and Corbicula models). C. fluminea is less efficient at bioaccumulating Se than C. amurensis (Se model, page 14).

Se dynamics in the Bay-Delta system are fairly well understood, but there is uncertainty about how changes in management of SJR flows, water exports, and potential future actions to solve the drainage problem on the west side of the San Joaquin Valley could affect Se loading and cycling in the Delta (Se model, pp 3 and 4). A quantitative analysis of the increased risk of Se toxicity resulting from this project would require estimates of the increase in the amount of time covered fish spend at this location relative to the baseline condition, as well as estimates of future river flows, water exports, and Se loads. Such an analysis is beyond the scope of this worksheet exercise, but should be considered if the project is recommended for evaluation in the NEPA process.

Magnitude = 1

Certainty = 3

Important Gaps in Information and/or Understanding

Data Needs

- Transition from intertidal to riparian vegetation poorly understood. No examples left in the system to allow determination of critical flooding regimes.
- The amount of existing habitat along Old River (e.g., floodplain, riparian, etc.) was not quantified for this evaluation team. Proximity of floodplain habitat to existing riparian habitat would also be useful information.
- What is the likelihood of entrainment of Old River juveniles via Middle River conveyance?

Research Needs

- The turbidity linkage for longfin smelt is not as well documented in the research as it is for delta smelt. Further studies positively linking turbidity and longfin smelt would be helpful.
- The basis of the assumption for the flooding frequency could be refined (Table 2, BDCP doc).
- Rearing habitat for steelhead? Rearing habitat for juvenile sturgeon?
- Hg accumulation in fish has been documented, but does not indicate effect on fish.
- Degree of contaminants affects on POD.
- Degree of sediment settling on floodplains.
- Degree of predation/competition within floodplains on native covered fish species by non-native fish species.
- Better diet information is needed for floodplain use of SH, green and white sturgeon.
- More information is needed about relative importance of food to population level effects for all of the species.
- Transport studies are needed to evaluate the footprint of food transport from floodplains.
- Timing duration of rearing for SH, green and white sturgeon.

Assess Reversibility and Opportunity for Learning

Reversibility

No/Hard. Low reversibility with high resources associated with structural investments in setback levees.

Comments:
Implementation of this action would not provide a suitable opportunity to address critical unknowns or uncertainties. An increase of habitat would not create monitoring ops that we would not be gained form other areas. Score would be higher if inundation was more frequent. Monitoring juvenile use of San Joaquin floodplains would advance understanding of juvenile Chinook in the San Joaquin basin. However we cannot conduct research on area that floods so infrequently. The 30 day inundation period (as written) is a high standard to meet.

Opportunity for Learning

Low, given uncertainty of entrainment risk via Middle River conveyance and diversion operations.

Comments

Opportunity for learning associated with habitat improvements for San Joaquin Basin Chinook juveniles is scored low based on infrequency of inundation .An increase of habitat would not create monitoring ops that we would not be gained form other areas. Score would be higher if inundation was more frequent. Monitoring juvenile use of San Joaquin floodplains would advance understanding of juvenile Chinook in the San Joaquin basin. However we cannot conduct research on area that floods so infrequently. The 30 day inundation period (as written) is a high standard to meet.

References Cited

Salmon model (Williams/Rosenfield 2007)
Steelhead
Splittail
Green and white sturgeon
Longfin smelt
Delta smelt
Floodplain
Boundary conditions
Riparian vegetation
Temperature
Mercury
Pyrethroids
Chemical stressors
Selenium
Hatton 1940
Healy 1991
Ward et al 2003
Sommer 2005
Sommer et al 2001, 2004, 2005
Harrell and Sommer 2003
Harrell and Sommer unpub
Williams 2006
SJRG annual reports 2004-2007
FWS 2007
Myers et al. 1998
San Joaquin Technical Annual Report 2004
Caswell Annual Report 2007
Kjelson 1982
McEwan 2001
Moyle 2002
Moyle et al 2006, 2007
Hunter et al 1999
Rosenfield 2007
Beckon 2008

Appendix A

HRCM 4:
Yolo/Cache Slough Complex ROA
Tidal Marsh & Shallow Subtidal Restoration

Scientific Evaluation Worksheet

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EVALUATION TEAM 1

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Action

Restore between 5,000 and 11,000 acres to tidal action and vegetated tidal marsh and shallow sub tidal habitat in the Yolo Bypass/Cache Slough Complex ROA (in addition to Liberty Island and Little Holland Tract). *(Evaluate both 5,000 and 11,000 acres)*.

Evaluation Team

Dave Harlow (Chair), Stuart Siegel (Coach), Jon Rosenfield, Wim Kimmerer, Chris Enright, Dan Kratville, Charlie Alpers, and Amy Richey.

Date of Last Revision: June 11, 2009

Action Description and Clarifying Assumptions

The evaluation team was asked to consider two restoration scenarios as follows:

5,000-Acre Option Extent

Haas Slough A & B; Shag Slough; and Egbert A & B.

11,000-Acre Option Extent

Areas suitable for restoration include, but are not limited to: Haas Slough (A & B); Hastings Cut; Lindsey and Barker Sloughs and Calhoun Cut (Egbert A & B); Liberty Island, Little Holland, Westland's property, Shag Slough, Little Egbert Tract, and Prospect Island.

Restoration would include a combination of: (1) vegetated marsh plain; (2) tidal channel networks with depths that are shallow to medium subtidal; and (3) shallow subtidal open water in the deeper portions of the restoration sites. Achieving the 5,000 or 11,000 acre restoration target would involve restoring *some* but not all of the sites noted above.

Figure 1 and Table 1 depict the different habitat types that would be expected to result from tidal reintroduction in the Yolo/Cache ROA based on existing elevations. Elevations are reported in the current federal geodetic datum (land surface elevation) of the North American Vertical Datum of 1988 (NAVD88). Elevations are grouped relative to *existing* local tide heights as reported by the National Ocean Service for the Rio Vista station (NOS 941-5316). BDCP modeling has shown that tide ranges will be reduced with implementing tidal reintroduction projects but we have not attempted to integrate those modeling findings at this time. It should also be noted that existing intertidal areas for Liberty, Little Holland and Westlands' property are combined. Sea level rise is indicated by the abbreviation (SLR).

A brief description of each elevation category depicted in Table 1 is provided below the table. Descriptions of the plant community composition associated with the elevation categories listed in Table 1 come from the DRERIP Tidal Marsh Conceptual Model (Kneib et al 2008), findings of the CALFED Integrated Regional Wetland Monitoring Pilot Project (www.irwm.org), and the DRERIP Aquatic Vegetation Conceptual Model (Anderson 2008).

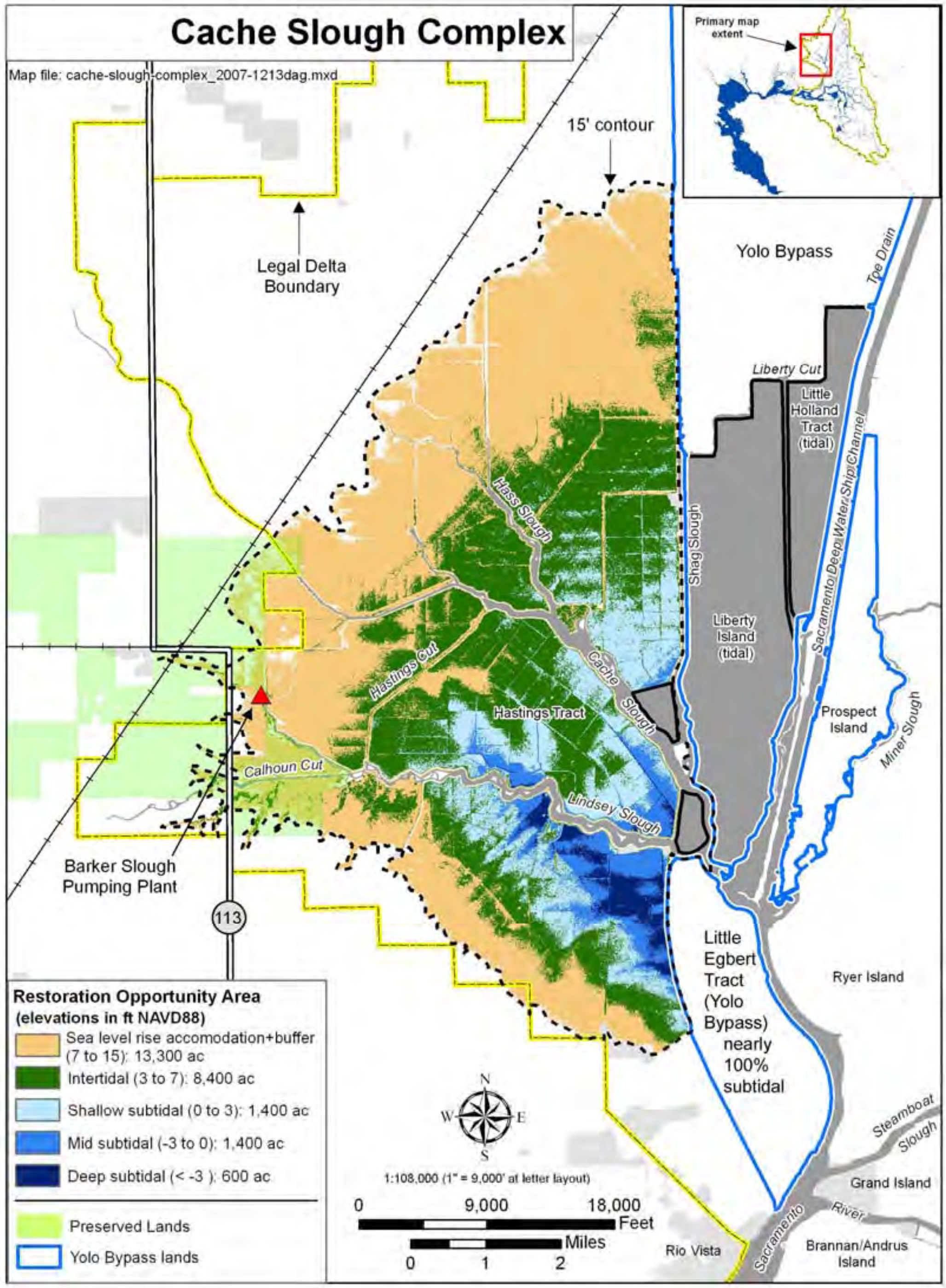
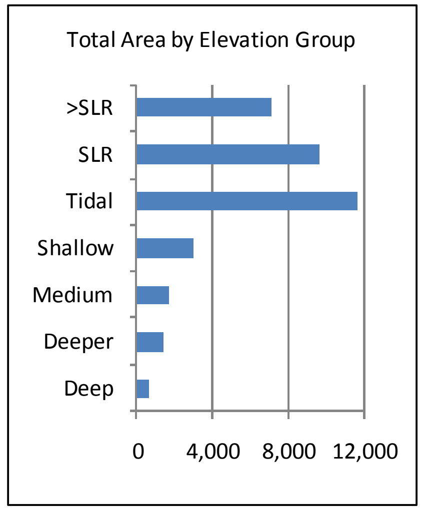


Figure 1. Topography of proposed restoration areas.
Lands shown in green (intertidal) and blue (sub tidal) plus Little Egbert Tract and Prospect Island (both mostly sub tidal) comprise the larger, 11,000-acre option. *Source: Stuart Siegel 2008.*

Table 1.

Total Area Available at BDCP Sites Considered, by Elevation Group

Site (5K option only)	Total (ac)	Area (ac) by Elevation Group (ft NAVD88)			Subtidal			
		> SLR (>12')	SLR (7-12')	Tidal (3-7')	Shallow (0-3')	Medium (-3-0')	Deeper (-6--3')	Deep (<-6')
Egbert A	4,644	3,323	1,034	276	2	3	3	4
Egbert B	7,107	1,496	1,455	1,687	1,541	779	51	97
Haas A	1,900	431	989	457	5	2	4	11
Haas B	1,233	489	728	16				
Hastings Cut	7,721	872	2,139	3,343	936	181	63	187
Little Egbert	3,457	67	381	536	312	725	1,196	240
Prospect	1,818	59	181	1,480	46	14	8	30
Shag	6,859	267	2,651	3,731	64	28	30	87
Total	34,738	7,003	9,558	11,527	2,907	1,732	1,356	656
% of total		20%	28%	33%	8%	5%	4%	2%
% of tidal, subtidal				63%	16%	10%	7%	4%



* Data provided by SAIC 2/2/09 with corrected Little Egbert data 2/6/09

1) **Above SLR** (sea level rise): elevations above the currently projected upper end of sea level rise. These areas would be expected to remain as uplands over the long term after tidal reintroduction. These areas could support seasonal wetlands and upland habitats utilized by species that also use the marsh (e.g., birds, small mammals, reptiles, amphibians).

2) **SLR**: elevations that are within the currently projected upper end of sea level rise and thus would be expected to become inundated over time after tidal reintroduction as sea level rises. These areas could support a mix of seasonal wetlands, uplands, upland-wetland transition, infrequently inundated tidal marsh at the lowest elevations, and in the future increased extent of tidal marsh as sea level rises.

3) **Tidal**: elevations that are within the current local tide range of mean lower low water (MLLW) (3 ft NAVD88) to mean higher high water (MHHW) (7 feet NAVD88). This elevation category would be dominated over time by a diverse suite of emergent marsh plants showing some zonation patterns relative to elevation and thus inundation regime.

4) **Shallow Subtidal**: elevations that are between MLLW and 3 feet below local MLLW (0 to 3 ft NAVD88). This elevation category would be dominated by open water with tule vegetation extending into its shallowest regions; also subject to colonization by submerged aquatic vegetation in low-energy areas with suitable substrate.

5) **Medium Subtidal**: elevations that are 3 to 6 feet below local MLLW (-3 to 0 ft NAVD88). This elevation category would be open water and subject to colonization by submerged aquatic vegetation in low-energy areas with suitable substrate; SAV would have a greater probability of occurrence at shallower depths with more light penetration.

6) **Deeper Subtidal**: elevations that are 6 to 9 feet below local MLLW (-6 to -3 ft NAVD88). This elevation category would be open water and subject to colonization by submerged aquatic vegetation in low-energy areas with suitable substrate only in areas with high light penetration.

7) **Deep Subtidal**: elevations that are more than 9 feet below local MLLW (below -6 ft NAVD88). This elevation category would be open water and subject to colonization by submerged aquatic vegetation in low-energy areas with suitable substrate only in areas with extremely high light penetration.

Approach

1. Breach levees to provide for tidal exchange with lands being restored; breaches will be of sufficient length not to limit water motion into and out of restored habitat.
2. Modify ditches and cuts to encourage the development of a dendritic system of tidal channels based on local hydrology, sized appropriately for the tidal prism being conveyed.
3. Restore stream functions of erosion and sedimentation (e.g., Ulatis Flood Control channel) to improve spawning conditions for Delta smelt and other fish and macro invertebrates.
4. On subsided lands (e.g., Little Egbert Tract), plant tules before breaching levees to raise ground surface to elevations suitable for tidal marsh restoration.

Intended Outcomes as Stated in Conservation Measure

1. Increase rearing habitat area for Chinook salmon, Sacramento splittail, and possibly steelhead.
2. Increase the production of food for rearing salmonids, splittail, and other covered species.
3. Increase the availability and production of food in the Delta downstream of Rio Vista by exporting organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta.
4. Locally provide areas of cool water refugia for Delta smelt.

Conceptual Model Information Regarding Intended Outcomes

The Outcomes tables document the following linkages between tidal marsh restoration efforts generally in the Delta and the specific cause-effect relationships implied in the Action:

1. Rearing habitat is a stated outcome for habitat quantity and quality (specifically, water quality). It is a driver for Delta smelt, longfin smelt, splittail, and white and green sturgeon. The higher turbidity levels of Cache Slough region compared to other Delta locations (see Schoellhamer et. al., 2007) improves habitat suitability for Delta smelt.
2. Exported production is a stated outcome. It is a driver for Delta smelt, steelhead, and white and green sturgeon.
3. Cool water refugia is not integrated into the Outcomes table. To the extent that "water quality" implies temperature (it usually implies salinity unless otherwise stated) then it is captured.

Assumptions

Provided in BDCP Conservation Measure

1. Barker Slough Pumping Plant is relocated such that it does not adversely affect benefits of restoration.

Added by Evaluation Team

1. Barker Slough Pumping Plant relocation also eliminates potential conflicts between drinking water supplies and increased organic carbon in the water column.
2. Other large agricultural intakes in the area will be relocated such that they do not adversely affect benefits of restoration.
3. Levee breaches will be large enough not to cause muted tides within a restoration site.
4. Levee breaches will be large enough to avoid steep velocity gradients (eddies) that promote fish predation.
5. Approach #2 includes the excavation of subtidal dendritic channel networks, recognizing that down cutting through prior agricultural fields is unlikely.
6. The time frame for realizing restoration benefits depends upon the approaches used. Reversal of subsidence on restored areas can take several years to a decade or more depending on starting elevations. The accretion rate depends on sediment supply and biomass accretion which depends on site-specific conditions. Sediment supply in the Delta is generally very low. Cache Slough and Suisun Marsh generally have higher concentrations of sediment than other Delta locations (Schoellhamer et. al., 2007).
7. Efforts to reverse subsidence before active restoration would be focused on the more deeply subsided portions of these landscapes, i.e., lands more than 6 feet below low tide. To speed up the subsidence reversal process, an alternative method would be to separate low-lying areas with new levees and reconnect those areas after subsidence reversal is accomplished.
8. Prior to implementation, a complete Phase I Environmental Assessment with on-site sampling to assess legacy and other soil contaminants (i.e. mercury and pesticides) would be conducted.
9. The frequency, magnitude, and duration of Yolo Bypass flooding would be the same as current existing conditions.

Problem(s) with Action as Written:

1. The conservation measure would benefit from an explicit recognition that restoration of tidal marsh functions on subsided landscapes, especially those subsided below emergent vegetation elevations, will take many years to many decades. In the interim, the region will function as a shallow intertidal habitat.
2. The evaluation should consider alternative approaches for shallowly subsided lands. Approach #4 indicates one approach – pre-breach tule planting on the subsided areas. The approach should also consider leaving some part of the restored area as shallow sub tidal habitat, as the Action itself states "tidal marsh and shallow sub tidal habitat". Each approach leads to a different outcome on different time scales. See assumption #8 above.
3. It is unlikely that intertidal mudflats will develop in the Delta because dominant intertidal emergent vegetation species in the Delta can grow throughout the tidal

range and just into shallow sub-tidal elevations (Brown 2003, Simenstad et al 2000 as cited in Schoellhamer et. al., 2007, page 26).

4. Because rearing habitat for juvenile fish by necessity includes local availability of food, the evaluation team merged the first two Intended Outcomes (rearing habitat and local food) into one outcome.
5. As currently written, approach #3 (stream functions) is not clear. The Evaluation Team doubts this watershed is large enough to provide significant sedimentation. Therefore, this approach is not included in this evaluation.

Scale of Action:

Large for both acreage options.

Rationale:
This is a large scale restoration action due to its spatial extent. As listed in Table1 below, the Delta currently has approximately 21,600 acres of tidal marsh habitat (baseline). Additionally 67,000 acres of diked and other lands have been identified as potentially restorable to tidal marsh (neglecting effects of restoration on reducing tidal range). The proposed 5,000 and 11,000 acre restoration options would increase marsh acreage 23% and 51% (respectively) above current conditions. Significant amounts of the 67,000 acres of identified restorable lands are highly constrained such that they could not be restored in the near term (South Delta and Netherlands alone account for 31,000 acres of the 67,000 acres). Therefore, this action also represents an important part of the potentially restorable tidal marsh lands.

Table 2. Summary of Tidal Marsh Acreages

Area	**Acreage**	**Source**
Delta (entire Delta proper)	738,000	DWR, 2009
Historic tidal marsh/wetlands in Delta	525,000	TBI, 2002
Current extent of tidal marsh/wetlands in Delta.	21,600	TBI, 2002
Restorable intertidal lands within Delta.	67,000	CA DVSP, 2008, Table 1, p.77.
Proposed Cache Slough tidal marsh restoration (this action)	5,000 or 11,000	BDCP, 2009

Evaluation Summary Tables

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Outcomes with Direction of Change Uncertain

The outcomes listed below could be either positive or negative (the direction of change is not certain).

- P/N1. Slough turbidity changes as it affects Delta smelt food locating capacity. This outcome was not evaluated. The team believes there is a relationship but lack of data precludes evaluation (we don't know whether the sign would be positive or negative).
- P/N2. Increased velocities in larger sloughs may alter the energetics of covered fish species. Velocities will increase in some parts of the Delta and decrease in other parts. The direction of change is not known.

Outcomes with Zero Magnitude

- OP1: Increase rearing habitat and local food production for Eastside and San Joaquin Chinook salmon, fall run.
- OP2a: Locally provide areas of cool water refugia for winter-run salmon.
- OP2b: Locally provide areas of cool water refugia for late fall-run salmon.

Other Potential Positive Outcomes Identified, Not Evaluated

When BDCP originally crafted this action, they identified the four potential positive outcomes listed below. The Evaluation Team was instructed to focus evaluation efforts on covered fish species. Since the four outcomes consider species other than covered fish, the team did not evaluate these outcomes.

- OP1. Increase giant garter snake habitat
- OP2. Increase Mason's lilaeopsis habitat
- OP3. Increase habitats for resident native fish (blackfish, Sacramento perch, tule perch)
- OP4. Increase habitats for birds
- OP5: Reduce low velocity-associated salmonid predation pressure in Sutter and Steamboat sloughs (see details in Appendix C)

Other Potential Negative Outcomes Identified, Not Evaluated

During the course of this evaluation, the team identified one potential negative outcome that it did not evaluate due to lack of time. It is recommended that this potential outcome be evaluated at some point in the future when additional time is available.

- ON1. Pesticide use for mosquito control. Tidal marsh provide habitat for mosquito larvae and adults. Since this restoration action will increase tidal marsh habitat, it will also increase the availability of habitat for mosquitoes. County environmental health departments are authorized to utilize pesticides to the extent necessary to manage mosquitoes in order to protect public health and prevent west nile and other viruses. Sacramento, San Joaquin, and other Delta counties have active mosquito management programs that include the application of pesticides on marsh habitats. The effect such pesticide use may have on the flora and fauna in the restored marsh and connected areas have not been evaluated in this worksheet.

Relation to Existing Conditions

Significant changes to hydrodynamics due to Cache Slough restoration have been simulated by the BDCP modeling team (BDCP 2009. and John DeGeorge, pers. comm.). The one-dimensional model results combine Cache Slough restoration with other core elements including modification of the Fremont Weir and new North Delta diversion. The two-dimensional modeling simulated multiple restoration areas at one time in some cases. For this particular evaluation, only altered hydrodynamics in response to Cache Slough restoration are considered. In this section, the evaluation team primarily considers the Cache Slough restoration on its own merits. However, some comments on the integration of Cache Slough restoration and Yolo bypass flow augmentation are also provided.

In general, opening hydraulic connections to formerly diked lands will dissipate tidal energy on a regional (in this case, nominally northwest Delta) scale. Reductions in tidal range and redistribution of tidal flows and associated tidal velocity may also be observed.

While the modeling of Cache Slough restoration includes the north Delta diversion and intermittent Fremont Weir flow, the influence of these elements on tidal range is thought to be minimal (BDCP 2009).

Cache Slough restoration decreases regional tidal range, with generally more reduction near, and less reduction far from the project. The magnitude and aerial extent of decrease is also a function of project acreage, hydraulic connection attributes, the restoration volume or accommodation space, and the roughness characteristics of the site.

Tidal stage range in Cache Slough and the Liberty Island area is estimated to decrease by up to 0.75 feet from its current range of about 4 feet. Simulated changes in Sacramento River stage range downstream of Cache Slough (near Rio Vista) are similar. Upstream, Sacramento River stage range is estimated to be reduced by approximately 0.5 ft. More of the tidal range reduction will on the high tides than the low tides. Sutter, Steamboat, and Georgiana Slough stage changes are anticipated to be similar to that at Freeport.

The magnitude and duration of tidal inundation on newly restored sites is a function of the particular configuration of the project. It is expected that the site will evolve geomorphically over time. Project evolution will be characterized by sediment and vegetation accretions that will reduce accommodation space. This may have the effect of increasing regional tidal range once again. However, along the trajectory of change over time, the balance of forces may yet reduce tidal range further while the site still has most of its initial accommodation space, but also becomes highly frictional as emergent vegetation begins to dominate the tidal fringes. The evolving balance between the tidal prism and the frictional characteristics of the site ultimately determines how regional stage and tidal flow will be affected over time (Friedrichs et al. 2001, Culberson et al. 2003).

Tidal restoration in Cache Slough ROA differentially influences regional tidal flow and velocity depending on channel proximity to the restoration area. In general, tidal flow and velocity increases in Cache Slough as much as 30,000 cfs, because it conveys flow to the increased accommodation space created by the restoration. Tidal flow increases despite the reduced tidal range because there is now slightly less asymmetry between stage and velocity phasing (peak flood and ebb flows occur ~1 hour later). Tidal flow at Rio Vista increases from approximately +/- 100,000 cfs to approximately +/- 130,000 cfs. Modeling suggests that peak tidal velocity will increase 30-40% to accommodate the added flow. This will likely be a transient effect until the channel scours to a new dynamic equilibrium between bed shear stress and sediment cohesion properties.

Tidal flow variability is dramatically decreased upstream of Cache Slough in concert with diminished tidal range. While net flow remains the same, variability of tidal flow at Freeport is decreased from approximately 4,000-15,000 cfs to +6,000-14,000 cfs (simulated spring tide, mid June 2002) (BDCP, 2009). Closer to Cache Slough, Sutter Slough flow range diminishes from +/-2,000-5,500 cfs to +1,000-4,500 cfs. Sutter Slough and Steamboat Slough also no longer exhibits bi-directional flow at their heads, and diminished bi-directional flow downstream. This is important because it reduces or stops the ability of salinity (or other scalars) to disperse upstream.

The hydrodynamic changes described above can be broadly used to describe changes under either the 5,000 or 11,000 acres restoration scenarios, with the magnitude of change corresponding to the acreage restored. Tidal dampening and/or conveyance restrictions appear to increase as more acres are restored, limiting the extent of inundation; further hydrodynamic modeling would be needed to confirm or reject and quantify this effect.

Overview of Productivity Import-Export

The purpose of this section is to discuss the general concepts around productivity in the restored tidal marshes and shallow open water and availability of primary productivity to the aquatic food web within and outside of restoration sites. Available productivity is one of the main intended positive outcomes of this conservation measure. Factors that influence biological productivity include resource availability (e.g., light, nutrients), import-export dynamics (biological and physical), invasive species, and predator-prey relationships As restoration sites evolve over time, the nature and relative magnitude of these factors may change. Climate change and sea level rise will introduce additional dynamics (Callaway et al, 2007).

Freshwater tidal marshes are among the most productive ecosystems globally. The efficiency with which organic material produced at the base of the food web will reach covered fish species has a large influence on the potential positive benefits of tidal marsh restoration. The DRERIP tidal marsh model (Kneib et. al., 2008) hypothesizes that the most prevalent form of carbon bioavailable to the aquatic food web is exported from tidal marshes in the form of small fish, a concept referred to as the “trophic relay”. In addition, the Conservation Measure includes restoration of emergent vegetated tidal marsh, shallow sub tidal channel networks within the restored tidal marshes, and adjacent shallow sub tidal open water areas. See Figure 3 below for a schematic representation of a generic tidal marsh.

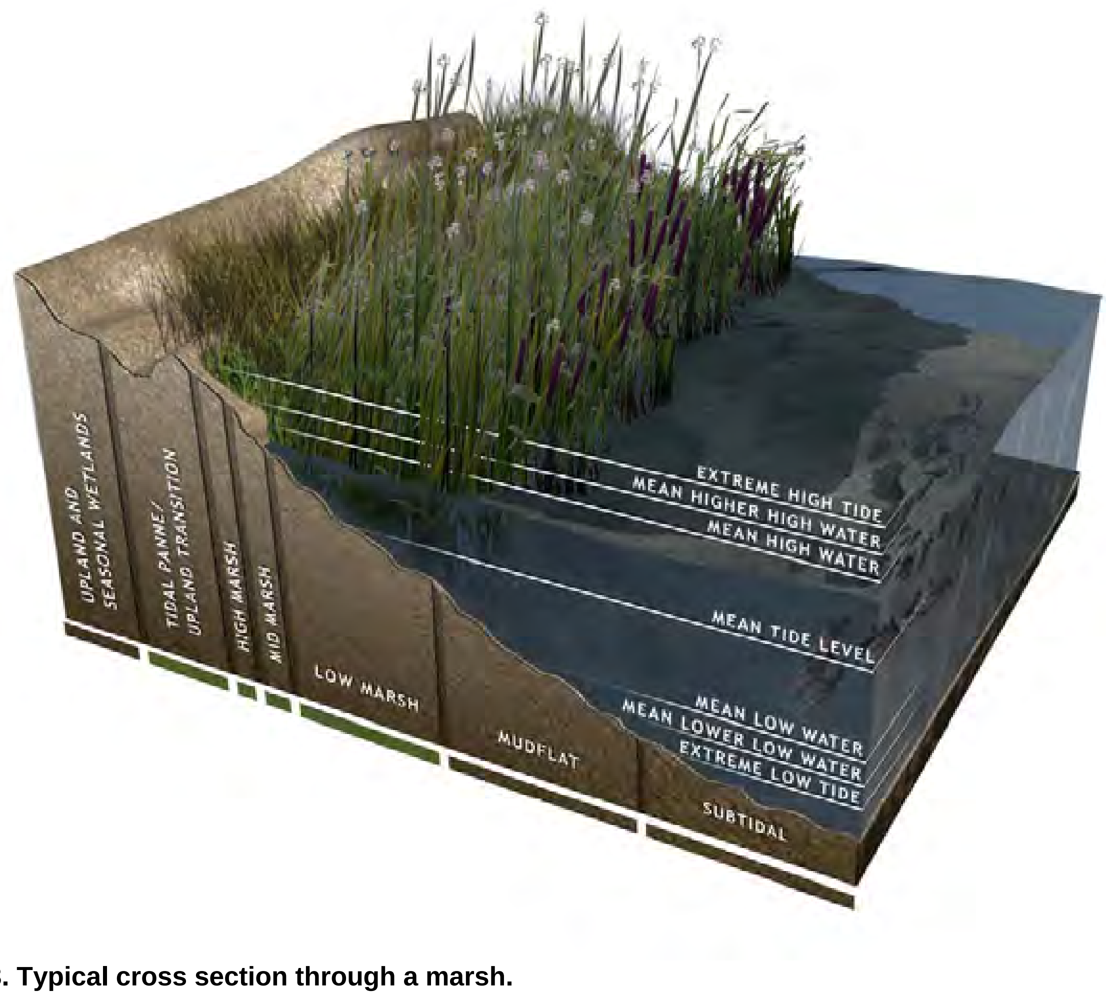


Figure 3. Typical cross section through a marsh.

Tidal marshes generally are net producers of organic matter because of high primary production by marsh plants, epiphytes, submerged and floating vegetation, and phytoplankton. This material is available to support local foodwebs and provide food energy for invertebrates, fish, and other animals. Tidal marshes can both import and export organic carbon in dissolved or particulate, living and nonliving, and bioavailable or refractory forms. However, much of the organic matter exported is in the dissolved form which provides less direct benefit to the estuarine foodweb because the organic matter is not very bioavailable and the microbial foodweb that can use this material is inefficient (Sobczak et al. 2005). Newly created or restored marshes, or marshes that are mainly subtidal, may accrete organic soil and thereby bury organic matter (Kneib et. al., 2008).

An intended outcome is the export of organic matter, based on the assumption that marsh restoration will increase production of phytoplankton and other bioavailable forms. Experiments to stimulate phytoplankton production in natural water bodies have been conducted to investigate nutrient limitation and to explore the possibility of stimulating production of fish. These studies include lake fertilization experiments (Schindler 1977, Carpenter et al. 1995) and iron addition experiments in the ocean (Chisholm et al. 2001). The general conclusion of such studies is that natural ecosystems are complex and that consequences of any change in forcing, whether from nutrient enrichment or alteration of trophic structure, can be difficult to predict (Carpenter et al., Chisholm et al. 2001). This suggests that forecasts of gains in export of productivity from the restored marshes should be made cautiously.

When net flow rates are low, the movement of individual foodweb components depends on tidal exchange and the concentration gradient, affected in turn by source and loss rates in and outside the marsh, and the swimming of organisms. For example, marshes produce particulate detritus that is then available for export, but marshes can also import detritus through particle trapping by marsh plants. Data shows that net phytoplankton production is highest in shallow water because phytoplankton production requires light (Thompson 2000). Although this implies the potential for export there is little quantitative information to support this, and the degree of export depends critically on shallow-deep system connectivity (Cloern 2007 and Monsen et al 2007) and the local phytoplankton growth-loss balance (Lucas et.al. 2009). For example, establishment of invasive clams or mussels in the shallow subtidal regions or marsh channels (Outcome N1B) may increase local phytoplankton loss rates and thus convert restored areas into food sinks instead of sources. Similarly, planktivorous fish in marshes may consume zooplankton at a higher rate than occurs outside the marsh, resulting in a concentration gradient favoring net import of zooplankton. Thus, the restored marsh may or may not export phytoplankton, zooplankton, or other organic matter to the broader foodweb.

Role of Restoration Stage, Sedimentation, and Biomass Accumulation, and Sea Level Rise: Inundation regime (depth, frequency, and duration of flooding) and salinity are the two most dominant controls of tidal marsh ecology (Callaway et al, 2007). Inundation regime is controlled mainly by marsh elevations relative to the tides, with the Delta having a relatively significant seasonal riverine influence. Restored marshes will increase in elevation over time through sediment accretion and biomass accumulation. Accretion rates are not well documented in the Delta but what little information exists suggests generally low rates with high variability (data from BREACH and Integrated Regional Wetland Monitoring Pilot Project), though the Yolo Bypass provides somewhat more sediment (see Schoellhamer et. al., 2007, Simenstad 2000 and Reed 2002) that should benefit restoration in the Cache-Yolo area compared to other Delta locations.

Role of *Corbicula* in Affecting Exported Production: The outcome in terms of organic carbon production depends critically on whether freshwater clams (*Corbicula*) become established in the vicinity of the restored area (Lopez et al. 2007). If they become established and abundant either within marsh channels or in river channels in the vicinity of the marsh or in shallow sub tidal restored areas, they may consume most of the phytoplankton carbon produced there and remove it from the pelagic food web. See Outcome N1c below.

Role of Residence Time in Affecting Productivity Levels: Residence time refers to the time that a particle of water or some constituent of water remains in a water body. This concept is applied here more as a broad concept than a specifically measured quantity (see Monsen et al. 2002 for a discussion of residence time). When the movement of water in the Delta slows either because of lower net flow or reduced tidal velocities, residence time increases (see Kimmerer and Nobriga 2008). With the decrease in inflow to the Delta due to the export of water from the Sacramento River, and the decrease in north-to-south flow of water toward the south Delta export pumps, residence time generally will increase.

The speed of exchange between the Cache Slough restoration area and the rest of the Delta would be influenced by the tidal range, freshwater flow, the physical configuration of the breaches, and how that configuration changed over time. Hydrodynamic modeling results suggest that waters in the Cache Slough area after restoration would have relatively long residence times due to limited mixing in the tidal marsh areas, despite increased exchange of tidal flows in the main connecting channels. When the Yolo Bypass floods, mixing might increase and residence time would be inversely related to the flow rate. The amount of food produced in an area and the fate of this food depends on residence time as well as the local growth-loss balance (Lucas et. al. 2009). When residence time is long, food production can be high but little is exported. When residence time is very short, little production results. Intermediate residence times can maximize the production and export of foodweb organisms, but the magnitude of that export is unknown.

Potential Positive Ecological Outcome(s)

Outcome P1: Increase rearing habitat and local food production

As indicated at the beginning of this worksheet under the section entitled "Problems with Action", the team decided to merge two Intended Outcomes (rearing habitat and local food) into one outcome, P1, as shown below because rearing habitat for juvenile fish by necessity includes local availability of food. This outcome includes food (both primary and secondary production) produced within the vegetated marsh, within marsh channels, and within the subtidal areas adjacent to the vegetated marsh.

P1a. Delta smelt

General Observations: The aquatic food web supporting Delta smelt production is a primary component of habitat suitability that affects Delta smelt growth rates, health, fecundity, and mortality (page 21 in Nobriga and Herbold, 2008). The food web supporting Delta smelt is based on the production of pelagic zooplankton.

Historically, Delta smelt had a larger spawning range as compared with their spawning range in recent years. In some recent years, the Cache Slough area appears to have supported a substantial portion of spawning and rearing Delta smelt (page 11 in Nobriga and Herbold, 2008). Maintenance of suitable habitat conditions in the Cache Slough region is very important to conservation of this species and it is possible (though not at all certain) that habitat conditions for Delta smelt in this area can be improved; however, without restoration of spawning/rearing conditions in other locations (maintenance of spatial distribution and diversity), Delta smelt will remain in great peril of extinction.

Delta smelt are believed to be food limited for at least some life stages (Herbold and Nobriga 2008, page 9). In summary, food resources for Delta smelt would be produced within the restored marsh habitat, and the combination of physical space and food production would constitute habitat for Delta smelt.

Food generated on this site might be lost to invasive clams. This phenomenon is described in detail in Negative Outcome N1b. Predation (especially if it is facilitated by colonization of SAV) may also eliminate any beneficial effect of this action.

Magnitude = 3 - Medium: If implemented, this action is expected to produce a sustained minor population level effect on Delta smelt. The benefit of the action is expected to vary over time depending on the Delta smelt population distribution. When Delta smelt are distributed in many areas of the Delta, the overall population will derive a relatively minor benefit from this localized action. However, if the population is constrained to the Cache Slough area, the relative benefit from this action may increase.

One of the major concerns for Delta smelt relates to their narrow geographic distribution. The maximum suspected spawning range for Delta smelt (i.e. all localities where gravid or early larval fish have been detected) is small enough that this species is at risk of extinction due to localized catastrophic or demographic events (see Rosenfield 2002); this risk is exacerbated by their short life span and semleparous life history. In fact, the geographic range of Delta smelt appears to have decreased in recent years and, during

low outflow years, may be limited to just a few sites (this year, in the Northern Delta, Montezuma and west Delta), totaling just a few square kilometers. Increasing the Delta smelt population without increasing their geographic range (meaning available spawning and rearing habitat within the Delta) addresses only a portion of the threats to Delta smelt.

An additional factor contributing to the medium magnitude score for this outcome is that under circumstances described in the conceptual model (which may no longer hold, as discussed above) the production of habitat here would affect only a portion of the life cycle and the outcome will only benefit a fraction of the population.

Certainty = 2 - Low: The value of food produced on site is related to how much of that food makes it into the adjacent channels and to the suitability of the adjacent open-water regions to continue supporting Delta smelt. Both of these are uncertain. The food available to Delta smelt in directly adjacent channel and open-water habitats depends on how much of the zooplankton produced in the region is consumed by fish that actually forage there. The ability of Delta smelt to compete for available zooplankton is influenced by how well the habitat meets its physiological and behavioral needs.

Corbicula establishment could reduce the productivity benefits of the restoration to Delta smelt. See Negative Outcome N1b. If SAV starts to become established in a restoration site, there also may be an increase in the rate of predation on Delta smelt by several predators during the period SAV begins to establish. If SAV becomes well established, Delta smelt will not occupy the site with much frequency. Thus, poorly designed restoration could dissuade Delta smelt from using the north Delta as extensively as they do currently.

P1b. Longfin smelt

General Observations: Rearing longfin smelt larvae and juveniles are infrequently found in this area at low abundances according to Rosenfield, 2008 and data from the 20mm survey (http://www.delta.dfg.ca.gov/data/20mm/CPUE_Map.asp) and the tow-net survey (http://www.delta.dfg.ca.gov/data/townet/CPUE_Map.asp).

Magnitude = 1 - Minimal: The effect of this action on longfin smelt is expected to be negligible. Tidal marsh is not considered "rearing habitat" for longfin smelt. Although larvae are generally found near the water column surface (Rosenfield, 2008 p.5), where

they might access shallow habitats, juveniles can adjust their position in the water column (Rosenfield, 2008, p.6) and tend to concentrate in deepwater environments (Rosenfield and Baxter 2007). Only a very small proportion of late-stage longfin smelt larvae would be expected to occur in shallow tidal environments.

In addition, longfin smelt are rarely detected above Rio Vista on the Sacramento River (Wang 1991; R. Baxter, CDFG, unpublished data). Recent survey data (in years 2008 and 2009) have shown longfin smelt larvae to be more common in this area (e.g. Smelt Survey; http://www.delta.dfg.ca.gov/data/sls/CPUE_Map.asp; and 20mm survey, http://www.delta.dfg.ca.gov/data/20mm/CPUE_Map.asp). It is possible that the very small proportion of larvae-transitioning-to-juvenile longfin smelt rearing in this area may benefit from food items produced locally.

Certainty = 2 - Low: The scientific certainty about achieving any benefit is low. Sampling rarely detects longfin smelt in the Cache Slough complex and, when they are detected (generally larvae or very small juveniles), abundances are extremely low. In addition, establishment of *Corbicula*, SAV and/or predators on the restoration site could eliminate any net benefits to covered fish species. See Negative Outcome N1b.

P1c. Chinook salmon and steelhead

General considerations that apply to all the salmonids are described below followed by run-specific magnitude and certainty evaluations. The DRERIP Salmonid conceptual model indicates the value of estuarine rearing varies across runs (see Williams and Rosenfield, In preparation page 15).

General Seasonality of Delta Use: Juveniles of most runs migrate during winter through spring.

Role of Outmigrant Size in Duration of Delta Use: Larger outmigrants generally rear for shorter periods in the lower estuary before moving to the ocean. Life histories that include rearing upstream (including in-rivers and on floodplains) produce large outmigrants that are believed to derive less benefit from restoration of rearing habitat in the Delta.

Temperature: Salmonids are sensitive to warm water. Average daily water temperatures from May to September in the vicinity of this restoration (as indicated by those at IEP monitoring station RSAC 101) regularly exceed 20-21 degrees C, beyond which sublethal effects accumulate (Myrick and Cech 2004; Richter and Kolmes 2005). With warming that may occur under climate change, these temperatures are expected to occur in this area with some frequency during April and October as well. Steelhead, fall run Chinook salmon, and spring run Chinook salmon are typically present in the Delta

during some of these months and value of Cache/Yolo tidal marsh restoration to these runs would be reduced because of the warmer water.

Role of Delta in Overall Life-History of Salmonids: Delta rearing is one relatively short period in the overall life of salmonids and is not believed to be a key limiting factor for spring run, winter run, late-fall run or steelhead. Other factors such as upstream spawning and rearing habitats and water diversion structures and operations are more important in the overall life history for these salmonids (Williams and Rosenfield, In preparation).

Food Productivity to Support Rearing: Factors affecting food productivity described in this worksheet indicate that salmonids would find food resources in the Cache Slough area. The benefits of this productivity would accrue more to smaller migrants and when water temperatures support growth and smoltification (Williams and Rosenfield, In preparation).

Predator Exposure: Estuarine habitats that support salmonid rearing potentially also support predator populations, including (in particular) introduced Centrarchids that prefer shallow slow-moving freshwater environments. Increasing the residence time of salmonids in the Delta (by increasing rearing habitat) may also increase exposure to predator populations – the number of predatory fish in the Delta is much higher now than it was historically because of the introduction of Centrarchid and other non-native predators and maintenance of conditions that support those predators.

P1c1. Chinook salmon, Sacramento, winter run

General Observations: Winter-run juveniles move through the northern Delta from late-summer through winter. Winter-run life history strategy is unique. Because they may rear for several months in upstream environments, they are not expected to utilize the estuary extensively for rearing. Winter-run will consume the types of zooplankton produced in this restoration (under the assumed condition). Most winter-run migrate through this area when temperatures are cool enough to support rearing.

Magnitude = 2 - Low: The Salmonid life history conceptual model (Williams and Rosenfield, In preparation, page 16) states that "Spring Chinook, or at least the Butte Creek population, pass quickly through the Delta, so habitat restoration there seems unlikely to do much for them. The same is probably true for late fall Chinook and for steelhead. The presumed benefit of this conservation measure is the provision of food resources for outmigrating smolts. The benefits provided by proposed restoration action for winter run are equivocal.

The magnitude of this benefit for winter-run Chinook is low because of their comparatively large size when they migrate through the Estuary and because it is unlikely that they are limited by the extent of rearing habitat. Winter run are believed to grow little in the Delta. The Salmonid model suggests a moderate impact of this kind of habitat on competition, which may have a moderate impact on growth. However, both of these impacts are highly speculative. Winter-run have the smallest population of any Chinook salmon run in this system and they have access to the same estuarine habitats as the other runs. Also, their migratory season overlaps little with the more populous spring and fall run migrations. Thus, growth limitation due to inter- or intra-population competition for habitat in the Estuary is least likely for this run among all the Central Valley Chinook populations.

Food limitation is not considered a major limitation on survival in this life stage. Limitations on spawning and rearing habitat upstream are far more important to winter-run Chinook salmon conservation than putative habitat limitations in the Delta.

Certainty = 1 - Minimal: No direct studies of this run's habitat use in estuarine habitats have been published. Establishment of *Corbicula*, SAV, or predatory fish populations could limit, if not eliminate the productivity benefits of the restoration to Chinook salmon. See Negative Outcome N1b. Predation by invasive predators (especially if it is facilitated by colonization of SAV) may also eliminate any beneficial effect of this action.

P1c2. Chinook salmon, Sacramento, spring run

General Observations: Spring-run juveniles move through the northern Delta from winter through spring.

Magnitude = 2 - Low: The DRERIP Salmonid conceptual model (Williams and Rosenfield, In preparation, page 16, states that "Spring Chinook, or at least the Butte Creek population, pass quickly through the Delta, so habitat restoration there seems unlikely to do much for them. The same is probably true for late fall Chinook, and for steelhead".

The salmonid model's evaluation focused on one spring run population (Butte Creek). In fact, many juveniles from other populations migrate at a smaller size than Butte Creek juveniles. They migrate at about the same time as fall-run and thus may experience competition with fall run. So, this restoration may alleviate competition for a segment of the population. Williams and Rosenfield (In preparation) indicates moderate benefits of increasing rearing habitat.

Benefits are limited to those emigrants rearing in this habitat in the early-mid spring, before temperatures in this region increase above optimal rearing threshold (12-16 degrees C, Marine and Cech 2004).

Certainty = 2 - Low: There are no direct studies of spring-run Chinook salmon habitat use in this ecosystem. Driver-Linkage-Outcome (i.e. conceptual model) indicates variability (inter-population and inter-annual) in the relationship between habitat volume-density-competition and growth.

Given the temperature limitations and differences in life history among spring-run populations, the Evaluation Team can be moderately certain that the maximum positive magnitude of this impact from this action is low; however, there is relatively low certainty that there will be any beneficial impact at all. Establishment of *Corbicula*, could limit if not eliminate the productivity benefits of the restoration to Chinook salmon. See Negative Outcome N1b. Predation by invasive predators (especially if it is facilitated by colonization of SAV) may also eliminate any beneficial effect of this action.

P1c3. Sacramento Chinook salmon, fall run

Magnitude = 3 – Medium: The conceptual model (Williams and Rosenfield, In preparation, page16), states that "Fall Chinook […] could benefit strongly from tidal marsh restoration". Fall Chinook enter estuarine habitats at a small size and the text anticipates benefits from additional rearing/growth opportunities. Fall-run will consume the types of zooplankton produced in this restoration (under the assumed condition). However, the benefits that may accrue to fall run Chinook are uncertain because it is possible that the "ocean type" life history strategy of this run minimizes Delta residency in favor of rapid migration to the ocean (NMFS 2009, p12 Citing MacFarlane and Norton 2001).

Fall-run juveniles move through the northern Delta from winter through spring. Fall run rearing in this proposed restoration site during late spring will probably be impacted by high temperatures.

This outcome will benefit only the Sacramento portion of the fall-run population. Please note that the eastside Chinook salmon run is discussed in Appendix C.

Certainty = 2 - Low: Sacramento fall run Chinook use of fresh water tidal and sub-tidal environments is documented in other systems but is not well studied in this system – possibly because this kind of habitat is limiting in this system.

The effect of global climate change on water temperatures in this area during Sacramento River fall run migration period also decrease the window of time during each year when restoration will produce benefits. The temperatures experienced in this area during late spring and summer indicate that only a portion of the Sacramento River fall-run population will benefit from this action.

Other factors create uncertainty as to the benefits of this measure for this population. *Corbicula* establishment could limit if not eliminate the productivity benefits of the restoration to Chinook salmon. See Negative Outcome N1b. Similarly, establishment of predators or SAV that supports predation could eliminate most or all of the benefits created by this measure.

P1c4. Chinook salmon, Sacramento, late fall run

General Observations: Late-fall run juveniles move through the northern Delta from early fall through spring. The fisheries biology community is currently debating whether late fall run Chinook exhibit separate reproduction from fall run. As that debate has not yet been settled, this evaluation presents late fall run as a distinct run.

Magnitude = 1 - Minimal: Late fall-run will consume the types of zooplankton produced in this restoration (under the assumed condition). Most late-fall run migrate through this area when temperatures are cool enough to support rearing. The discussion of drivers and outcomes in the figures of Williams and Rosenfield, (In preparation) indicates that tidal marsh has a low impact on competition and competition in this area has a low impact on growth.

Certainty = 1 - Minimal: The importance of growth in estuarine environments is unstudied for this run. Text concerning drivers, linkages, and outcomes in the conceptual model indicates low certainty of impact.

Establishment of *Corbicula* could limit, if not eliminate the productivity benefits of the restoration to Chinook salmon. See Negative Outcome N1b. Predation by invasive predators (especially if it is facilitated by colonization of SAV) may also eliminate any beneficial effect of this action.

P1c5. Steelhead

Magnitude = 1 - Minimal: Steelhead juveniles migrate through the Delta during a six month period from January to June. However, most migration occurs in a two-month window, “mainly in April and May” (Williams and Rosenfield, In preparation, page 34). Steelhead rearing in this proposed restoration site during and after May will probably be impacted by high temperatures and negative impacts could become more common with global warming.

The Salmonid conceptual model regarding estuarine – growth, shows a low impact of this kind of habitat on competition – competition may have a moderate impact on growth. The restoration of tidal marsh habitat will impact only steelhead from Sacramento Basin.

Certainty = 1 - Minimal: There is no direct research on the use of shallow estuarine habitat by steelhead in the Delta system. Any effect will be limited to the Sacramento population and to those times of year when temperatures are not too high in the target area.

Establishment of *Corbicula*, could limit, if not eliminate, the productivity benefits of the restoration to Chinook salmon. See Negative Outcome N1a, b, and c. Predation by invasive predators (especially if it is facilitated by colonization of SAV) may also eliminate any beneficial effect of this action.

P1d. Splittail

Magnitude = 3 - Medium: Additional tidal marsh acreage in the Cache Slough region would be expected to help rearing of juvenile splittail, particularly due to the restoration site’s proximity to the Yolo Bypass, a major spawning location for Sacramento splittail. Post-spawners coming off the Yolo Bypass might benefit. The marsh may also provide dry period spawning habitat when the bypass is flooded less frequently (Kratville 2008). Splittail are benthic fish which forage during the day. Adult splittail typically consume detritus (60-79%), mysid shrimp (2-24%), Corbula (6%), salmon eggs, worms, and invertebrates. Larval and juvenile splittail are typically found on the floodplain and while there they consume small rotifers, cladocerans, chironomid larvae, zooplankton, and copepods (Kratville 2008). To the extent that tidal marsh supports the production of these types of food resources and to the extent that these food resources are available at a time and location that is accessible to splittail, the proposed restoration may offer some food benefits during the limited time window when the fish would be in Cache Slough and moving towards the more brackish areas of Suisun Marsh.

Certainty = 2 - low: The ultimate effect this action will have on splittail population abundance is uncertain because while this restoration will increase opportunities for rearing juveniles, rearing habitat does not appear to be a limiting factor in splittail abundance compared to floodplain inundation (Kratville 2008). The bulk of the adult splittail population resides in brackish areas of Suisun Marsh (Kratville 2008). The freshwater Cache Slough marsh will only provide habitat for juvenile fish migrating into

Suisun Marsh. It might not provide a new population center or increase the number of fish making it to Suisun Marsh.

Outcome P2: Increase food production for local consumption by green and white sturgeon

Magnitude = 2 -Low: Information on juvenile sturgeon diets and physical habitat needs in the Delta is limited. Juvenile sturgeons of other species located in other systems do feed on drifting insects. This area of the Delta will not provide extensive intertidal-mud bottoms as found in lower portions of the estuary. Since the former farm fields on this proposed shallow sub tidal restoration site will remain comparatively hard for many years (such as at Liberty Island and Little Holland Tract), it could take considerable time for conditions that support the growth of soft bottom benthos (organisms) to develop. These soft bottom benthos are a food resource for the sturgeon. Most habitat limitations for sturgeon appear to occur outside of the restoration area (i.e. upstream and downstream), as described on pages 4, 8, 9 in Israel and Klimley, 2008 and pages 19-21 of Israel et. al., 2009.

Certainty = 1 - Minimal: Most of the available information on sturgeon diets and predator/prey relationships is based upon other species of sturgeon, located outside of this system. It is unknown to what extent adult sturgeon historically used fresh water tidal marsh for foraging. The impact to individual sturgeon may be low but the loss of fresh water tidal marsh in the Delta may have lowered the carrying capacity of the entire system for sturgeon. See pages 4, 8, 9 in Israel and Klimley, 2008 and pages 19-21 Israel et. al., 2009 for more detail.

Outcome P3: Food resources produced on the restored marsh will be exported and contribute to food availability downstream of Rio Vista.

General Observations: Outcome P1 above addresses the potential for restoration to produce increased food resources locally within the restoration area (both in the marsh and in adjacent open water). Outcome P3 described below deals explicitly with the potential for food resources (phytoplankton, zooplankton, insects, and small fish) to be exported out of the restoration area and become available to covered species downstream of Rio Vista.

The Tidal Marsh and Foodweb models [Kneib et. al., 2008, page 9 and Durand, 2008, section 2.16)] provide a general indication that there may be a linkage between tidal marsh habitat as a driver and increases in availability and production of food resources as an outcome, but that the mechanism for this linkage may be movement by fish. The tidal marsh conceptual model also states that freshwater tidal marshes are net exporters of high-quality organic production (page 2 in Kneib et. al., 2008). See also Dame et al. 1986, Kimmerer and McKinnon 1989, Kneib 1997, Lucas et al. 2009.

There was disagreement within the evaluation team regarding the magnitude and certainty of expected benefits of tidal reintroductions with regard to the export of food (phytoplankton, zooplankton, insects, and small fish) to areas downstream of Rio Vista and the likely benefits to covered fish species. In the spirit of presenting the scientific discourse, both points of view are captured below.

Two key questions discussed were: (1) can we predict the sign of the flux of productivity (i.e. will the restoration area be a source or a sink for primary and secondary productivity); and (2) will there be adequate advection to move material out of the restoration area and downstream to Rio Vista (assuming the restoration area is a source of productivity, as opposed to a sink). Additional information and analyses is needed to better answer these key questions. To develop this additional information, the team recommends future development of a Tropho-dynamic model as described in the section on page 40 entitled “Research Needs”.

Viewpoint #1

Estuaries are open systems that comprise interconnected yet spatially heterogeneous habitat. Connectivity of these functionally variable habitats is a key design consideration for sustaining biological diversity on degraded landscapes (Cloern, 2007, Friedrichs et al. 2001). Channel habitats downstream of Rio Vista are deeper, light limited, heterotrophic pelagic habitats. In contrast, the proposed Yolo/Cache Slough restoration is shallow intertidal/subtidal, and not nutrient limited. It is likely to comprise autotrophic habitat from which excess productivity could enhance regional pelagic carrying capacity if phytoplankton and a range of secondary production types is exported downstream (Lopez et al. 2006). The export, or water connectivity rate, is key. Regional ecosystem production efficiencies occur when the water connectivity rate between shallow and deep habitats is similar to autotrophic habitat phytoplankton growth rates (Cloern 2007).

Without flow augmentation, the Yolo/Cache area would exhibit variable seasonal water connectivity with channels downstream of Rio Vista. When the Bypass is strongly flowing, complete water exchanges occur on short timescales. In contrast, when the Bypass is dry, water connectivity depends on tidal dispersion that may be minimal due to distances (Cache Slough to Rio Vista) greater than tidal excursion length. On the tail end of hydrographs when the Bypass is draining (usually in Spring), hydraulic connectivity could be near optimal for extended periods. These periods overlap well with native fish usage of deep channels downstream of Rio Vista (see conceptual models for Delta smelt, longfin smelt, and salmonids).

With flow augmentation (e.g. a Fremont Weir notch), water connectivity between Yolo/Cache and Rio Vista could be tuned to provide near optimal connectivity for much longer periods and across a greater number of years (from roughly 1 in 4 years at present to 1 in 2 years as proposed). In this case, the rate of water connectivity would be exactly known since transport to Rio Vista would be advective. The magnitude of the productivity subsidy will keenly depend on how flow augmentation is routed through the restoration area. For maximum subsidy, Yolo/Cache water inputs would be routed in ways that tend to spatially equalize phytoplankton and zooplankton concentration gradients. Adaptive management experiments would elucidate transport strategies that maximize regional ecosystem efficiencies.

The single greatest impediment to realizing these exported productivity benefits would be the colonization by invasive clams that, if established in large numbers, could divert much of the phytoplankton and zooplankton productivity. Clams would exert a greater detrimental effect during tidal dispersion periods (no Yolo outflow and long local residence times) and a lesser detrimental effect during advective transport periods (with Yolo outflow and short local residence times).

Magnitude = 3-4 – Moderate to High: Without advective connection, restoration will still have significant productivity benefits to covered fish species and to many other species due to providing large areas of highly functional habitat in conjunction with restoration elsewhere that collectively provide fish species a range of options that spread risk through exploiting available resources when they are present. Refer to Ted Sommers, IEP Esutarine Ecology Team or CAERS poster. In addition, these areas would export that productivity through the "trophic relay" concept described in the tidal marsh conceptual model (fish export the productivity).

With advective connectivity driven by current and proposed Yolo Bypass flows, productivity will be exported strongly during periods of Yolo flow, generally in the February to May time period. These time periods are identified as very crucial to many covered species. Under current conditions, Yolo floods roughly 1 in 4 years. The Yolo Conservation Measure proposes to increase this frequency to 1 in 2 years. Under either condition, advective-driven transport of Cache Slough productivity will provide important and very substantial productivity contributions to larger geographic regions of the northwestern Delta.

Certainty = 3 – Moderate: Certainty is reduced by the potential for establishment of invasive clams that could consume substantial portions of phytoplankton and hinder zooplankton productivity. These effects would be greater during time periods without Yolo flows through the Cache Slough complex.

Viewpoint #2

Net primary production is highest in shallow water (given the excellent light resources and plentiful nutrients). However, the additional primary production that results from this restoration may be limited due to short residence time. The positive impact of food production also atenuates with distance. Export off the restored marsh will be non-existent when Yolo Bypass is not flowing. When Yolo Bypass is flowing, the additional small quantity of organic matter may (uncertain probability) be exported downstream. However, there is little quantitative information to support the idea that this phytoplankton will be exported downstream. The degree of phytoplankton export is critically dependent on whether clams become established in the shallow subtidal regions or marsh channels, climate change, and other factors (Callaway et al 2007). Dissolved organic carbon, by far the largest component of the organic pool, is very likely exported from marshes. However, for the most part, DOC supports bacterial production and relatively little of the bacteria supports the open-water foodweb of which pelagic fish participate. Established tidal marshes can both import and export organic carbon in dissolved or particulate (living and nonliving) form. The overall net flux of organic carbon must be out of the marsh to the extent that high plant productivity within the marsh exceeds local burial. The direction of the flux of a given constituent across the marsh-channel interface depends on the net flow (i.e., through freshwater runoff through the marsh), the concentration gradient, affected in turn by source and loss rates in and outside the marsh, and the swimming of organisms. For example, marshes produce organic detritus that is then available for export. However, marshes can also import detritus through particle trapping by marsh plants. Zooplankton may be zooplankton sinks because of consumption in the marsh by planktivorous fish (Dean et al. 2005). In some marshes, fish may be important carriers of organic carbon from the marsh to open waters.

Please note that potential modifications to weirs and other water management structures in Cache Slough could alter hydrologic patterns and thereby change residence time and other factors that affect food productivity (i.e. the scores presented below would need to be updated accordingly).

Magnitude = 1 to 2 – Minimal to Low: The implied relationship is that restoring 5,000 to 11,000 acres of tidal marsh will export nonliving and living organic matter including plankton and fish, thereby supporting foodwebs of the upper estuary. An implicit assumption is that any increase in the area of shallow habitat would result in enhanced plant productivity some of which would be exported.

When the Yolo Bypass is flowing, the Cache Slough area may export organic matter, but the additional productivity due to the marsh restoration will be limited because of the short residence time. At other times, relatively little of the production from within the Cache Slough area is likely to be exported.

Certainty = 1 -Minimal: The sign of the signal is difficult to determine, except for total organic carbon, most of which is dissolved. Although dissolved organic carbon (DOC) will likely flow out of the marsh, fluxes of other components may be in or out (Kneib et. al., 2008, page 9).

Outcome P4: Provide local cool water refugia for Delta smelt and rearing salmonids

Temperature in a water body is determined by the balance between gains and losses of heat. Heat is gained from solar radiation and from conduction and convection between water and air, and lost through conduction, convection, evaporation, and infrared radiation. Heat is also gained or lost during mixing of water bodies. All of these processes depend on physical drivers such as current and wind speeds and tidal fluctuations, and on the physical configuration of the water body and landforms.

The fundamental physics of heat transfer is well understood (Malamud-Roam 2000, Stacey and Monismith 2008, Enright 2008), and the large-scale temperature fluctuations in a water body can be predicted to some degree. However, small-scale fluctuations depend critically on local conditions and can be somewhat more difficult to predict.

The temperature of a shallow water body will roughly track air temperature. However, very shallow bodies of water are susceptible to rapid changes in temperature because of small thermal mass and relatively large radiative gains and losses of heat. Thus, the water on a marsh plain at midday will be much warmer than that in an adjacent channel, whereas water on the same plain at night will be cooler.

In Suisun Marsh, the higher-high tide occurs near midnight, resulting in substantial cooling by radiation, conduction, and evaporation (Enright 2008). The result was substantial spatial and temporal variation in water temperature in the marsh channels. It is reasonable to suppose that fish under thermal stress would seek out and remain in cooler water in an area of spatially heterogeneous temperature. This cooling may occur in any mature marsh exposed to a similar tidal regime. The extent to which it will occur, and the extent to which Delta smelt and salmon will actually take advantage of it, are unknown.

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P4a. Delta smelt

Magnitude = 2 - Low: Thermal stresses for Delta smelt in this location occur typically in May and June, so some potential for a benefit exists. Most Delta smelt are not in the Cache Slough area during summer.

Certainty = 1 - Minimal: The basis for our understanding is a single unpublished study in Suisun Marsh. The extent to which this effect may transfer to the restoration site, and to which Delta smelt and salmon will take advantage of it, cannot be predicted.

P4b. Chinook Salmon

The following describes expected benefits to Spring run, Fall run, and Steelheed. Winter run and late-fall run are discussed in Appendix B.

P4b1: Spring run salmon

Magnitude = 2- Low.
Beneficial effect occurs for only a portion of the salmonid population passing through this region during a particular and narrow window of time. This outcome modifies Outcome P1 (creation of habitat). In evaluating that outcome, benefits of this action were interpreted in the light of unfavorable temperature conditions that occur in the area during late-spring and summer. To the extent that the tidal flooding/cooling phenomenon occurs on this restoration site (a function of geography and restoration design and site elevations) during the period of potential thermal stress (May through end of summer), it may provide some relief from the effects of thermal stress *for those salmon runs that migrate through this region at this time (fall and spring run and steelhead).* That benefit impacts only the proportion of the population that migrates at this time and only the proportion of the population that migrates through this area (i.e. not all fall run or all steelhead). Although the team suggests a magnitude score of 2, for this outcome there is some debate within team as to whether this action's cool water refugia will offer any benefit at all. Chinook salmon using this area during late spring are probably on their way out of the estuary, and if it is too warm they will probably move on. The existence of thermal refugia (if it occurs in the area) may not make much difference to the salmon.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

P4b2: Fall run salmon

Magnitude = 2- Low.
Beneficial effect occurs for only a portion of the salmonid population passing through this region during a particular and narrow window of time. This outcome modifies Outcome P1 (creation of habitat). In evaluating that outcome, benefits of this action were

interpreted in the light of unfavorable temperature conditions that occur in the area during late-spring and summer. To the extent that the tidal flooding/cooling phenomenon occurs on this restoration site (a function of geography and restoration design and site elevations) during the period of potential thermal stress (May through end of summer), it may provide some relief from the effects of thermal stress *for those salmon runs that migrate through this region at this time (fall and spring run and steelhead).* That benefit impacts only the proportion of the population that migrates at this time and only the proportion of the population that migrates through this area (i.e. not all fall run or all steelhead). Although the team suggests a magnitude score of 2, for this outcome there is some debate within team as to whether this action's cool water refugia will offer any benefit at all. Chinook salmon using this area during late spring are probably on their way out of the estuary, and if it is too warm they will probably move on. The existence of thermal refugia (if it occurs in the area) may not make much difference to salmon.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

P4b3: Steelhead

Magnitude = 2- Low.
Beneficial effect occurs for only a portion of the salmonid population passing through this region during a particular and narrow window of time. This outcome modifies Outcome P1 (creation of habitat). In evaluating that outcome, benefits of this action were interpreted in the light of unfavorable temperature conditions that occur in the area during late-spring and summer. To the extent that the tidal flooding/cooling phenomenon occurs on this restoration site (a function of geography and restoration design and site elevations) during the period of potential thermal stress (May through end of summer), it may provide some relief from the effects of thermal stress *for those salmon runs that migrate through this region at this time (fall and spring run and steelhead).* That benefit impacts only the proportion of the population that migrates at this time and only the proportion of the population that migrates through this area (i.e. not all fall run or all steelhead).

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

Potential Negative Ecological Outcome(s)

Outcome N1: Establishment of harmful invasive species

Harmful invasive species have the potential to cause two types of adverse effects. First is to worsen conditions relative to the existing baseline; i.e., creating an attractive nuisance. Second is to detract from achieving the positive benefits the action could provide. The magnitude and certainty scores below are based upon an assessment relative to the potential for conditions to become worse than the existing baseline.

N1a. Submerged Aquatic Vegetation (SAV)

General Observation: As described in the conceptual model, the establishment of SAV is controlled by local flow conditions and substrates (Anderson, In Preparation). Many aspects of SAV physiology are influenced by local flow conditions including turbidity and to some extent flow velocity which if too high can scour suitable substrate precluding SAV establishment. In nearby Liberty Island where turbidities are generally higher due to wind wave action and the substrate is a compacted old farm field, SAV is restricted to shallow near shore areas and narrow shallow sloughs (Ustin et al. 2008). If turbidities are high in the restoration area then SAV establishment and growth may be reduced to levels similar to those at Liberty Island. If not, there is the potential for SAV amounts similar to those at overgrown regions of the central and southern Delta. The substrates in the Cache Slough area would be restored farm field hardpan bottoms, which may not be conducive to establishment of SAV. The initial establishment of SAV is an intermediate outcome and the development of a large sustainable SAV population is the final outcome.

Please note that establishment of SAV reduces the certainty that the positive outcome, P1 will occur. This has been noted in the scoring for P1.

Magnitude = 3 - Medium: For this outcome, the baseline condition is that much of the existing 21,600 acres of Delta tidal marsh is infested with submerged aquatic vegetation (Ustin, 2008). The risk of a restored a tidal marsh becoming infested with SAV is significant. Large, sustainable populations of SAV will produce significant changes in water quality (turbidity, pH, DO and temperature), or water flow characteristics (velocity and direction), which in turn can affect the quantity and quality of sediments (Anderson, In Preparation). Eventually, the clarity of water at the site will increase by lowering velocities and allowing particulates to settle out of the water column. This increased water clarity could increase predation of fish entering the site from outside areas (i.e. predators now have greater visual range). One type of predator, Centrarchid fish, is strongly associated with SAV and increased Centrachid populations may create a population sink for native fish at this location, as discussed in N1b, below. In summary, this action may worsen conditions beyond that of baseline conditions and small to moderate fractions of all the covered fish species may experience highly significant but localized effects due to SAV. Given the rarity of Delta smelt, the impact of SAV establishment could be particularly significant on this species if conditions similar to the South Delta are created here.

Certainty = 2 - Low: The initial colonization and ultimate patch distribution of SAV on the substrate is uncertain. As the substrate softens over time, it may be more conducive to SAV establishment and growth (i.e. bed characteristics are described as a driver in the conceptual model – see Anderson, In Preparation). It is well documented that the physical structure of SAV facilitates slower water velocities which allows sediment particles to settle, thereby reducing turbidity, locally and creating a positive feedback loop for more SAV establishment (Anderson, In Preparation). The effect of specific restoration site substrate, how those substrates may change over time after restoration, and the role of flow velocity at these locations is not well understood.

N1b. Centrarchids

General Observations: Centrarchid fish, as an assemblage, cover a range of ecological niches in the Delta. They are competitors for resources as well as predators on native fish. The magnitude of this effect is dependent on the assemblage of centrarchids that invade and the size of the populations. This is in turn partially dependent on the amount of SAV invasion into the restored system.

Please note that establishment of centrachids reduces the certainty that the positive outcome, P1 will occur. This has been noted in the scoring for P1.

Magnitude = 3 - Medium: For this outcome, the baseline condition is that much of the existing 21,600 acres of tidal marsh are excellent habitat for Centrarchid fish where they are associated with adjacent deeper water. This is illustrated by the large number of Bass Tournaments that occur in the Delta. The Delta is a stop on the national professional bass fishing circuit with $100,000 prizes. This action could worsen conditions beyond that of baseline. Centrachids are a concern because they prey upon and compete for food and other resources with native covered fish. Establishment of centrarchids in conjunction with SAV is well documented in the Delta (Brown and Michniuk 2007; Grimaldo et al. 2004; Nobriga and Feyrer 2007; Nobriga et al. 2005). Centrarchid fish would likely become established in this area as they have in other areas of the Delta where flows are more tidal than riverine (Brown and Michniuk 2007). The magnitude score reflects the possible impact that these fish could have given evidence from the southern Delta. Delta smelt are believed to spawn in the Cache Slough area and an increase in populations of Centrarchids could have impacts on nearly every life stage of Delta smelt and other native fishes. Given the rarity of Delta smelt, the impact of Centrachids could be particularly significant.

Certainty = 2 -Low: The spatial extent of a Centrarchid population(s) after initial colonization and the subsequent impacts to local native fish use once established are not well understood. Their abundance and presumed impact on native fish is greatest in areas of large, dense patches of SAV (Brown and Michniuk 2007).

N1c. *Corbicula*

Consequences of *Corbicula* establishment. If established, *Corbicula* would likely have a significant effect on food web dynamics because it consumes phytoplankton in shallow areas (Lopez et al. 2007). *Corbicula*'s consumption of primary productivity represents a significant limiting factor throughout the Delta that could greatly reduce productivity benefits of restoration efforts (Thompson et al., In revision, page 12). No local studies have been undertaken to indicate whether *Corbicula* feeding has reduced zooplankton populations either through competition or direct predation (Thompson et al., In revision, page 11).

Probability and extent of potential establishment. *Corbicula* are prolific reproducers and colonizers of newly available habitats in salinities below 2 ppt. Source populations can come from elsewhere within the Delta or from upstream tributary populations. *Corbicula* can establish on soft and hard substrates and on vegetation and they can colonize intertidal zones as well as deeper water. (*Corbicula* model). Based upon the biology of the species and the physical setting of the restoration site, the probability of *Corbicula* establishment in the Cache Slough restoration areas appears to be high, but ultimately cannot be predicted, partially due high variability in environmental conditions.

Recent very limited *Corbicula* monitoring data from Liberty Island shows that they are present at Liberty Island, with greater abundance in areas with coarser substrate (sand-cobble), small abundance in hard clay substrate, and minimal abundance in soft sediment substrates (Errin Kramer-Wilt, pers. comm. 2009). These data are preliminary and not yet peer reviewed and a part of an ongoing study so findings may change.

Potential Control Options. There are no stressors identified that can limit the success of *Corbicula*. However, salinity can limit the spatial distribution of this species and food limitation is a source of stress (Thompson et. al., In revision, pages 8 and 13). The *Corbicula* conceptual model indicates that the only meaningful method to control their presence or abundance is salinity. This control method would require salinity intrusions into the Cache Slough area of sufficient duration and at the appropriate times of year to have a meaningful effect. The conceptual model does not specify the duration and timing which might be most effective during recruitment. Water temperatures may influence the effectiveness of both recruitment and control measures.

Please note that establishment of *Corbicula* reduces the certainty that the positive outcome, P1 will occur. Establishment of *Corbicula* would consume much of the positive benefits that were previously discussed above under positive outcomes. This has been noted in the scoring for P1.

Magnitude = 1 – Minimal
For this outcome, the baseline condition is that much of the Delta is infested with *Corbicula*. The restoration of tidal marsh that eventually becomes infested with *Corbicula* would not represent a significant change above baseline conditions. This restoration will introduction of *Corbicula* (and its associated phytoplankton cababilities) to a geographic location where it is not currently located. This action may add 5,000 or 11,000 acres of potential *Corbicula* habitat. See also text above.

Certainty = 2 - Low. See text above.

N1d. Inland Silversides Effects on Delta and Longfin Smelt

General Observations: Inland silversides (*Menidia beryllina*) are highly tolerant of warm water and variable salinity and are trophic generalists compared to Delta smelt (Moyle 2002). Inland silversides are the most numerous fish in shallow Delta habitats (Nobriga et al. 2005, Brown and May 2006). Page 3 of Nobriga and Herbold 2008 includes intraguild competition with inland silversides as one of the top five in-Delta stressors to Delta smelt. Inland silversides are thought to be a major predator of Delta smelt eggs (Bennett and Moyle 1996 and Bennett 2005 in Nobriga and Herbold 2008 page 12). In the laboratory, inland silversides reduce Delta smelt size relative to controls when they are reared together (Bennett 2005).

Inland silversides are also treated in the longfin smelt model. Moyle (2002, in Rosenfield 2008) suggested that based on timing of arrival in the Estuary and subsequent longfin population response, inland silverside might have had a major impact on longfin population dynamics. However, the model states that inland silverside prefer shallow water habitats where juvenile and sub-adult longfin are rare, thus, their impact as predators of juvenile and sub-adult longfin is probably slight (Rosenfield 2008, pg. 17). Spawning locations for longfin are unknown, so it is not known whether competition from inland silverside for spawning territory is a factor in their decline.

However, Delta smelt evolved with other intraguild competitors, including longfin smelt, and have survived with striped bass (introduced in 1879). Interaction between silversides and Delta smelt in the wild may be limited because Delta smelt typically inhabit offshore environments, while inland silversides typically inhabit shoreline habitats. Increased shoreline habitat would presumably increase the carrying capacity for inland silversides. However, predator-prey interaction between Delta smelt and inland silversides in the wild is speculative. Silversides may eat Delta smelt eggs or larvae if the eggs and larvae occur on the shorelines. It has not been shown that inland silversides reduce calanoid copepods (Nobriga and Herbold 2008, page 32), so they may not effectively compete with Delta smelt for prey.

Magnitude = 2 - Low: Inland silversides are the most abundant fish in shallow-water habitats in many areas of the Delta and may currently contribute to local depletions of zooplankton otherwise available to native fishes within these areas. Additionally, they may prey on embryos of species who lay eggs in these shallow areas (Moyle 2002). The crash of Delta smelt populations coincided with invasions of inland silversides into the estuary (Bennett and Moyle 1996). This action may change conditions relative to baseline by attracting (via restored marsh) a nuisance (inland silversides). This conservation measure will increase the local inland silverside population by providing additional shoreline breeding habitat. Because of the high existing abundance of inland silversides, the incremental increase in breeding habitat and thus population size above current conditions is considered small and the magnitude of this effect is considered to be low relative to baseline. Further, differential habitat selection (offshore environments for inland silverside) is expected to reduce the interspecific competition effects.

Certainty = 2 - Low: Understanding of interaction between Inland silversides and Delta smelt in the wild is low, particularly in regards to egg predation by inland silversides. Spatial interactions with longfin smelt are also uncertain.

Outcome N2: Local contaminant effects

General Observations, methyl mercury: Although current methylmercury levels on Liberty Island (analogue for future state of areas to be restored) are relatively low (Slotton et al. 2002, Alpers et al., 2008, figure 5), there is potential for enhanced production of methylmercury in areas of high marsh that will be inundated infrequently (only during highest tides). The process of drying out between wetting events tends to oxidize species of sulfur, iron, carbon, and mercury, leading to higher potential to form methylmercury upon rewetting. Once formed, methylmercury biomagnifies in the aquatic food web and ecological effects may occur in some sensitive species. Thus, the specific geomorphology of restoration sites and in particular the degree to which shallow depressions and poorly drained areas of high marsh are part of the restoration projects directly influences the degree of mercury methylization.

General Observations, other contaminants: Past land use determines risk of other contaminants: lead risk in areas with significant hunting, e.g., pheasant farms or duck clubs. There is risk of residual pesticides (e.g., pyrethroids) in areas used for agriculture in past 2 years, which suggests that if these pesticides were used, allowing for a 2 year lag period between application and tidal restoration would be a prudent mitigation measure. Selenium contamination from the San Joaquin Valley isn't an issue in the Cache Slough area.

N2a1. Methyl mercury, covered fish species

General Observations: Alpers et al., 2008 (Table 2 and associated text) describes the relevant issues.

Magnitude = 1 - Minimal: No toxicological studies have been conducted with any of the covered species regarding acute toxicity. Mercury concentrations in covered fish species are compared here against concentrations producing mortality in other fish species. Mercury concentrations in ppm-wet weight for white sturgeon, Chinook salmon and steelhead collected during 2006 were 0.165-0.279, 0.094-0.396 and 0.06-0.13, respectively (Melwani et al. 2007). No tissue data for either longfin or Delta smelt were found. Assume both species will have tissue concentrations similar to other fish taxa living one year and feeding primarily on zooplankton. Mercury concentrations in juvenile threadfin shad and juvenile largemouth bass in the Delta are 0.012-0.076 and 0.035-0.230, respectively (Slotton et al., 2006). In comparison, death in rainbow trout (steelhead) in laboratory studies occurred at 4-ppm wet weight and the NOAEC for death in brook trout at 2.7 ppm (Wiener and Spry, 1996). Conclusion: about a 10X safety factor exists between fish tissue concentrations measured in the Delta and values reported to cause mortality in lab studies.

Regarding chronic toxicity, again no toxicological studies exist with any of the target species. Therefore, we have compared reported tissue concentration for individual species against known laboratory effects in other taxa. Decreased feeding efficiency and some hormones response changes have been observed at 0.25-0.27 ppm wet weight (page 30 of Alpers et al., 2008). Decreases in growth have occurred in fathead minnows at 0.6-0.7 ppm (Hammerschmidt et al., 2002) and in juvenile walleye at 2.4 ppm (Friedmann et al., 1996). In conclusion, some up/down regulation of genes and alterations in feeding behavior are possible in the most contaminated individuals.

Certainty = 2 - Low: Limited tissue data available for most target species but large safety factor regarding acute toxicity. Limited toxicological data available for most of the important sub-lethal processes and none of this has been collected on species of interest.

N2a2. Methyl mercury, non-covered species

Magnitude = 2 - Low: Fifty-eight percent of Forster's terns in San Francisco Bay are at risk of reproductive impairment from consuming fish with elevated mercury levels (Ackerman et al., 2008). Although no Forster's terns nest in Delta, mercury levels in small fish consumed by terns are higher in parts of the Delta such as the Yolo Bypass (Davis et al. 2007) than in the San Francisco Bay (Ackerman et al., 2007). This suggests other bird species filling the Forster's tern niche in the Delta may be at risk.

In laboratory studies, mink have reproductive failure and die when fed fish diets of 0.5 and 1-ppm mercury, respectively (Dansereau et al., 1999). For comparison, mercury concentrations in 64% of largemouth bass, 23% of white catfish, and 35% of channel catfish caught in the Bay-Delta watershed have between 0.23 and 0.93 ppm mercury (Davis et al., 2008). Although the geometry of the high marsh area is poorly understood, evidence suggests a sustained minor population effect.

Most of the studies were conducted in the South San Francisco Bay and Petaluma River marshes with a focus on species native to that area, specifically Clapper and Black rail (endangered and threatened, respectively) (see also Grenier et al., 2002). These studies have shown that rails seem particularly susceptible to methyl mercury. Although neither of these species occurs in the Delta, the related Virginia rail (not a listed species) is present.

Biogeochemical processes create varying conditions and a subset of these conditions promotes mercury methylation and this is the key factor used in evaluating the magnitude of this actions effect. Mercury methylation in tidal wetlands is driven in large part by geomorphology and the resulting inundation regime. Methyl mercury production needs approximately one to four weeks of dryness to re-set the biogeochemical conditions necessary for mercury methylation (specific time frame not determined; table 2 in Alpers et al., 2008). Available restoration lands in the Cache Slough complex all have a relatively uniform and very gradual slope from the uplands to the tidal waterways, suggesting relatively little potential for providing the geomorphic setting needed for extensive high marsh plain that is most susceptible to methyl mercury production. However, available topographic data have not been analyzed to the level necessary to describe the setting more precisely.

Certainty = 2-3 Low - Medium: Scientific understanding of methylmercury effects on some bird and mammal species is high, based on peer-reviewed studies conducted in the San Francisco Bay and elsewhere. However, methylmercury effects on other bird, reptile, and mammal species are unknown. The nature of this outcome is also greatly dependent on highly variable ecosystem processes.

N2a3. Methyl mercury, human health

General Observations: This action could increase mercury content of sport fish.

Magnitude = 2 - Low: Fish consumption advisories for the Delta recommend that children under the age of 17 and women of child bearing age consume no largemouth bass or smallmouth bass, spotted bass or Sacramento pikeminnow, and others should limit their consumption of these species to one meal a month (Gassel et al. 2007, 2008). Between 10,000 and 20,000 fishermen in the Delta are presently eating fish with more than 10X the recommended methylmercury reference dose (RfD) (Klasing and Brodberg, 2008) and could experience some sublethal mercury poisoning (personal communication, Dr. Fraser Shilling). Action could increase mercury content of sport fish.

The probability of increased methylmercury production and export into the food web is the same as that described above for covered fish species and non-covered species.

Certainty = 3 - Medium: There is uncertainty regarding the magnitude and direction of change in mercury content of sport fish, although levels are more likely to increase than decrease. For a given increase in mercury content of sport fish, risk to human health is quantified based on peer-reviewed studies (Gassel et al. 2007, 2008). It is unknown how many anglers would access the project area and what fish they would catch and consume.

The role of restoration projects under this Conservation Measure in contributing to mercury levels in fish species consumed by humans needs to be explored in relation to other mercury sources for those fish species.

N2b1. Residual pesticides and herbicides, covered fish species

General Observations: Pesticide use for calendar year 2007 (DPR, 2008) indicates that 104 pounds of total pyrethroids and pyrethrins were used during 2007 in the Cache Slough area. Possible presence of legacy pesticides from 1960s (e.g. DDT) is unknown. More recent (illicit) use of DDT is likely given the presence of non-degraded forms of DDT in sediment (http://www.bdat.gov, accessed 2008 by P. Green, UC Davis). Pyrethroids are 20x more toxic compared to some other pesticides (organochlorides). They persist in the sediment and degrade in one or two years. Pyrethoids represent several individual pesticides out of about 300 pesticides used during 2007 (DPR, 2008).

Magnitude = 1-2: Mminimal- Low: To the extent that pyrethroids or pyrethrins were used in the area to be flooded, significant toxicity could occur within 1-2 years of application. After ~2 years, near-total degradation should occur. DDT and metabolites could cause reduction of insect populations and bioaccumulation in target fish species (and some non-target bird species).

Certainty = 1 - Minimal: The toxicity of various pesticides is not completely understood. Although some peer-reviewed studies for selected life stages of certain fish exist, there is not much data for covered fish species. The nature of this outcome is highly dependent on highly variable ecosystem processes affecting the fate (degradation) and transport of pesticides.

N2b2. Residual pesticides and herbicides, non-covered wildlife species

General Observations: Pesticide use for calendar year 2007 (DPR, 2008) indicates that 104 pounds of total pyrethroids and pyrethrins were used during 2007 in the Cache Slough area. More recent (illicit) use of DDT is likely given the presence of non-degraded forms of DDT in sediment (http://www.bdat.gov, accessed 2008 by P. Green, UC Davis). Pyrethroids are 20x more toxic compared to some other pesticides (organochlorides). They persist in the sediment and degrade in one or two years. Pyrethoids represent several individual pesticides out of about 300 pesticides used during 2007 (DPR, 2008).

Magnitude = 1-2 Minimal to low: To the extent that pyrethroids or pyrethrins were used in the area to be flooded, significant toxicity could occur within 1-2 years of application. After approximately two years, near-total degradation should occur. DDT and metabolites could cause reduction of insect populations and bioaccumulation in covered fish species (and some non-covered bird species).

Certainty = 1 - Low: The toxicity of various pesticides is not well understood. A limited number of peer-reviewed studies for certain life stages of selected fish species exist. However, there is not much data for covered fish species available (Werner et. al., 2008). The effect that tidal marsh restoration will have on the availability of residual pesticides is greatly dependent on highly variable ecosystem processes affecting the fate (degradation) and transport of pesticides. Additionally, legacy pesticides from 1960s (e.g. DDT) may be present on the restoration site and more recent (illicit) use is unknown.

Outcome N3: Contaminant resuspension

Analysis of resuspension affects considers two separate physical settings: the restoration marsh sites and the adjacent tidal sloughs. The restored marsh sites are not likely to experience much scour, since the adjacent tidal channels would be excavated as part of construction and the hard farm fields are not expected to scour easily. Adjacent tidal sloughs, which are typically comprised of more erodible substrate, may experience more scour both the bed and banks.

N3a. Mercury, methyl mercury

General Observations: The relationship between tidal marsh restoration as a driver of potential contaminant resuspenion is supported by facts outlined in the DRERIP Mercury model (Figures 4, 7, and 8 and associated text in Alpers et. al., 2008).

Magnitude = 1 - Minima: The degree of scouring manifested on pre-project soils depends on hydrodynamics and this could be a short-term phenomenon as channels reach geomorphic equilibrium. Concentrations of total mercury and methylmercury in sediment is relatively low pre-project on the Cache / Prospect Slough areas, compared with other parts of Delta (Heim et al. 2007). Methylmercury concentrations have the potential to increase on high-elevation portions of the marsh (infrequently wetted zone) and this mercury has the potential for export to downstream environments.

Certainty = 2 - Low: The certainty of this outcome is low due to the dependence on highly variable ecosystem processes affecting the fate (e.g. photo degradation) and transport of methylmercury.

N3b. Residual pesticides and herbicides

General Observations: Werner and Oram, 2008, Figure 1, indicates that tidal marsh restoration is a driver for the resuspension of residual pesticides and herbicides.

Magnitude = 1 -Minimal: The degree of scouring occurring on pre-project soils depends on hydrodynamics and it could be a short-term phenomenon as channels reach geomorphic equilibrium. Acute and chronic toxicity effects of some recently used pesticides (e.g. pyrethroids) and legacy pesticides (e.g. DDT) have been documented for some covered fish species and some non-covered species (fish, invertebrates, mammals, humans) (Werner et. al., 2008, pages 16-25).

Certainty = 1 - Minimal: There is a minimal degree of certainty about this outcome because concentrations of recently used pesticides (e.g. pyrethroids) and legacy pesticides (e.g. DDT) are largely unknown on the soils of proposed project area.

Outcome N4: Scour of spawning habitat for Delta smelt and other covered species

General Observations: Breaching levees for tidal restoration affects the hydraulic geometry of adjacent channels, both landward and seaward of the site (Hood 2004). In particular, levee breaching for tidal restoration can be expected to increase the tidal prism through distributary channels downstream of restoration areas. Downstream distributary channels will therefore exhibit transient increases in tidal velocity that, in turn, increase bed shear stress and bed erosion. Preliminary modeling of Cache Slough restoration indicates that the cross-section average tidal velocity in downstream channels will increase to greater than ~3ft/s (Munevar 2009). Depending on the materials, sandy silt material would likely be eroded rather rapidly toward a new (deeper) dynamic equilibrium that balances the increased tidal prism. In-channel island marsh fragments and fringing marsh along the channel edge may also erode; though likely more slowly. Erosion will selectively remove finer sediment from the bed. In summary, the proposed levee breach(es) will change the geomorphic/hydrological configuration of the site. This change in configuration will alter tidal currents, increasing them in some places and decreasing them elsewhere. This could erode or redistribute sediments used during spawning of Delta and longfin smelt (Dinehart, 2002). Since scientists do not actually know where native fish spawn or on what, it is very difficult to ascertain the importance of this effect.

N4a: Delta smelt

Magnitude = 4 - High: Tidal forcing energy is a zero sum game in the Delta. Tidal restorations will cause regional shifts of tidal range, prism, and velocity. Downstream distributary channels from new restoration areas may experience increased tidal prism with transient increase in tidal velocity and bed shear stress. In situ sediment will be eroded until the hydraulic geometry achieves dynamic equilibrium with the new tidal prism. The eroded sediment will be transported to lower energy channels that will become transient sediment sinks until their hydraulic geometry adjusts to the new lower tidal energy. The re-organization of sediment sources and sinks for Yolo-Cache Slough restorations may be confined to the northwest Delta.

During water year types with poor conditions for Delta smelt, Cache Slough appears to be a seriously important habitat area for this species. It is possible that Cache Slough currently represents one of the few areas where substrate availability, suitable hydrodynamics, and fish productivity overlap. Alteration of the hydrodynamics and substrate positioning in this region has the potential for catastrophic effects to Delta smelt (see Rosenfield, J.A. 2002).

Certainty = 1 - Minimal: Little is known about native delta resident fish spawning, especially with respect to the detail of egg placement and attachment to vegetation or sediment substrate. No one has even seen an emplaced Delta smelt egg. Some evidence suggests Delta smelt may use sandy sediment. Within an annual cycle, most of the sediment redistribution will have occurred and a new dynamic equilibrium reached. Progeny spawned in one reach of the lower Sacramento River may find that section deepened and the sediment characteristics changed with a year. It is not possible to predict whether sediment redistribution will occur at a location that is suitable as Delta smelt habitat (i.e. salinity or turbidity conditions etc).

Sediment transport processes are qualitatively understood but difficult to quantify. Erosion is more difficult to quantify than deposition.

N4b: Longfin Smelt

Magnitude = 2 – 3: Low to Medium: Rationale is similar to the information provided above in N4a Delta smelt.

Certainty = 1 - Minimal: Rationale is similar to the information provided above in N4a Delta smelt.

Important Gaps in Information and/or Understanding

Data needed to more fully evaluate tidal marsh restoration actions:

- A study of predator-prey-habitat interactions for Centrarchid fish.
- Striped bass model is needed to compile and synthesize life history information. This should also include a research study of predator-prey-habitat interactions.
- Expected retention time on restored tidal areas to understand likely productivity and food export potential to local sloughs.
- Predation rates in Cache slough vicinity to understand baseline predation pressure in this region.
- More spatially comprehensive hydrodynamics to understand whether changed flow patterns will reduce or simply redistribute predator pressure.
- Hydrologic and sediment information about turbidity levels, duration, and consequences on species as related to the following: Increased ability for Delta smelt to locate food due to increased turbidity from increased velocities in larger channels.
- *Corbicula* monitoring data from previous restoration sites in the Delta, such as Liberty Island or Little Holland Tract, would provide greater information about the probability of colonization on this Cache Slough site.
- Data on mercury bioaccumulation in waterbirds in the Delta would allow an assessment of transfer of methylmercury to higher trophic level wildlife and an assessment of ecotoxicological risk to reproduction.
- Better data on where and when Delta smelt lay their eggs would better allow us to assess the potential impact of inland silverside predation.
- Analysis of factors contributing the success or failure of other past tidal marsh restoration actions in the Delta.
- Liberty Island is often referred to as a model of a successful restoration project. Monitoring data and new bathymetric data from Liberty Island should be fully analyzed to determine the features that makes it successful and to consider how to apply those features to other restoration projects in the Delta. Specifically, the bathymetric data could be turned into a Digital Elevation Model (DEM) and combined with the habitat type mapping (i.e. vegetation and open water) to illustrate how the restoration provides habitat for covered and other species. This would include documenting the quality of existing LiDAR data for the vegetation mapping.
-

To fully evaluate Outcome P5, additional information listed below is needed:

- Data collection and analysis of the relative predation rate of salmon migrating through Cache slough compared with other areas of the Estuary (e.g. can it be estimated in even a qualitative sense?).
- Data collection and analysis of whether relevant predatory species would be displaced by the expected changes in hydrodynamics in these sloughs.
- Modeling of a situation in which predators are displaced from the sloughs, and analysis of whether this would result in a reduced predator population in this region, or whether predators would simply relocate to another part of the migration corridor where hydrodynamics are more suitable (i.e. what is the new distribution of low velocity/tidally influenced habitat that could be suitable to predators?).

- Data collection and analysis of whether other predatory species (i.e. pikeminnow and striped bass, which prefer riverine habitats) benefit from the altered hydrodynamics and occupy Sutter and Steamboat sloughs.

Research Needs

Run (and life-history) specific studies of Central Valley Chinook salmon and studies of steelhead use of tidal marsh habitats would be extremely valuable to defining magnitude of impacts to these populations and increasing certainty. Various tools (including genetic markers and otolith signatures of population origin) could be used to asses both growth and survival of salmonids in tidal marsh habitats as well as changes in life history characteristics (survival and fecundity) over the course of the life cycle that arise from residence in tidal marsh habitats. Currently, all of the evidence for benefits of tidal marsh on salmonids comes from steelhead and fall run populations located well to the north (where high temperatures and invasive predators are not as problematic). Translating these results to all Central Valley salmonid populations is unwarranted and could lead to disastrous "restoration" projects.

In addition, data on nutrient flow from the marsh plain to juvenile fish rearing in the adjacent channels is essential to determining the value of restored marshes as a food source for pelagic fish larvae (i.e. longfin and Delta smelt).

Greater understanding and more research is needed about the availability and production of food in tidal marshes. Export of organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta has not been studied.

Potential negative effects of methylmercury exposure on covered fish species remain largely unknown. Based on published studies involving other (non-covered fish species, there is reason for concern regarding possible chronic effects caused by methylmercury exposure, including: endocrine disruption, reduced reproductive success, reduced predator avoidance, and reduced feeding efficiency. (See Mercury Conceptual Model, Alpers et al. 2008, Table 4, page 30). Research is especially needed to determine possible effects caused by exposure during early life stages.

A better understanding is needed regarding the relationship of mercury methylation to the duration of wetting and drying events in areas that are intermittently inundated (i.e. tidal marsh and floodplain). Laboratory and field studies of mercury cycling and bioaccumulation involving sediments in tidal marsh and floodplain environments should quantify the duration of drying time and the extent of dryness necessary to change the oxidation-reduction character of iron, sulfur, carbon, and mercury in sediments such that microbial activity associated with mercury methylation is enhanced.

A better understanding is needed of mercury cycling, bioaccumulation and ecological effects on waterbirds in tidal marsh habitats.

Tropho-dynamic model of ecological interactions linking primary production to the food web structure and production flows into, through, and out of the tidal marsh system.

Landscape-level models that address the effects of variation in structural features of the tidal marsh environment (e.g., tidal channel complexity, channel width, channel length, edge: area ratios, etc.) on the population or production dynamics of specific plants and animals.

Reversibility

No/Hard: The following on-the-ground actions would be needed to reverse this action:
1) levees would need to be reconstructed
2) newly created tidal sloughs would have to be regraded
3) sites would have to be dewatered
4) wetland vegetation would have to be removed
5) monitoring pre, during, and post construction

Although this reconstruction is technically possible, there would be significant financial and regulatory costs. Prior to action reversal, the following planning activities would be needed:
1) geotechnical evaluations for levee reconstruction
2) engineering design
3) evaluate land use options for areas subject to subsidence reversal actions
4) environmental permitting and associated agency ESA consultation,
5) mitigation planning

Levee repair costs are estimated to range between $1,000 and $9,000 per linear foot (Snow 2006).

Opportunity for Learning

High: Implementation of this project can be designed such that different engineering designs can be compared. Numerous physical and biological components can be monitored and ideally, the monitoring data would be used to assess and refine modeling simulations of the restoration. Monitoring questions/data collection could address: marsh function, use of marsh by plant and animal species, abundance/influence of non-native species in restored areas, evolution of marsh habitat including patterns of change, and affect on MeHg levels. It is assumed that monitoring and learning would be part of a comprehensive adaptive management program.

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Appendices:

Appendix A Summary Tables Organized by Outcome

Table A1. Positive Outcomes

Outcome	Magnitude	Certainty
P1. Increase rearing habitat and local food production		
a. Delta smelt	3	2
b. Longfin smelt	1	2
c1. Chinook, Sac, winter run	2	1
c2. Chinook, Sac, spring run	2	2
c3. Chinook, fall run		
1. Sacramento River	3	2
c4.Chinook, Sac, late fall run	1	1
c5.Steelhead	1	1
d.Splittail	3	2
P2. Increase food production for:		
a. Green sturgeon	2	1
b. White sturgeon	2	1
P3. Increase availability and production of food downstream of Rio Vista	Viewpoint 1: 3-4	Viewpoint 1: 3
	Viewpoint 2: 1	Viewpoint 2: 1
P4. Provide local cool water refugia.		
a: Delta smelt	2	1
b1: Spring-run,	2	1
b2. Fall-run Salmon	2	1
b3. Steelhead.	2	1

Table A2. Negative Outcomes

Outcome	Magnitude	Certainty
N1. Establishment of harmful invasive species		
a. SAV	3	2
b. Clams	2-3	2
c. Centrarchids	3	2
d. Inland silversides	2	2
N2. Local contaminant effects		
a. Methyl mercury		
1. Covered fish species	1	2
2. Non-covered species	2	2-3
3. Human health	2	3
b. Residual pesticides, herbicides		
1. Covered fish species	1-2	1
2. Non-covered species	1-2	1
N3. Contaminant resuspension and export		
a. Mercury, methyl mercury	1	2
b. Residual pesticides, herbicides	1	1
N4. Scour of spawning habitat for Delta smelt or other covered species.	4	1

Appendix B: Other Potential Positive Outcomes Identified, Not Evaluated

Outcome OP5: Reduce low velocity-associated salmonid predation pressure in Sutter and Steamboat sloughs

Preliminary hydrodynamic modeling indicates that tidal velocities will be damped in Sutter and Steamboat Sloughs with the restoration of tidal action to 5,000 -11,000 acres of habitat in the Cache Slough region (Munevar, pers. comm.). This change in hydrodynamics may make Sutter and Steamboat Sloughs less hospitable to certain predators of salmonids (i.e. those that prefer low velocity and/ or tidal environments). Also, the altered hydrodynamics may reduce the encounter rate with predators that remain, once riverine conditions become established. Predation of salmonid juveniles moving through these two sloughs may be high, however, the studies needed to reach a definitive conclusion have not been conducted. This hypothetical outcome cannot be vetted without additional information about relative predation rates, potential for predators to be displaced, and potential benefits predators may reap from the altered hydrodynamic conditions. These information needs are detailed in the “Important Gaps in Information and/or Understanding” section located in this worksheet.

Appendix C - Outcomes With Zero Magnitude

Outcome OP1a: Increase rearing habitat and local food production for Eastside and San Joaquin Chinook salmon, fall run.

Magnitude = 0 for East Side and San Joaquin River

Fall-run juveniles move through the northern Delta from winter through spring. Fall run rearing in this proposed restoration site during late spring will probably be impacted by high temperatures.

This outcome will benefit only the Sacramento portion of the fall-run population.

Certainty = 2 - Low: Fall run Chinook use of fresh water tidal and sub-tidal environments is documented in other systems but is not well studied in this system – possibly because this kind of habitat is limiting in this system.

The effect of global climate change on water temperatures in this area during Sacramento River fall run migration period also decrease the window of time during each year when restoration will produce benefits. The temperatures experienced in this area indicate that only a portion of the Sacramento River fall-run population will benefit from this action.

Other factors create uncertainty as to the benefits of this measure for this population. *Corbicula* establishment could limit if not eliminate the productivity benefits of the restoration to Chinook salmon. See Negative Outcome N1b. Similarly, establishment of predators or SAV that supports predation could eliminate most or all of the benefits created by this measure.

OP2a: Locally provide areas of cool water refugia for winter-run salmon.

Magnitude = 0- Zero.
There will be no benefits of this restoration to winter-run salmon because this run passes through the region during a window of time when temperatures are not believed to be highly stressful to salmonids.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

OP2b: Locally provide areas of cool water refugia for late fall-run salmon.

Magnitude = 0- Zero.
There will be no benefits of this restoration to late fall-run salmon because this run passes through the region during a window of time when temperatures are not believed to be highly stressful to salmonids

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

Appendix D: Background information on Hydrologic Processes

About Hydrologic Connectivity: Exchange of materials (i.e. import-export balance) between the Cache Slough area and the western Delta is controlled by a number of factors including the following:

- Site hydrologic connection including size, location, and number of levee breaches; levee lowering; emergent vegetation; channel network geometry
- seasonal variation in tidal versus riverine characteristics at the lower end of the Yolo Bypass,
- enlargement of local sloughs through scour,
- other restoration projects locally and elsewhere in the Delta, and
- water exports.

Individual components of the organic matter flux may go into or out of the marsh and the region depending on the net flow, flow velocities, concentration gradients, trapping by vegetation, and the swimming of organisms relative to currents.

About Scour and its potential affect on Delta native fish: Estuary channel geometry reflects the dynamic interaction between channel morphology and physical forcings including wind, waves, tidal currents, and river discharge. The fundamental geomorphic function of estuaries is to attenuate the energy of physical forcings (Orr et al. 2003). One way this is accomplished is by transporting sediment from high to low energy areas in ways that tend to distribute and attenuate wave energy (Pethick 1996).

Sediment on the bed is characterized by particle size, density, and organic content (Schoellhamer et al. 2008). Higher energy channels like the lower Sacramento River where Delta smelt may spawn, tend to have sandy sediment and contain moving bed forms (Dinehart, 2002).

Given this understanding, a potential negative consequence of tidal restoration is loss or relocation of spawning habitat for Delta smelt or other covered species. Since there is a finite amount of tidal energy in the Delta, newly created restoration areas that increase downstream distributary channel energy will also cause reduction in tidal energy elsewhere. Near region reduction of tidal range and tidal velocity can be expected to vary as a function of distance from the site. Eroded sediments from the immediate downstream distributary channel may therefore be deposited relatively nearby, and perhaps even on the newly restored land.

Little is known about native delta resident fish spawning, especially with respect to the detail of egg placement and attachment to vegetation or sediment substrate. Some evidence suggests Delta smelt may use sandy sediment. Since the time from egg laying to spawn is about a fortnight, the transient erosion of bed sediment may not affect a particular spawn. However, within an annual cycle, most of the sediment redistribution will have occurred and a new dynamic equilibrium reached. Progeny spawned in one reach of the lower Sacramento River may find that section deepened, and the sediment characteristics changed with a year. However, it is not possible to predict whether the sediment will be redistributed to a location that is also suitable as Delta smelt habitat. If sandy substrates were to be moved to locations that do not have suitable Delta smelt habitat (i.e. salinity or turbidity is not quite right) then this could pose a serious obstacle to smelt reproduction and livelihood.

HRCM 5:
Cosumnes/Mokelumne ROA
Tidal Marsh & Shallow Subtidal Restoration

Scientific Evaluation Worksheet

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Action Description

Restore 1,150 acres of vegetated tidal marsh and 300 acres of shallow subtidal habitat within the Cosumnes/Mokelumne ROA (see map presented in Figure 1 below and appendix C).

Evaluation Team

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Date of Last Revision: May 18, 2009

Note about this "Incomplete Working Draft": this document is not completed. The Tidal Restoration Evaluation Team had limited time for this evaluation. Much information has been replicated from the Cache evaluation and has not been revised throughout to reflect the specific restoration sites and geographies of this ROA.

Approach

1. Breach levees to reintroduce tidal exchange to currently leveed lands in portions of McCormick-Williamson Tract, New Hope Tract, and Snodgrass Slough. Levee breaches will be of sufficient length to not limit water motion into and out of restored habitat.
2. Construct new levees to isolate deeply subsided lands and protect private property.
3. Plant tules or place fill material to raise elevations of shallowly subsided lands.
4. Modify existing channels to encourage formation of dendritic channels

Intended Outcomes as Stated in Conservation Measure

1. Increase rearing habitat area for Sacramento splittail and Cosumnes and Mokelumne River fall-run Chinook salmon and possibly steelhead.
2. Increase the production of food for rearing salmonids, splittail, and other covered species migrating to and from the Cosumnes and Mokelumne Rivers.
3. Increase the availability and production of food in the east and central Delta by exporting organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta.
4. Locally provide areas of cool water refugia for Delta smelt.

Conceptual Model Information Regarding Intended Outcomes

The basic drivers and outcomes are described in the following DRERIP conceptual models: Salmon, Delta smelt, Longfin smelt, Temperature, Foodweb, Tidal marsh, Corbicula, Sediment, and Mercury.

Assumptions

Provided in BDCP Conservation Measure

1. Restoration would be located in portions of Snodgrass Slough, McCormick Williamson Tract, and New Hope Tract.

Added by Evaluation Team

1. Restoring tidal marsh habitat on different sub-areas will have varying levels of both positive and negative effects. For example, some sub-areas may be more efficient at the methylization of mercury and so may have a higher magnitude score for an associated negative outcome. Differences in hydrology, topography, soils, and land-use history will also manifest as distinctions in success of this action among sub-areas. BDCP's background information for this ROA is presented in Appendix C. Background information from other sources is presented in Appendix D.

2. The time frame for realizing restoration benefits depends upon the approaches used. Reversal of subsidence on restored areas can take several years to a decade or more depending on starting elevations. The accretion rate depends on sediment supply and biomass accretion which depends on site-specific conditions. Sediment supply in the Delta is generally very low (Schoellhamer et. al., 2007).

3. Efforts to reverse subsidence before active restoration would be focused on the more deeply subsided portions of these landscapes, i.e., lands more than 6 feet below low tide. There is a hypothesis that shallow open water regions located contiguous to emergent tidal marsh provide enhanced ecosystem complexity and functions compared to those tidal marsh habitats located directly adjacent to deeper sloughs. Although this hypothesis has not been tested, preliminary information on current conditions at Liberty Island and Little Holland Tract suggest support. However, the details of these sites are not readily available to the broad research community at this time and so the information is anecdotal. This assumption also includes a time limit to allow for subsidence reversal so that restoration of an entire parcel is not delayed indefinitely. To speed up the subsidence reversal process, an alternative method would be to separate low-lying areas with new levees and reconnect those areas after subsidence reversal is accomplished.

4. Source of fill material will be identified and use of all material, including dredge spoils, will be approved by the RWQCB.

5. Water output from the site, post-restoration, will meet water quality standards.

6. Flood and ownership issues associated with McCormick Williamson Tract and other restoration areas will be resolved (See Florsheim et al 2008).

7. Prior to implementation, a Phase I Environmental Assessment with on-site sampling to assess legacy and other soil contaminants (i.e. mercury and pesticides) would be completed.

Problem(s) with Action as written:

1. Since rearing habitat for juvenile fish by necessity includes local availability of food, the evaluation team merged the Intended Outcomes 1 and 2 (tidal marsh, rearing habitat, and local food) into one outcome.

2. Loading of fill material on top of a shallow island may compress the underlying soils. This approach may not yield the intended result. A close study of existing soil conditions including analysis of the local soil map is needed to further evaluate this issue.

3. The conservation measure would benefit from an explicit recognition that restoration of tidal marsh functions on subsided landscapes, especially those subsided below emergent vegetation elevations, will take many years to many decades. In the interim, restoration sites below vegetation elevations will function as shallow subtidal habitat.

4. It is unlikely that intertidal mudflats will develop in the Delta because dominant intertidal emergent vegetation species in the Delta can grow throughout the tidal range and just into shallow sub tidal elevations (Brown 2003, Simenstad et al 2000 as cited in Schoellhamer et. al., 2007, p.26).

5. The action should state clearly in Approach #1 and #2 that set-back levees will be required to provide tidal flood protection to lands within the islands not restored to tidal action.

Scale of Action:

Small

Rationale:

This is a small scale restoration action due to its limited spatial extent. As listed in Table1 below, the Delta currently has approximately 21,600 acres of tidal marsh habitat (baseline). Additionally, 67,000 acres of diked and other lands have been identified as potentially restorable to tidal marsh (neglecting effects of restoration on reducing tidal range). The proposed 1,150 of tidal marsh plus 300 acres of shallow sub-tidal restoration options would increase marsh acreage 5% above current conditions. Significant amounts of the 67,000 acres of identified restorable lands are highly constrained such that they could not be restored in the near term (South Delta and Netherlands alone account for 31,000 acres of the 67,000 acres). Therefore, this action also represents an important part of the potentially restorable tidal marsh lands.

Table 1. Summary of Tidal Marsh Acreages

Area	Acreage	Source
Delta (entire Delta proper)	738,000	DWR, 2009
Historic tidal marsh/wetlands in Delta	525,000	TBI, 2002
Current extent of tidal marsh/wetlands in Delta.	21,600	TBI, 2002
Restorable intertidal lands within Delta.	67,000	CA DVSP, 2008, Table 1, p.77.
Proposed Cosumnes – Molkemne tidal restoration (this action)	1,150 tidal marsh 300 sub-tidal	BDCP, 2009

Figure 1: Cosumnes/Mokelumne Restoration Opportunity Areas

Evaluation Summary

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Outcomes with Zero Magnitude

- OP1: Increase rearing habitat area (including physical and biotic attributes) for longfin smelt: No life stage of longfin smelt occurs in this area. There is no impact of this action on this species. Since longfin smelt do not occur with any regularity or abundance in this region, magnitude is scored as a "0" (zero) and certainty as a "4"- High.
- OP2a: Locally provide areas of cool water refugia for winter-run salmon.
- OP2b: Locally provide areas of cool water refugia for late fall-run salmon.

Other Negative Outcomes Identified, Not Evaluated

During the course of this evaluation, the team identified one potential negative outcome that it did not evaluate due to lack of time. It is recommended that this potential outcome be evaluated at some point in the future when additional time is available.

- ON1. Flooding on adjacent properties
- ON2. Mosquito production
- ON3. Pesticide use for mosquito control
- ON4: Increase in the availability of selenium
- ON5: Resuspension and export of contaminants to downstream areas effects on non-covered wildlife species.

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

No

Nature of Change:

This small scale action to restore 1, 450 acres of tidal marsh and shallow subtidal habitat may change the environment on a local scale but not to such an extent that our current understanding of boundary conditions (Harrell et al 2008), hydrodynamics and ecological processes in the Delta would change.

Overview of Productivity Import-Export

The Cache Slough evaluation (HRCM4) worksheet provides a complete discussion of productivity levels, import and export. Here we describe how conditions may differ from Cache Slough in order to provide the Conservation Measure evaluation appropriate specificity.

The primary difference between this Cosumnes/Mokelumne ROA and the Cache Slough ROA is that the primary sites (McCormick Williamson, New Hope Tracts A&B, and Snodgrass Slough):

- Some restorations sites are located along lower energy waterways, while other areas are further removed. Has similar tidal exchange (to move marsh exports) compared to Cache, due to its geographic location (downstream of the Cosumnes and Molkemne river channels etc).
- May experience increased primary production compared to other restoration sites because its easterly location offers warmer spring and summer temperatures. However, the scale of the action is small in size and it is highly uncertain whether any of this production will be exported or will benefit covered fish species.
- The residence time may be relatively similar to that Cache Slough.

Potential Positive Ecological Outcome(s)

Outcome P1: Increase rearing habitat area (including physical and biotic attributes) for covered fish species.

As indicated at the beginning of this worksheet under the section entitled "Problems with Action", the team decided to merge two Intended Outcomes (rearing habitat and local food) into one outcome, P1, as shown below because rearing habitat for juvenile fish by necessity includes local availability of food. This outcome includes food (both primary and secondary production) produced within the vegetated marsh, within marsh channels, and within the subtidal areas adjacent to the vegetated marsh. General information that applies to salmon runs is provided in the worksheet for HRCM 4 – Cache Slough, Outcome P1c on page 15. Please note that green and white sturgeon are not known to utilize the Cosumnes and Molkemne River systems and so these species are not listed in the analysis below.

P1a. Delta smelt:

General Observations: Delta smelt formerly (1963-1964) occurred in this area (Norbriga and Herbold, 2008, page 43). Although they are uncommon in this area today (2005).

Magnitude = 1 - Minimal
Historically, Delta smelt spawned and reared as larval fish in the vicinity of these east Delta marshes (Norbriga and Herbold, page 11). They eat food produced on tidal marshes; but do not forage in shallow environments (Norbriga and Herbold, 2008 page 27 and pers. comm. with B. Herbold, US EPA). So, the food Delta smelt consume *in the shallow tidal areas* is likely to be nil.

Delta smelt spawning in, and use of, this area was rare historically. Restoration of an area this size might improve rearing habitat for a small numbers of Delta smelt during a limited number of years (Herbold, pers. comm.; Nobriga, pers. comm.).

Consumption of prey resources located in directly adjacent channels or deepwater habitats is dependent upon the quantity of zooplankton produced in shallow areas and competition from other fish species. The benefit of food produced and consumed in the direct vicinity of this project will be confined to a limited fraction of the Delta smelt through only a portion of their life cycle (the larval stage).

This outcome assumes that Delta smelt are limited by food production in this region. Delta smelt rearing in open water habitats may have, in the past, relied on export of food from a vast network of tidal marshes (Norbriga and Herbold, page 12). Water temperatures in this region are not measured? However temperatures >20^{o}C could impede smelt rearing in some years during May and June.

Certainty = 1 - Minimal
Scientific understanding is medium and the nature of this outcome is greatly dependent on highly variable ecosystem processes or other external factors. The Delta smelt conceptual model (Nobriga and Herbold 2008) does not indicate what may cause the

apparent absence of spawning activity in this region. There is no indication that current food production near the Mokelumne/Cosumnes confluence with the Delta limits the spawning productivity of this species in the Delta. The quantity of prey items consumed in channels located directly adjacent to the restored marsh is dependent upon on how much of the zooplankton produced in the restored shallow areas is consumed by fish that actually forage in shallow environments where the food is produced. Water temperatures in this region are unknown and high temperatures could impede smelt rearing in some years during May and June.

Additionally, establishment of *Corbicula*, could limit, if not eliminate the productivity benefits of the restoration to Delta smelt. See Negative Outcome N1b. Similarly, colonization by invasive predators could result in added mortality that would counteract any benefits of restoration (especially if SAV invasion facilitates predation success).

Worth = Low

P1b. Steelhead

General Observations: Steelhead juveniles are produced by a hatchery on the Mokelumne and may exist in the Cosumnes as well, though the conceptual model provides no evidence of this (Williams and Rosenfield, In preparation). The worksheet for HRCM4-Cache Slough provides more detailed information about tidal restoration in relation to salmon and steelhead populations.

Magnitude = 1 - Minimal
This outcome assumes that "rearing habitat area" (quantity) and/or food is limiting. "Spring Chinook, or at least the Butte Creek population, pass quickly through the Delta, so habitat restoration there seems unlikely to do much for them. <u>The same is probably true for late fall Chinook, and for steelhead</u>" (Williams and Rosenfield, In preparation page 16).

In other systems, steelhead utilize this kind of habitat. However, the conceptual model indicates the steelhead which smolt in this system are larger compared to other systems. Therefore research conducted in other systems is not likely to apply here. Steelhead will eat the types of food produced in this habitat. Steelhead migrate through this area "mainly in April and May" (Williams and Rosenfield page 34). Average daily water temperatures in the vicinity were not made available to the evaluation team. However, at sites throughout the lower Sacramento and lower San Joaquin, temperatures regularly exceed 20^{o}C (beyond which sublethal effects accumulate; Reese and Harvey 2002 *and*

see Richter and Kolmes 2005) from May-September. With warming that may occur under climate change, these temperatures will occur in this area with some frequency during April and October as well. Thus, steelhead rearing in this proposed restoration site during May, June, and July will probably be impacted by high temperatures and negative impacts could become more common with global warming. The DRERIP conceptual model for salmon (Williams and Rosenfield In preparation, Estuarine – growth section) shows a low impact of this kind of habitat on competition. Competition may moderately impact growth of steelhead. Restoration will benefit only steelhead from

Mokelumne and Cosumnes Basin and these beneficiaries will largely be hatchery-reared, not wild, fish.

Certainty = 2-Low
Since there is no direct research on use of shallow estuarine habitat by steelhead in this system a low certainty score is warranted. Any effect will be limited to the east side population and to those times of year when temperatures are not too high in the target area.

Establishment of *Corbicula*, could limit, if not eliminate the productivity benefits of the restoration to steelhead. See Negative Outcome N1b. Similarly, colonization by invasive predators could result in added mortality that would counteract any benefits of restoration (especially if SAV invasion facilitates predation success). There is low certainty that this outcome will offer minimal benefits to the steelhead population as a whole.

P1c. Cosumnes and Mokelumne River Fall-run Chinook salmon

General Observations: Fall run juveniles are produced by a hatchery on the Mokelumne and appear to spawn in the Cosumnes as well (Williams and Rosenfield in preparation, page 32).

Magnitude = 1 - Minimal
This outcome assumes that "rearing habitat area" (quantity) and/or food is limiting. "Fall Chinook […] could benefit strongly from tidal marsh restoration"(Williams and Rosenfield, in preparation, page 16). Fall Chinook enter estuarine habitats at a small size and does typically benefit from additional rearing/growth opportunities.

Fall-run will consume the types of zooplankton produced in this restoration (under the assumed condition). Average daily water temperatures in the vicinity were not available to the evaluation team. However, at sites throughout the lower Sacramento and lower San Joaquin, temperatures regularly exceed 20^{o}C (beyond which sublethal effects accumulate (Myrick and Cech 2004; Richter and Kolmes 2005) from May-September. With warming that may occur under climate change, these temperatures will occur in this area with some frequency during April and October as well. Thus, fall run rearing in this proposed restoration site during May, June, and July are likely to be impacted by high temperatures.

Many fall run salmon from east side tributaries migrate later in the year than do the Sacramento River counterparts (Williams and Rosenfield, in preparation, Figure 3), thus their "rearing" time in the Delta is relatively short and occurs when temperatures in this area may be too high to support growth and emigration.

Certainty = 2-Low
Fall run Chinook use of fresh water tidal and sub-tidal environments is documented in other systems but is not well studied in this system – possibly because this kind of habitat is limiting in this system. Effect of global climate change on water temperatures in this area during fall run migration period also decrease the window of time during each

year when restoration will produce benefits. Certainty that the hoped for benefits will be realized is low due to the temperatures likely experienced in this area and the small fraction of the fall run population that will benefit. .

Establishment of *Corbicula*, could limit, if not eliminate the productivity benefits of the restoration to Chinook salmon. See Negative Outcome N1b. Similarly, colonization by invasive predators could result in added mortality that would counteract any benefits of restoration (especially if SAV invasion facilitates predation success).

Worth = Low

P1d. Splittail.

General Observations: Drivers, linkages, and outcomes are described in pages 1h, 12, 13, 14, 15 of the DRERIP Splittail conceptual model (Kratville, 2008).

Magnitude = 3 - Medium
While more tidal marsh will help rearing of juvenile splittail, the expect population benefit is medium. The Cosumnes floodplain system provides important alternate spawning locations for splittail in all years and especially in years when there may be flooding here and not in the Yolo Bypass. This may provide increased population resilience if juvenile fish spawned on the Cosumnes floodplain gain improved passage to Suisun Marsh. For Sacramento splittail, the limiting factor for population abundance is floodplain inundation

that provides spawning habitat. When large scale inundation occurs, splittail population abundance is high for several years following an event. Long periods without floodplain inundation reduce splittail population abundance. Splittail do not appear to be habitat limited at other life history stages.

Certainty = 3 - Medium
The uncertainty lies in whether this new rearing areas will increase splittail population abundance. This area will increase the opportunity for rearing juveniles; however this does not appear to be a limiting factor in splittail abundance compared to floodplain inundation. The bulk of the adult splittail population resides in brackish areas of Suisun Marsh. The Cosumnes/Mokelumne marsh is expected to be freshwater and so will only provide habitat for juvenile fish migrating into Suisun Marsh. This restoration might not provide habitat that supports a new population center or increases the numbers of fish successfully making it to Suisun Marsh.

Establishment of *Corbicula*, could limit, if not eliminate the productivity benefits of the restoration to splittail. See Negative Outcome N1b. Similarly, colonization by invasive predators could result in added mortality that would counteract any benefits of restoration (especially if SAV invasion facilitates predation success).

Outcome P2: Food resources (i.e. organic material from the marsh plain and organic carbon, phytoplankton, zooplankton, and other organisms from intertidal channels) produced on the restored marsh will be exported, via tidal flow, and contribute to food availability downstream in the central and east Delta.

P2a. All covered fish species

General Observations: The Tidal Marsh and Foodweb models [Kneib et. al., 2008, page 9 and Durand, 2008, section 2.16)] provide a general indication that there may be a linkage between tidal marsh habitat as a driver and increases in availability and production of food resources as an outcome, but that the mechanism for this linkage may be movement by fish. The tidal marsh conceptual model also states that freshwater tidal marshes are net exporters of high-quality organic production (page 2 in Kneib et. al., 2008). See also Dame et al. 1986, Kimmerer and McKinnon 1989, Kneib 1997, Lucas et al. 2009. Please see the evaluation worksheet for action # HRCM4-

Cache/Yolo, Outcome P3, for more details about **Tidal Marsh Contributions to Exported Production.**

There was disagreement within the evaluation team regarding the magnitude and certainty of expected benefits of tidal reintroductions with regard to the export of food (phytoplankton, zooplankton, insects, and small fish) to areas downstream of Rio Vista and the likely benefits to covered fish species. In the spirit of presenting the scientific discourse, both points of view are captured below.

Two key questions discussed were: (1) can we predict the sign of the flux of productivity (i.e. will the restoration area be a source or a sink for primary and secondary productivity); and (2) will there be adequate advection to move material out of the restoration area and downstream to Rio Vista (assuming the restoration area is a source of productivity, as opposed to a sink). Additional information and analyses is needed to better answer these key questions. To develop this additional information, the team recommends future development of a Tropho-dynamic model as described in the section on page 41 entitled “Research Needs”.

Viewpoint #1

Please see the text of Outcome P3 in worksheet HRCM4 – Cache Slough for additional background information about Viewpoint #1.

Magnitude = 3-4 – Moderate to High
Without advective connection, restoration will still have significant productivity benefits to covered fish species and to many other species due to providing areas of highly functional habitat in conjunction with restoration elsewhere that collectively provide fish species a range of options that spread risk through exploiting available resources when they are present. Refer to Ted Sommers, IEP Estuarine Ecology Team or CAERS poster. In addition, these areas would export that productivity

through the "trophic relay" concept described in the tidal marsh conceptual model (fish export the productivity).

Certainty = 3 – Moderate
Certainty is reduced by the potential for establishment of invasive clams that could consume substantial portions of phytoplankton and hinder zooplankton productivity.

Viewpoint #2

Please see the text of Outcome P3 in worksheet HRCM4 – Cache Slough for additional background information about Viewpoint #2.

Magnitude = 1-2 - Minimal to Low
The implied relationship is that restored tidal marsh will export nonliving and living organic matter including plankton and fish, thereby supporting foodwebs of the upper estuary. An implicit assumption is that any increase in the area of shallow habitat would result in enhanced plant productivity some of which would be exported.

Certainty = 1 - Minimal
The sign of the signal is difficult to determine, except for total organic carbon, most of which is dissolved. Although dissolved organic carbon (DOC) will likely flow out of the marsh, fluxes of other components may be in or out (Kneib et. al., 2008, page 9). Colonization by invasive clam species can wipe out the food web production effect entirely. We have no certainty at all that they will not colonize. In addition, colonization of the site by vertebrate consumers (e.g, inland silverside) can also significantly reduce the amount of food available for export beyond the site boundaries (Moyle 2002). There is evidence from within this system (Dean et al. 2005) that restored marshes can act as sinks for certain zooplankters; in this case, the sign of the signal would be negative.

Outcome P3: Provide local areas of cool water refugia (Feb-Jun) for Delta smelt and salmon.

The cause and effect relationship associated with this outcome is described in Stacey and Monismith 2008, Malamud-Roam 2000, and Enright 2008. Considering the local scale (small) of the action, the relationship between tides, physiography, and water temperature could be moderate. The relationship between drivers (wind, insolation, fetch, tides, currents) and linkages (long-wave, short wave, latent, and sensible heat flux) is complex and may produce both warmer and cooler water on a variety of time and space scales. Larger spatial gradients of water temperature will likely occur. The frequency of threshold temperatures for various species is uncertain. See Stacey and Monismith (2008), Malamud-Roam (2000), Enright (2008).

For more details, please see the introductory text in the HRCM 4- Cache Slough action worksheet and the Suisun Marsh Tidal Marsh Restoration Worksheet, specifically, Outcome P4.

P3a. Delta smelt

Magnitude = 2- Low
The spatial extent of cool water refugia could be relatively limited. However, in some cases a large effect could be felt across relatively large area across the range. Please refer to the discussion located in HCRM4 – Cache Slough Restoration Action, Outcome P4, page 25 for more details.

Certainty = 1 - Minimal
The basis for our understanding is a single unpublished study in Suisun Marsh. The extent to which this effect may transfer to the restoration site, and to which Delta smelt and salmon will take advantage of it, cannot be predicted. Please refer to the discussion located in HCRM4 – Cache Slough Restoration Action, Outcome P4, page 26 for more details.

P3b. Salmonids

High temperatures are currently rare during May (as indicated by IEP gauges rsac075 and rsac054; Enright *pers. comm.*). Temperatures exceeding 20-21^{o}C (beyond which sublethal effects accumulate; Reese and Harvey 2002 *and see* Richter and Kolmes 2005) are more common and widespread in June, July, and August (as indicated by IEP gauges rsac075 and rsac054; Enright pers. comm.). With warming that may occur under climate change projections, high temperatures may become more frequent and extreme. Thus, Chinook salmon (spring-run and fall-run) and steelhead rearing in this proposed restoration site during June and July will probably be impacted by high temperatures. Forces that reduce those temperatures may improve survival, growth and smoltification success.

Benefits are limited to those emigrants rearing in this habitat after May, when temperatures in this region increase above optimal rearing threshold of 12-16^{o}C (Marine and Cech 2004). These benefits are expected to be transient (on annual and decadal

time scales) and will never effect more than a small fraction of populations for any of the covered species (unless there is a cumulative impact from numerous restoration that produce the same cooling effect. Also, as mentioned in the description, this phenomenon is transient over time as the timing of tidal cycle shifts. Complexity of thermodynamics in conjunction with local geomorphology and long-term climate change and sea level rise introduce considerable uncertainty.

In addition to the runs listed below, please see Appendix B for winter-run etc.

P3b1: Spring run salmon

Magnitude = 2- Low.
This outcome modifies Outcome P1 (creation of habitat). In evaluating that outcome, benefits of this action were interpreted in the light of unfavorable temperature conditions that occur in the area during late-spring and summer. To the extent that the tidal flooding/cooling phenomenon occurs on this restoration site (a function of geography

and restoration design and site elevations) during the period of potential thermal stress (May through end of summer), it may provide some relief from the effects of thermal stress *for those salmon runs that migrate through this region at this time (fall and spring run and steelhead).* That benefit impacts only the proportion of the population that migrates at this time and only the proportion of the population that migrates through this area.

Certainty = 1-Minimal

Certainty is minimal for reasons similar to that described in P3a, above. This outcome is highly dependent upon highly variable ecosystem processes. Although scientists have a reasonable understanding at the general level, the range of data needed to evaluate at the action scale is lacking.

P3b2: Fall run salmon

Magnitude = 2- Low.
As noted above, the beneficial effect occurs for only a portion of the salmonid population passing through this region during a particular and narrow window of time.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

P3b3: Steelhead

Magnitude = 2- Low.
Beneficial effect occurs for only a portion of the salmonid population passing through this region during a particular and narrow window of time.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

Potential Negative Ecological Outcome(s)

Outcome N1: Establishment of harmful invasive species .

Harmful invasive species have the potential to cause two types of adverse effects. First is to worsen conditions relative to the existing baseline; i.e., creating an attractive nuisance. Second is to detract from achieving the positive benefits the action could provide. The magnitude and certainty scores below are based upon an assessment relative to baseline conditions. The scores below for N1a to N1d do not represent the potential to distract detract from the positive benefits of the action because these deductions were considered i by reducing the certainty scores for positive outcome # P1. Where appropriate, the impacts associated with the establishment of harmful invasive species on the restored marsh are discussed below.

N1a: Submerged Aquatic Vegetation (SAV) (including Egeria)

General Observations: As described in the conceptual model, the establishment of SAV is controlled by local flow conditions and substrates (Anderson, In Preparation). Many aspects of SAV physiology are influenced by local flow conditions including turbidity and to some extent flow velocity which if too high can scour suitable substrate precluding SAV establishment. The initial establishment of SAV is an intermediate outcome and the development of a large sustainable SAV population is the final outcome. .

Please note that establishment of SAV reduces the certainty that the positive outcome, P1 will occur. This has been noted in the scoring for P1.

Magnitude: 3 - Medium

The establishment of SAV in general is controlled by local flow conditions and substrates. Local flow conditions control many aspects of SAV physiology, most importantly in this area turbidity. In nearby Liberty Island where turbidities are generally higher due to wind wave action SAV is restricted to shallow near shore areas (Ustin et al. 2008). If turbidities are high in the restoration area then SAV establishment and growth may be reduced to levels similar to Liberty Island. If not there is the potential for SAV amounts similar to Franks Tract. The substrates in this area would be expected to support establishment of SAV (Anderson, In preparation). Small to moderate fractions of all the covered fish species may experience highly significant but localized effects due to SAV and therefore the net effect is medium.

For this outcome, the baseline condition is that much of the existing 21,600 acres of Delta tidal marsh is infested with submerged aquatic vegetation (Ustin, 2008). The restoration of a tidal marsh that eventually becomes infested with SAV is significant. Large, sustainable populations of SAV will produce significant changes in water quality (turbidity, pH, DO and temperature), or water flow characteristics (velocity and direction), which in turn can affect the quantity and quality of sediments (Anderson, In Preparation).

Eventually, the clarity of water entering the site from upstream will increase by lowering velocities and allowing particulates to settle out of the water column. This increased water clarity could increase predation of fish entering the site from outside areas (i.e. predators now have greater visual range). One type of predator, Centrarchid fish, is strongly associated with SAV and increased Centrachid populations may create a population sink for native fish at this location, as discussed in N1b, below. In summary, this action will worsen conditions beyond that of baseline conditions and small to moderate fractions of all the covered fish species may experience highly significant but localized effects due to SAV. Given the rarity of Delta smelt, the impact of SAV establishment could be particularly significant on this species.

Certainty: 2- Low
There is high uncertainty about the initial colonization and ultimate patch distribution of SAV on the substrate. As the substrate softens over time, it may be more conducive to SAV establishment and growth (i.e. bed characteristics are described as a driver in the conceptual model). It is well documented that the physical structure of SAV facilities slower water velocities which allows sediment particles to settle, thereby reducing turbidity, locally and creating a positive feedback loop for more SAV establishment (Anderson, In Preparation). The effect of specific restoration site substrate, how those substrates may change over time after restoration, and the role of flow velocity at these locations is not well understood (Anderson, In Preparation).

N1b: Non-native Centrarchids

General Observations: Centrarchid fish, as an assemblage, cover a range of ecological niches in the Delta. They are competitors for resources as well as predators on native fish. The magnitude of this effect is dependent on the assemblage of centrarchids that invade and the size of the populations. This is in turn partially dependent on the amount of SAV invasion into the restored system.

Please note that establishment of centrachids reduces the certainty that the positive outcome, P1 will occur. This has been noted in the scoring for P1. The relationship among drivers and outcomes is described by Brown and Minchniuk 2007, Grimaldo et al 2004, Nobriga and Feyrer 2007, and Nobriga et al 2005.

Magnitude: 4 - High

For this outcome, the baseline condition is that much of the existing 21,600 acres of tidal marsh are excellent habitat for Centrarchid fish where they are associated with adjacent deeper water. This is illustrated by the large number of Bass Tournaments that occur in the Delta. The Delta is a stop on the national professional bass fishing circuit with $100,000 prizes. This action could worsen conditions beyond that of baseline. Centrachids are a concern because they prey upon and compete for food and other resources with native covered fish.

The establishment of Centrarchids in conjunction with SAV is well documented in the Delta (Brown and Michniuk 2007; Grimaldo et al. 2004; Nobriga and Feyrer 2007; Nobriga et al. 2005). Centrarchid fish, as an assemblage, cover a range of ecological niches in the Delta. They are competitors for resources as well as predators on native fish. The magnitude of this effect is dependent on the assemblage of Centrarchids that invade and the size of the populations. This is in turn partially dependent on the amount of SAV invasion into suitable habitat areas of the restored system. The extent of their impact on the native ecology of the restored marsh is partially dependent on the extent of SAV establishment and patch size. Centrarchid fish will become established in this area as they have everywhere else in the Delta. If the eastern Delta becomes brackish to the extant that Suisun Marsh is today, this may change.

Certainty: 2 - Low
The uncertainty is not whether or not Centrarchid fish will become established at the restoration site, but the extent of their populations and impacts on local native fish use once established. In areas with low SAV patch size the numbers of Centrarchid fish and their presumed impact on native fish are lower then where the opposite is true (Brown and Michniuk 2007). If the western Delta becomes brackish to the extant that Suisun Marsh is today, this may change.

N1c: *Corbicula*

General Observations: The relationship between drivers and outcomes is described in the DRERIP Corbicula Conceptual Model (Thompson et. al., In revision).

Consequences of *Corbicula* establishment. If established, *Corbicula* would likely have a significant effect on food web dynamics because it consumes phytoplankton in shallow areas and/or consumes the productivity of shallow areas exported to channels to such a high extent that it exhibits top-down trophic control. *Corbicula*'s consumption of primary productivity represents a significant limiting factor throughout the Delta that could greatly reduce productivity benefits of restoration efforts (Thompson et. al., In revision). According to the *Corbicula* model (Thompson et. al., In revision page 11), no local studies have been

undertaken to indicate whether *Corbicula* feeding has reduced zooplankton populations either through competition or direct predation. In this case, the baseline condition is that much of the Delta is infested with *Corbicula*. The restoration of tidal marsh which may also become infested with *Corbicula* at some future time would not represent a significant change above baseline conditions. Establishment of *Corbicula* would however, consume much of the positive benefits that were previously discussed above under positive outcomes.

Potential Control Options. There are no stressors identified that can limit the success of Corbicula in a significant manner. However, salinity can limit the spatial distribution of this species and food limitation is a source of stress. (Thompson et. al., In revision, pages 8 and 13). The *Corbicula* conceptual model indicates that the only meaningful method to control their presence/abundance is salinity. This control method would require salinity intrusions into the restoration area of sufficient duration and at the appropriate times of year to have a meaningful effect. The conceptual model does not specify the duration and timing which might be most effective during recruitment. Water temperatures may influence the effectiveness of both recruitment and control measures.

Magnitude: 1- Minimal
Corbicula can control phytoplankton biomass development in shallow areas, or consume the productivity of shallow areas exported to channels. Corbicula is a significant limiting

factor throughout Delta (Thompson et. al., In revision). For this outcome, the baseline condition is that much of the Delta is infested with *Corbicula*. The restoration of tidal marsh that eventually becomes infested with *Corbicula* would not represent a significant change above baseline conditions.

Certainty: 2 - Low
The timing and extent of colonization by Corbicula cannot be predicted because of a lack of data.

Corbicula are prolific reproducers and colonizers of newly available habitats in salinities below 2 ppt. Source populations can come from elsewhere within the Delta or from upstream tributary populations. *Corbicula* can establish on soft and hard substrates and on vegetation and they can colonize intertidal zones as well as deeper water. (*Corbicula* model). Based upon the biology of the species and the physical setting of the restoration site, the probability of *Corbicula* establishment in the West Delta restoration areas appears to be high, but ultimately cannot be predicted, partially due high variability in environmental conditions. The low certainty score considers the probability and extent of potential establishment.

Corbicula monitoring data from previous restoration sites in the Delta, such as Liberty Island or Little Holland Tract, would provide greater information about the probability of colonization on these eastern Delta sites. More information would improve the certainty rating. However, such data and analysis was not made available to the evaluation team.

N1d: Inland Silversides Effects on Delta and Longfin Smelt

General Observations: Inland silversides (*Menidia beryllina*) are highly tolerant of warm water, salinity variability and are trophic generalists compared to Delta smelt (Moyle 2002). Inland silversides are the most numerous fish in Suisun Marsh shoreline habitats (Matern et al. 2002), and the most numerous fish in shallow Delta habitats (Nobriga et al. 2005, Brown and May 2006). The Delta smelt model (page 3) includes intraguild competition with inland silversides as one of the top five in-Delta stressors to Delta smelt. Inland silversides are thought to be a major predator of Delta smelt eggs (Bennett and Moyle 1996 and Bennett 2005 in the Delta smelt conceptual model pg 12). In the laboratory, inland silversides reduce Delta smelt size relative to controls when they are reared together (Bennett 2005).

Inland silversides are also treated in the longfin smelt model. Moyle (2002, in Rosenfield, 2008) suggested that based on timing of arrival in the Estuary and subsequent longfin population response, inland silverside might have had a major impact on longfin population dynamics. However, the model states that inland silverside prefer shallow water habitats where juvenile and sub-adult longfin are rare, thus, their impact as predators of juvenile and sub-adult longfin is probably slight (Rosenfield, 2008, pg. 17). Spawning locations for longfin are unknown, so it is not known whether competition from inland silverside for spawning territory is a factor in their decline.

However, Delta smelt evolved with other intraguild competitors, including longfin smelt, and have survived with striped bass (introduced in 1879). Interaction between silversides and Delta smelt in the wild may be limited because Delta smelt typically inhabit offshore environments, while inland silversides typically inhabit shoreline habitats. Increased shoreline habitat would presumably increase the carrying capacity for Inland silversides. However, predator-prey interaction between Delta smelt and inland silversides in the wild is speculative. Silversides may eat Delta smelt eggs or larvae if the eggs and larvae occur on the shorelines. It has not been shown that inland silversides reduce calanoid copepods (Norbriga and Herbold, 2008, page 32), so they may not effectively compete with Delta smelt for prey.

Williams and Rosenfield, In preparation; Israel and Klimley, 2008; Kratville**,** 2008; and Israel et. al., 2009 do not mention inland silversides so this evaluation assumes no adverse effects and focuses its evaluation on Delta smelt and longfin smelt.

Magnitude = 2 - Low

Inland silversides are the most abundant fish in shallow-water habitats in many areas of the Delta and may currently contribute to local depletions of zooplankton otherwise available to native fishes within these areas. Additionally, they may prey on embryos of species who lay eggs in these shallow areas (Moyle 2002). The crash of Delta smelt populations coincided with invasions of inland

silversides into the estuary (Bennett and Moyle 1996). This action may change conditions relative to baseline by attracting (via restored marsh) a nuisance (inland silversides). This conservation measure will increase the local inland silverside population by providing additional shoreline breeding habitat. Because of the high existing abundance of inland silversides, the incremental increase in breeding habitat and thus population size above current conditions is considered small and the magnitude of this effect is considered to be low relative to baseline. Further, differential habitat selection (offshore environments for inland silverside) is expected to reduce the interspecific competition effects. .

Certainty = 2 - Low

Understanding of interaction between Inland silversides and Delta smelt in the wild is low, particularly in regards to egg predation by inland silversides. Spatial interactions with longfin smelt are also uncertain.

Outcome N2: Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A – Covered fish species, N2-B, Non-covered wildlife species, N2-C, Human health.

N2a: Covered fish species

General Observations - methyl mercury: The relationship between drivers and outcomes is supported by (Alpers et. al., 2008, Table 2 and associated text). Although current methylmercury levels on Liberty Island (analogue for future state of areas to be restored) are relatively low (Slotton et al. 2002, (Alpers et. al., 2008, figure 5), there is potential for enhanced production of methylmercury in areas of high marsh that will be inundated infrequently (only during highest tides).

The process of drying out between wetting events tends to oxidize species of sulfur, iron, carbon, and mercury, leading to higher potential to form methylmercury upon rewetting. Once formed, methylmercury biomagnifies in the aquatic food web and ecological effects may occur in some sensitive species. Thus, the specific geomorphology of restoration sites and in particular the degree

to which shallow depressions and poorly drained areas of high marsh are part of the restoration projects directly influences the degree of mercury methylization.

General Observations, other contaminants
Past land use determines risk of other contaminants: lead risk in areas with significant hunting. Risk of residual pesticides (e.g., pyrethroids) in areas used for agriculture in past 2 years, which suggests that if these pesticides were used, allowing for a 2 year lag period between application and tidal restoration would be a prudent mitigation measure. Selenium contamination from the San Joaquin Valley and other sources is also a concern, however it was not evaluated in this worksheet..

Magnitude: 1 - Minimal
No toxicological studies have been conducted with any of the target species regarding acute toxicity. Mercury concentrations in target fish are compared here against concentrations producing mortality in other fish species. Mercury concentrations in covered fish species are compared here against concentrations producing mortality in other fish species. Mercury concentrations in ppm-wet weight for white sturgeon, Chinook salmon and Steelhead collected during 2006 were 0.165-0.279, 0.094-0.396 and 0.06-0.13, respectively (Melwani et al. 2007). No tissue data for either longfin or Delta smelt was found. It is assumed that both species will have tissue concentrations similar to other fish taxa living one year and feeding primarily on zooplankton. Mercury concentrations in juvenile threadfin shad and juvenile largemouth bass in delta are 0.012-0.076 and 0.035-0.230, respectively (Slotton et al., 2006). In comparison death in rainbow trout in laboratory studies occurred at 4-ppm wet weight and the NOAEC for death in Brook trout at 2.7 ppm (in Wiener and Spry, 1996). In conclusion, there exists about a 10X safety factor between fish tissue concentrations in the Delta and values reported to cause mortality in lab studies.

Regarding chronic toxicity, again, there are no toxicological studies with any of target species. Therefore, have compared reported tissue concentration for individual species against known laboratory effects in other taxa. Decreased feeding efficiency and some hormones response changes observed at 0.25-0.27 ppm wet weight (page 30 of (Alpers et. al., 2008). Decreases in growth occurred in fathead minnows at 0.6-0.7 ppm Hammerschmidt et al., 2002) and in juvenile walleye at 2.4 ppm (Friedmann et al., 1996). In conclusion, some up/down regulation of genes and alterations in feeding behavior are possible in the most contaminated individuals.

Certainty: 2 - Low
Scientists have a low certainty that the magnitude of this outcome is minimal (i.e. magnitude may be higher). The uncertainty is due to the limited amount of tissue data that is currently available for most target species (large safety factor regarding acute toxicity) which makes it impossible to determine the proportion of population potentially at risk. Additionally, only limited toxicological data is available for most of the important sub-lethal processes and none of this has been collected on species of interest.

N2b: Methyl mercury, non covered species

General Observations: The relationship between drivers and outcomes is described in the DRERIP Mercury Conceptual model (Alpers et. al., 2008, Table 2 and associated text).

Magnitude: 3 - Medium
Fifty-eight percent of Forster's terns in San Francisco Bay are at risk of reproductive impairment from consuming fish with elevated mercury levels (Ackerman *et al*., 2008). No Forster's Terns nest in the Delta. However, mercury levels in small fish consumed by terns are higher in parts of the Delta such as the Yolo Bypass than in San Francisco Bay suggesting that other bird species filling the Forster's tern niche in the Delta may be at risk. Mercury may result in a possible sustained, minor population effect on a large area.

In laboratory studies, mink have reproductive failure and die when fed fish diets of 0.5 and 1-ppm mercury, respectively (Dansereau *et al*., 1999). For comparison, mercury concentrations in 64% of largemouth bass, 23% of white catfish, and 35% of channel catfish caught in the Bay-Delta watershed have between 0.23 and 0.93 ppm mercury (Davis et al., 2006). Expected sustained minor population effect or effect on large area.

Additional studies on rails and other species are described in the evaluation worksheet for Cache Slough #HRCM 4, page 36.

Certainty: 2-3 Low-Medium
Scientific understanding of methylmercury effects on some bird and mammal species is high, based on peer-reviewed studies in the San Francisco Bay area and elsewhere. However, methylmercury effects on other bird, reptile, and mammal species are unknown. The nature of this outcome is greatly dependent on highly variable ecosystem processes.

N2c: Methyl mercury, human health

General Observations: See also results from water quality team.

Magnitude: 2 - Low
Fish consumption advisories for the Delta recommend that children under the age of 17 and women of child bearing age consume no largemouth bass or smallmouth bass, spotted bass or Sacramento pikeminnow, and others should limit their consumption of these species to one meal a month (OEHHA, 2006, 2008a,b). Between 10,000 and 20,000 fishermen in the Delta are presently eating fish with more than 10X the recommended methylmercury RfD and could experience some sublethal mercury poisoning (personal communication, Dr Fraser Shilling). Action could increase mercury content of sport fish.

The probability of increased methyl mercury production and export into the food web is the same as that described above for covered and non-covered species.

Certainty: 3 - Medium
Uncertain magnitude and direction of change in mercury content of sport fish, although levels are more likely to increase than decrease. For a given increase in mercury content of sport fish, risk to human health is quantified based on peer-reviewed studies (OEHHA, 2008a,b). Unknown how many anglers would access the project area and what fish they would catch and consume.

The role of restoration projects under this Conservation Measure in contributing to mercury levels in fish species consumed by humans needs to be explored in relation to other mercury sources for those fish species.

Outcome N3: Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids.

N3a: Covered fish species

General Observations: Possible presence of legacy pesticides from 1960s (e.g. DDT) is unknown. More recent (illicit) use of DDT is possible. Pyrethroids are 20x more toxic compared to some other pesticides (organochlorides). They persist in the sediment and degrade in one or two years (DPR, 2008). The relationship between drivers and outcomes is described by the DRERIP Pyrethroids conceptual model (Werner and Oram, 2008, Figure 1).

Magnitude: 1-2 – Minimal - Low
To the extent that pyrethroids or pyrethrins were used in the area to be flooded, significant toxicity could occur within 1-2 years of application. After ~2 years, near-total degradation should occur. DDT and metabolites could cause reduction of insect populations and bioaccumulation in target fish species (and some non-target bird species). Possible presence of legacy pesticides from 1960s (e.g. DDT) is unknown.

Certainty: 1 - Minimal
The toxicity of various pesticides is not completely understood. Although some peer-reviewed studies for selected life stages of certain fish exist, there is not much data for covered fish species. The nature of this outcome is highly dependent on highly variable ecosystem processes affecting the fate (degradation) and transport of pesticides.

N3b: Non covered wildlife species

General Observations: The relationship between drivers and outcomes is described in Werner and Oram, 2008, Figure 1.

Magnitude: 1-2 Minimal - Low
To the extent that pyrethroids or pyrethrins were used in the area to be flooded, significant toxicity could occur within 1-2 years of application. After ~2 years, near-total degradation should occur. DDT and metabolites could cause reduction of insect

populations and bioaccumulation in target fish species (and some non-target bird species).

Certainty: 1 - Minimal
The toxicity of various pesticides is not well understood. A limited number of peer-reviewed studies for certain life stages of selected fish species exist. However, there is not much data for covered fish species available (Werner et. al., 2008). The effect that tidal marsh restoration will have on the availability of residual pesticides is greatly dependent on highly variable ecosystem processes affecting the fate (degradation) and transport of pesticides. Additionally, legacy pesticides from 1960s (e.g. DDT) may be present on the restoration site and more recent (illicit) use is unknown.

Outcome N4: Resuspension and export of contaminants to downstream areas (A) mercury and methylmercury, (B) pesticides and herbicides (e.g. pyrethroids)

N4a: Covered fish species

Analysis of resuspension affects considers two separate physical settings: the restoration marsh sites and the adjacent tidal sloughs. The restored marsh sites are not likely experience much scour, since the adjacent tidal channels would be excavated as part of construction and the hard farm fields are not expected to scour easily. Adjacent tidal sloughs, which are typically comprised of more erodible substrate, may experience more scour both the bed and banks.

General Observations: The relationship between drivers and outcomes is described in Alpers et. al., 2008 (Figures 4, 7, and 8 and associated text) and Werner and Oram, 2008, Figure 1.

Magnitude: 1 - Minimal
The degree of scouring of pre-project soils depends on hydrodynamics. Scour could be a short-term phenomenon as channels reach geomorphic equilibrium. There is potential for increasing methylmercury concentrations in high-elevation marsh (infrequently wetted zone) and possible export of this to downstream environments.

Certainty: 2 - Low
Nature of this outcome is greatly dependent on highly variable ecosystem processes affecting fate (e.g.photodegradation of methylmercury) and transport.

Important Gaps in Information and/or Understanding

Data needed to more fully evaluate tidal marsh restoration actions

- Residence times (average and spatial variance in that value) are necessary to determine how much and what kind of food would be produced on site and exported from the site. Residence time projections also affect temperature and dissolved oxygen conditions and these are important attributes of physical habitat. Finally, residence times for particles of water could inform assessment of “residence” times for fish. There is a non-linear relationship between fish “residence time” and the benefit of the rearing habitat as, at high “residence times” new habitat may serve to delay important migratory activities whereas at very low residence times, the new habitat will have reduced benefit because fish (or at least those that behave like particles) will experience the habitat for only a short period.
- Additional data and analysis of water temperature at the confluence of the Cosumnes and the Delta and the Molkeumne and the Delta is needed to better evaluate Outcome P1a.
- Centrarchid models to understand predator-prey-habitat interactions.
- Striped bass model to understand predator-prey-habitat interactions.
- Expected retention time on restored tidal areas to understand likely productivity and food export potential to local sloughs.
- More spatially comprehensive hydrodynamics to understand whether changed flow patterns will reduce or simply redistribute predator pressure.
- Hydrologic and sediment information about turbidity levels, duration, and consequences on species as related to the following: Increased ability for felta smelt to locate food due to increased turbidity from increased velocities in larger channels.
- *Corbicula* monitoring data from previous restoration sites in the Delta, such as Liberty Island or Little Holland Tract, would provide greater information about the probability of colonization on this Cache Slough site.
- Better data on where and when Delta smelt lay their eggs would better allow assessment of the potential impact of inland silverside predation.
- Analysis of factors contributing the success or failure of other past tidal marsh restoration actions in the Delta.
- Liberty Island is often referred to as a model of a successful restoration project. Monitoring data and new bathymetric data from Liberty Island should be fully analyzed to determine the features that makes it successful and to consider how to apply those features to other restoration projects in the Delta. Specifically, the bathymetric data could be turned into a Digital Elevation Model (DEM) and combined with the habitat type mapping (i.e. vegetation and open water) to illustrate how the restoration provides habitat for covered and other species. This would include documenting the quality of existing LiDAR data for the vegetation mapping.

Research Needs

- Restoration techniques that will prevent colonization by invasive species.
- Management practices that can control invasive vegetation, clams, and predators (centrarchids and inland silversides) and limit colonization of these sites.

- Run (and life-history) specific studies of Central Valley Chinook salmon and studies of steelhead use of tidal marsh habitats would be extremely valuable to defining magnitude of impacts to these populations and increasing certainty. Various tools (including genetic markers and otolith signatures of population origin) could be used to asses both growth and survival of salmonids in these habitats as well as changes in life history characteristics (survival and fecundity) over the course of the life cycle that arise from residence in tidal marsh habitats. Currently, all of the evidence for benefits of tidal marsh on salmonids comes from steelhead and fall run populations well to the North (where high temperatures and invasive predators are not as problematic). Translating these results to all CV salmonid populations is unwarranted and could lead to disastrous "restoration" projects.
- Future research should generate simulations of generic “applications” of the DRERIP Conceptual Models. For example, the temperature model could be “applied” to generic landscape characteristics, such as a restoration site with specific shapes (bowl or gradation), to consider how temperature dynamics are affected on various spatial and temporal scales. This exercise would help managers understand where further detail is needed by taking the conceptual models to the next level by conducting simulations to apply the concepts to a landscape.
- Data on nutrient flow from the marsh plain to juvenile fish rearing in the adjacent channels is essential to determining the value of restored marshes as a food source for larvae of pelagic fish (like longfin and Delta smelt).
- Evaluate the effectiveness of water management strategies on managed wetlands to reduce the production of low dissolved oxygen events associated with managed wetlands operations and transfer what is learned into best management practices for the broader managed wetlands community in this region. In addition, it is likely the reduction of low DO events will result in conditions less favorable for MeHg production and thus reduce MeHg loading to the surrounding aquatic environment. This hypothesis needs testing.
- Greater understanding and more research is needed about the availability and production of food in tidal marshes. Export of organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta has not been studied.
- Potential negative effects of methylmercury exposure on covered fish species remain largely unknown. Based on published studies involving other (non-targeted) fish species, there is reason for concern regarding possible chronic effects caused by methylmercury exposure, including: endocrine disruption, reduced reproductive success, reduced predator avoidance, and reduced feeding efficiency. (See Mercury Conceptual Model, Alpers et al. 2008, Table 4, page 30). Research is especially needed to determine possible effects caused by exposure during early life stages.
- A better understanding is needed regarding the relationship of mercury methylation to the duration of wetting and drying events in areas that are intermittently inundated (i.e. tidal marsh and floodplain). Laboratory and field studies of mercury cycling involving sediments in tidal marsh and floodplain environments should quantify the duration of drying time and the extent of dryness necessary to change the oxidation-reduction character of iron, sulfur, carbon, and mercury in sediments such that microbial activity associated with mercury methylation is enhanced.
- Tropho-dynamic model of ecological interactions linking primary production to the food web structure and production flows into, through, and out of the tidal marsh system.

- Landscape-level models that address the effects of variation in structural features of the tidal marsh environment (e.g., tidal channel complexity, channel width, channel length, edge: area ratios, etc.) on the population or production dynamics of specific plants and animals.

Assess Reversibility and Opportunity for Learning

Reversibility

No/Hard. The following on-the-ground actions would be needed to reverse this action:

1) levees would need to be reconstructed
2) newly created tidal sloughs would have to be regarded
3) sites would have to be dewatered
4) wetland vegetation would have to be removed
5) newly installed levees would need to be removed as necessary
6) monitoring pre, during, and post construction

Although this reconstruction is technically possible, there would be significant financial and regulatory costs. Prior to action reversal, the following planning activities would be needed:

1. geotechnical evaluations for levee reconstruction
2. engineering design
3. evaluate land use options for areas subject to subsidence reversal actions
4. environmental permitting and associated agency ESA consultation
5. mitigation planning

Opportunity for Learning

High:

Implementation of this project can be designed such that different engineering designs can be compared. Numerous physical and biological components can be monitored and ideally, the monitoring data would be used to assess and refine modeling simulations of the restoration. Monitoring questions/data collection could address: marsh function, use of marsh by plant and animal species, abundance/influence of non-native species in restored areas, evolution of marsh habitat including patterns of change, and affect on MeHg levels. It is assumed that monitoring and learning would be part of a comprehensive adaptive management program.

See text in the Evaluation Worksheet for HRCM 4 –Cache Slough Tidal Marsh Restoration for details.

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Appendices

Appendix A: Summary Tables Organized by Outcome

Table 3: Positive Outcomes

Outcome	Magnitude	Certainty
P1. Increase rearing habitat area (including physical and biotic attributes) for covered fish species.		
a. Delta smelt	1	1
b. Steelhead	1	2
c. Cosumnes and Mokelumne Chinook, fall run	1	2
d. Splittail	3	3
P2. Increase the availability and production of food in the east and central Delta by exporting organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta. • All covered fish species		
a. Viewpoint #1	3-4	3
b. Viewpoint #2	1-2	1
P3. **Locally provide areas of cool water refugia** (Feb-Jun) for Delta smelt.		
a. Delta smelt	2	1
b1. Chinook salmon spring run	2	1
b2. Chinook salmon fall run	2	1
b3. steelhead	2	1
OVERALL WORTH RATING		

Table 4. Negative Outcomes

Outcome	Magnitude	Certainty
N1. Establishment of undesirable species that may prey, compete, or alter habitat conditions for covered fish.		
a. SAV and Egeria	3	2
b. Non-native Centrarchids	4	2
c. Corbula	4	2
d. Inland silversides	2	2
N2. Local effects of contaminants: Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A - Target species, N2-B, Non-target wildlife species, N2-C, Human health.		
a. Covered fish species	1	2

b. Other species (not covered.)	3	2-3
c. Humans	2	3
N3. Local effects of contaminants, *including l*ocal toxicity from residual pesticides and herbicides: e.g. pyrethroids.		
a. Covered species	1-2	1
b. Other species (not covered.)	1-2	1
N4: Resuspension and export of contaminants to downstream areas (A) mercury and methylmercury, (B) pesticides and herbicides (e.g. pyrethroids)		
a. Covered species	1	2
OVERALL RISK RATING		

Appendix B - Outcomes with Zero Magnitude

OP2a: Locally provide areas of cool water refugia for winter-run salmon.

Magnitude = 0- Zero.
There will be no benefits of this restoration to winter-run salmon because this run passes through the region during a window of time when temperatures are not believed to be highly stressful to salmonids.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

OP2b: Locally provide areas of cool water refugia for late fall-run salmon.

Magnitude = 0- Zero.
There will be no benefits of this restoration to late fall-run salmon because this run passes through the region during a window of time when temperatures are not believed to be highly stressful to salmonids

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

Appendix C: BDCP Info Cosumnes/Mokelumne ROA

BDCP Steering Committee
November 21, 2008

HANDOUT HABITAT #3

PRELIMINARY DRAFT—FOR DISCUSSION ONLY
Potential Opportunities for Tidal Marsh Restoration
by ROA based on Implementability, Suitability, and Cost
(Does not include assessment of covered fish species benefits.)

Restoration Opportunity Area and Land Units	Potential Opportunities for Tidal Marsh Restoration (acres)[1]					
	Very High[2]	High[3]	Moderate[4]	Low[5]	Very Low[6]	Total Potential
Cosumnes/Mokelumne ROA						
New Hope Tract A	0	0	2,300	10	0	2,310
New Hope Tract B	0	0	0	1,900	100	2,000
McCormack-Williamson Tract	0	1,400	100	0	0	1,500
Snodgrass Slough A	0	0	0	1,600	80	1,680
Subtotal	0	1,400	2,400	3,510	180	7,490

BDCP Steering Committee
November 21, 2008

HANDOUT HABITAT #2

PRELIMINARY DRAFT—FOR DISCUSSION ONLY

Estimated Extent of Lands within Restoration Opportunity Areas that may be Suitable for Tidal Marsh Restoration Area by Elevation Class

Restoration Opportunity Area (ROA)	Area by Elevation Class (acres)										Total
	Upland (>+15 feet)[1]	Transitional Upland 2 (>+3-15 feet)[2]	Transitional Upland 1 (>+3-6 feet)[2]	Sea level Rise Accommoda-tion (>0-+3 feet)[2,3]	Tidal Marsh[4]	Subtidal 1 (<0-3 feet)[4]	Subtidal 2 (>-3-6 feet)[4]	Subtidal 3 (>-6-9 feet)[4]	Subtidal 4 (>9-12 feet)[4]	Subtidal 5 (>-12 feet)[4]	
Cosumnes/Mokelumne ROA											
New Hope Tract A	N/A	8	121	535	1,398	321	10	1	0	0	2,394
New Hope Tract B	N/A	4	6	44	692	1,207	98	2	0	0	2,053
McCormack-Williamson Tract	N/A	3	7	42	813	504	99	5	0	0	1,473
Snodgrass Slough A	N/A	3	38	275	693	602	82	6	0	0	1,699
Subtotal	N/A	18	172	896	3,596	2,634	289	14	0	0	7,619

Appendix D: Description of McCormick Williamson Tract

McCormack-Williamson (Bean Ranch)
Owner: The Nature Conservancy

Acquisition Date: 1999 Property Acreage: 1,713.4
USGS Quad: Bruceville and Thorton

Property Description

The location and boundaries of this property are shown in Figure 7.8. This property is located west of I-5 and north of Staten Island. It has four linear miles of frontage along the Mokelumne River and is within the 100-year FEMA flood zone. This site is enrolled in a Williamson Act contract with the County. Soils are classified as Prime and Unique.

Land Cover Summary

As shown in Figure 7.9, land cover for the McCormack Williamson property is as follows:

Land Cover Type	*Acreage*
Agricultural Infrastructure	2.9
Crops - Annual or Truck & Berry	1,231.0
Developed	1.1
Grain and Hay Crop	264.2
Grasslands	130.8
Riparian Vegetation	56.5
Water	26.9

Conservation Targets

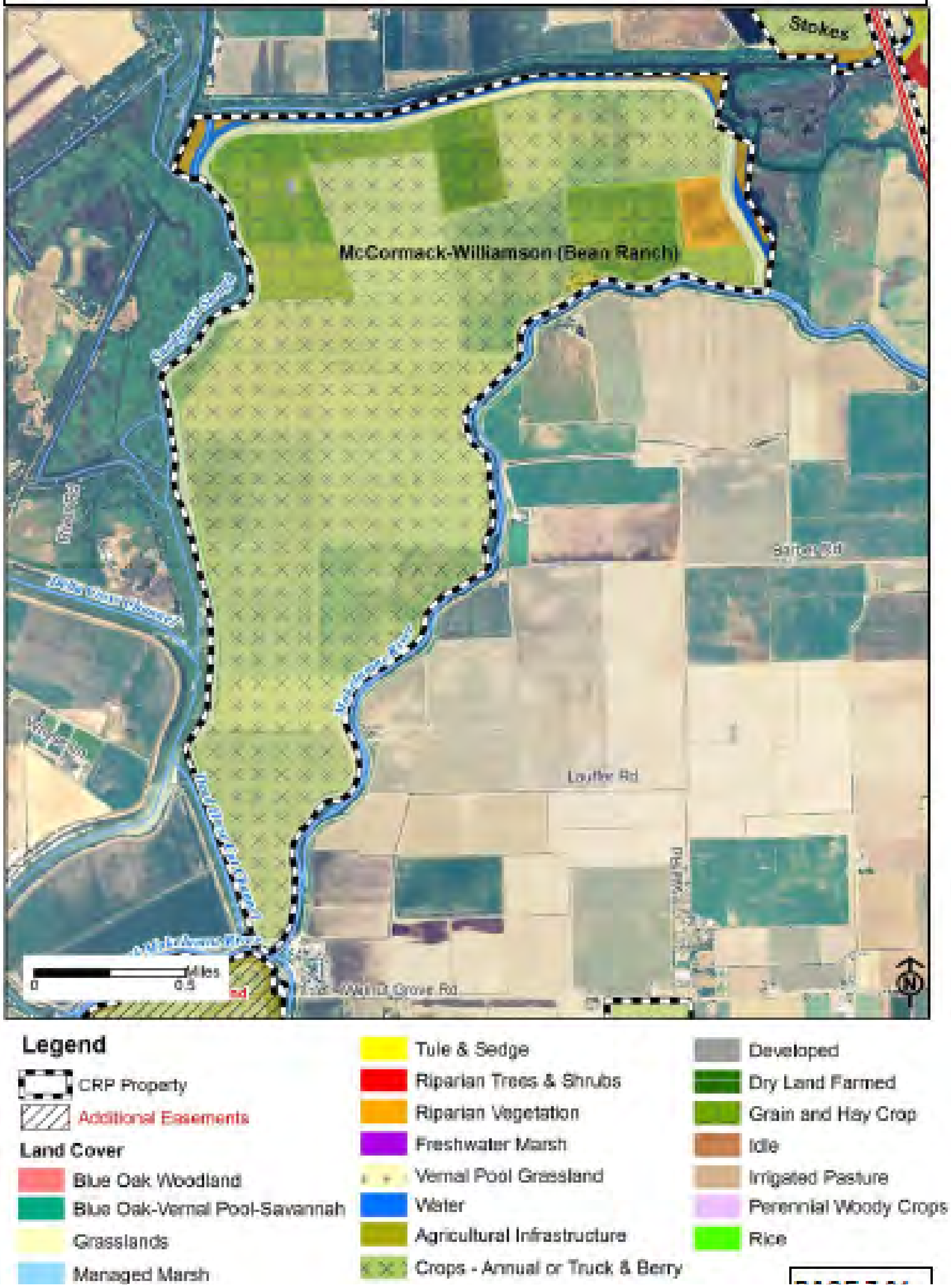
The McCormick Williamson Tract currently supports two conservation targets: riparian forest and salmon. The Mokelumne River passes through this site and allows salmon passage. An Environmental Impact Report prepared by the Department of Water Resources for the North Delta project will address future management of this site and anticipate restoration efforts within the 2008–2018 timeframe. Future management actions are anticipated to restore freshwater wetlands and riparian scrub habitat on this site. An existing small marsh supports a small stand of willow trees. Giant garter snake has not been documented although suitable habitat may exist for this species. The riparian scrub habitat on this property supports elderberry shrubs and exit holes of the valley elderberry longhorn beetle have been found in some of the elderberry shrubs. The levees ringing this island are being re-sloped in order to accommodate future flooding of the island and restoration to marsh habitat. Native species are being restored on the re-sloped levees.

Land Management Notes

- Routine maintenance of on-site water lines.
- Levee present on-site.
- Agriculture managed via lease to private farmer.
- Invasive plants, fig and locust present on site.
- TV tower lease.

FIGURE 7.8: BOUNDARY FOR MCCORMACK-WILLIAMSON PROPERTY

FIGURE 7.9: LAND COVER FOR MCCORMACK-WILLIAMSON PROPERTY



HRCM 6:
West Delta ROA Tidal Marsh
And Shallow Subtidal Restoration

Incomplete Working Draft
Scientific Evaluation Worksheet

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Action:

Restore 3,900 acres of vegetated tidal marsh and 900 acres of shallow subtidal habitat in the West Delta ROA (see map presented in Figure 1 below).

Evaluation Team: Tidal Marsh Workgroup

Dave Harlow (chair); Stuart Siegel (coach); Dan Kratville; Jon Rosenfield; Chris Enright; Armin Munevar; Wim Kimmerer; Amy Richey; Charlie Alpers; Kateri Harrison (note taker).

Date of Last Revision: May 19, 2009

Note about this "Incomplete Working Draft": this document is not completed. The Tidal Restoration Evaluation Team had limited time for this evaluation. Much information has been replicated from the Cache evaluation and has not been revised throughout to reflect the specific restoration sites and geographies of this ROA.

Approach

1. Place fill material on shallowly subsided restoration sites to raise land surfaces to elevations suitable for restoration of intertidal marsh.
2. Plant tules, or other techniques, to raise ground surface elevations suitable for intertidal marsh restoration on shallowly subsided portions of islands and breach levees when target elevations are achieved.
3. Breach and set back levees to provide for tidal exchange with restored habitats. Levee breaches will be of sufficient length to not limit water motion into and out of restored habitat.
4. Excavate channels and/or create berms to encourage the development of dendritic channel networks within restored areas.

Intended Outcomes as Stated in Conservation Measure

1. Provide a continuous corridor of habitat and food productivity linking current and future restored habitat in the Cache Slough Complex with habitat in Suisun Marsh and Bay.
2. Provide intertidal marsh habitat within the anticipated future eastward position of the low salinity zone with sea level rise.
3. Increase rearing habitat area for Chinook salmon, Sacramento splittail, and possibly steelhead.
4. Improve future habitat areas for Delta smelt and longfin smelt within the anticipated eastward movement of the low salinity zone with sea level rise.
5. Increase the production of food for rearing salmonids, splittail, and other covered species.
6. Increase the availability and production of food in the western Delta and Suisun Bay by exporting organic material via tidal flow from the marsh plain and organic carbon,

phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta.

7. Locally provide areas of cool water refugia for Delta smelt.

Conceptual Model Information Regarding Intended Outcomes

The basic drivers and outcomes are described in the following DRERIP conceptual models: Salmon, Delta smelt, Longfin smelt, Temperature, Foodweb, Tidal marsh, Corbicula, Sediment, and Mercury.

Assumptions

Provided in BDCP Conservation Measure

1. Restoration would occur on all suitable areas identified within the Restoration Opportunity Area (ROA).

Added by Evaluation Team

1. This West Delta restoration action is expected to occur within many sub-areas which the Evaluation Team has defined as follows: (1) Decker Island, (2) Sherman Island (north end), (3) Bradford Island (west side), (4) Twitchell Island – A (adjacent to Three Mile Slough), (5) Twitchell Island – B (adjacent to Seven Mile Slough), (6) Twitchell Island C (adjacent to Seven Mile Slough), (7) Brannan Island – A (north shore, across Sacramento River from Grand Island), (8) Brannan Island – B (west shoreline), (9) Brannan Island – C (between Three Mile Slough and Sacramento River), (10) West Bank of Sacramento River (across from Brannan Island and Decker Island), (11) Grand Island (southwestern tip). Restoring tidal marsh habitat on these different sub-areas will have varying levels of both positive and negative effects. For example, some of these sub-areas may be more efficient at the methylization of mercury and so may have a higher magnitude score for an associated negative outcome. Differences in hydrology, topography, soils, and land-use history will also manifest as distinctions in success of this action among sub-areas. General information about sub-area size and previous restoration activity is described in Appendix D. BDCP's estimated extent of restoration types based upon elevation for each sub-area is presented in Appendix E. Although the Evaluation Team presents a general analysis of the entire West Delta ROA in this worksheet, BDCP is encouraged to study the issues at a finer spatial resolution (i.e. the sub-area scale) due to the previously noted important differences among sub-areas.

2. The time frame for realizing restoration benefits depends upon the approaches used. Reversal of subsidence on restored areas can take several years to a decade or more depending on starting elevations. The accretion rate depends on sediment supply and biomass accretion which depends on site-specific conditions. Sediment supply in the Delta is generally very low with the West Delta area having slightly higher levels than much of the Delta but not as high as Cache Slough and North Delta (Schoellhamer et. al., 2007).

3. Efforts to reverse subsidence before active restoration would be focused on the more deeply subsided portions of these landscapes, i.e., lands more than 6 feet below low tide. There is a hypothesis that shallow open water regions located contiguous to emergent tidal marsh provide enhanced ecosystem complexity and functions compared to those tidal marsh habitats located directly adjacent to deeper sloughs.

Although this hypothesis has not been tested, preliminary information on current conditions at Liberty Island and Little Holland Tract suggest support. However, the details of these sites are not readily available to the broad research community at this time and so the information is anecdotal. This assumption also includes a time limit to allow for subsidence reversal so that restoration of an entire parcel is not delayed indefinitely. To speed up the subsidence reversal process, an alternative method would be to separate low-lying areas with new levees and reconnect those areas after subsidence reversal is accomplished.

4. Source of fill material will be identified and use of all material, including dredge spoils, will be approved by the RWQCB.

5. Water output from the site, post-restoration, will meet water quality standards.

6. Prior to implementation, a Phase I Environmental Assessment with on-site sampling to assess legacy and other soil contaminants (i.e. mercury and pesticides) would be completed.

Problem(s) with Action as Written:

1. Since rearing habitat for juvenile fish by necessity includes local availability of food, the evaluation team merged the Intended Outcomes 2 through 5 (tidal marsh, rearing habitat, and local food) into one outcome.

2. Loading of fill material on top of a shallow island may compress the underlying soils. This approach may not yield the intended result. A close study of existing soil conditions including analysis of the local soil map is needed to further evaluate this issue.

3. Intended Outcome #1 states "Provide a continuous corridor of habitat and food productivity linking current and future restored habitat in the Cache Slough Complex with habitat in Suisun Marsh and Bay". The choice to use the term "corridor" within this context is a misapplication of a principle from terrestrial conservation biology. The "corridor" concept is more applicable to terrestrial migratory species, where a corridor links separate habitat patches. But for the pelagic fish this concept does not apply as the West Delta is instead a reach of pelagic habitat rather a path between two patches. Pelagic fish may need to travel between low or high salinity zones. Connectivity of habitat can be improved or increased by removing engineered structures (i.e. rip rap) and restoring habitat edges along channels. Thus, Intended Outcome #1 should modified and simplified to something like "provide a continuous reach of tidal marsh and aquatic habitats and associated food productivity between current and future restored habitats in the Cache Slough Complex and Suisun Marsh and Bay."

4. The conservation measure would benefit from an explicit recognition that restoration of tidal marsh functions on subsided landscapes, especially those subsided below emergent vegetation elevations, will take many years to many decades. In the interim, restoration sites below vegetation elevations will function as shallow subtidal habitat.

5. It is unlikely that intertidal mudflats will develop in the Delta because dominant intertidal emergent vegetation species in the Delta can grow throughout the tidal range and just

into shallow sub tidal elevations (Brown 2003, Simenstad et al 2000 as cited in Schoellhamer et. al., 2007, p.26).

6. The action should state clearly in Approach #3 that significant set-back levees will be required to provide tidal flood protection to lands within the islands not restored to tidal action.

Scale of Action:

Medium

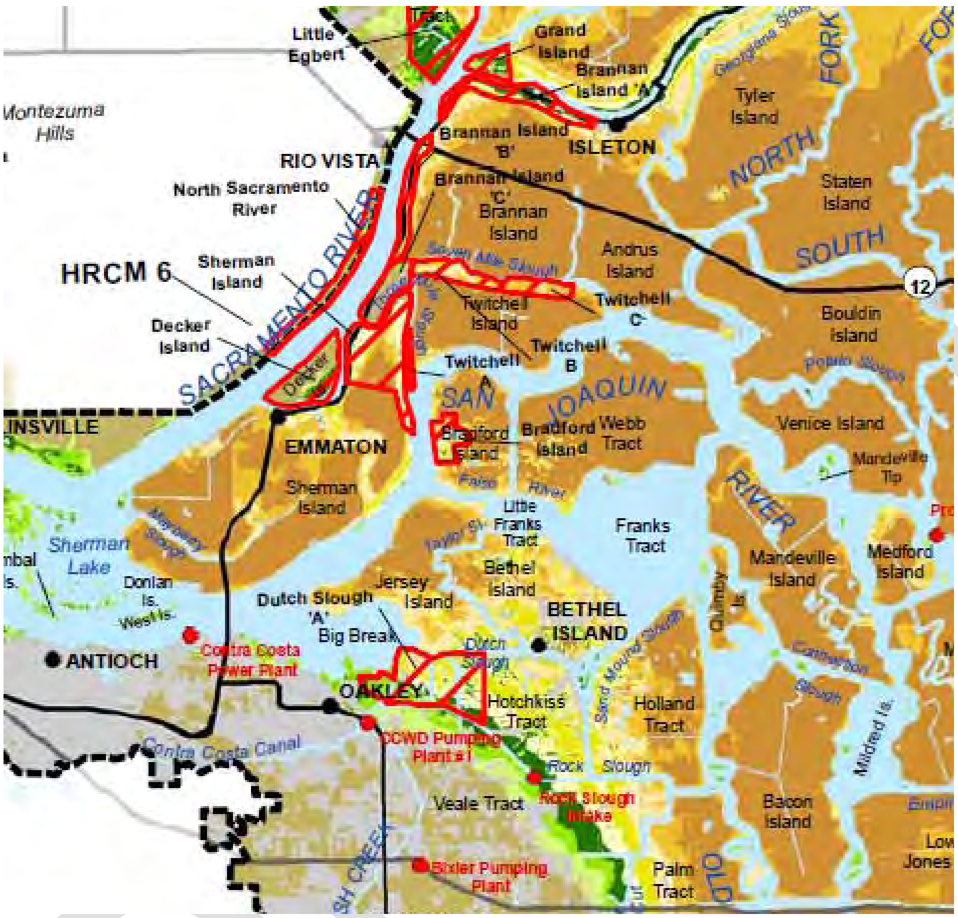
Rationale:

This is a medium scale restoration action due to its moderate spatial extent. As listed in Table1 below, the Delta currently has approximately 21,600 acres of tidal marsh habitat (baseline). Additionally 67,000 acres of diked and other lands have been identified as potentially restorable to tidal marsh (neglecting effects of restoration on reducing tidal range) (Delta Vision Strategic Plan, October 2008, Table 1, p.77). The action proposes restoring 3,900 acres of vegetated tidal marsh and 900 of shallow intertidal habitat. This represents an increase of 18% above the current tidal marsh acreage. Significant amounts of the 67,000 acres of identified restorable lands are highly constrained such that they could not be restored in the near term (South Delta and Netherlands alone account for 31,000 acres of the 67,000 acres). The West Delta restoration action relates to a regional scale.

Table 2. Summary of Tidal Marsh Acreages

Area	**Acreage**	**Source**
Delta (entire Delta proper)	738,000	DWR, 2009
Historic tidal marsh/wetlands in Delta	525,000	TBI, 2002
Current extent of tidal marsh/wetlands in Delta.	21,600	TBI, 2002
Restorable intertidal lands within Delta.	67,000	CA DVSP, 2008, Table 1, p.77.
Proposed West Delta tidal marsh restoration (this action)	4,800 acres total (includes 3,900 acres of vegetated tidal marsh and 900 acres of shallow intertidal habitat.)	BDCP, 2009

Figure 1. West Delta Restoration Opportunity Areas



Evaluation Summary

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Other Positive Outcomes Identified, Not Separately Evaluated

Several outcomes were identified by BDCP early in the process. Other outcomes were identified by the Evaluation Team. The list below represents those outcomes that were identified, but not listed in the worksheet, because they were merged with another outcome for full evaluation.

OP1. Provide intertidal marsh habitat within the anticipated future eastward position of the low salinity zone with sea level rise.
This outcome was merged with Outcome P1 and fully evaluated in the worksheet below. The benefits of providing intertidal marsh habitat within the anticipated future eastward position of the low salinity zone is a matter of the geographic placement of restoration sites. The benefits will accrue to those species that utilize the restoration site as described in Outcome P1.

OP2. Improve future habitat areas for Delta smelt and longfin smelt within the anticipated eastward movement of the low salinity zone with sea level rise.
This outcome was merged with Outcome P1 and fully evaluated in the worksheet below. The benefits of providing intertidal marsh habitat within the anticipated future eastward position of the low salinity zone is a matter of the geographic placement of restoration sites. The benefits will accrue to those species that utilize the restoration site as described in Outcome P1.

Outcomes with Zero Magnitude

During the Evaluation process, several of the outcomes identified by BDCP early in the process, were found to have a zero magnitude. These outcomes are listed below and their evaluation is provided in Appendix B.

- OP3a: Increase rearing habitat (physical and biotic attributes) area – Steelhead.
- OP3b: Increase rearing habitat (physical and biotic attributes) area. - Winter-run Salmon
- OP3c: Increase rearing habitat (physical and biotic attributes) area. - Late Fall-run Salmon
- OP4. Provide a continuous corridor of habitat and food productivity linking current and future restored habitat in the Cache Slough Complex with habitat in Suisun Marsh and Bay – Salmonids.
- OP5a: Locally provide areas of cool water refugia for winter-run salmon.
- OP5b: Locally provide areas of cool water refugia for late fall-run salmon.

Other Potential Negative Outcomes Identified, Not Evaluated

During the course of this evaluation, the team identified one potential negative outcome that it did not evaluate due to lack of time. It is recommended that this potential outcome be evaluated at some point in the future when additional time is available.

- ON1. Pesticides for mosquito control.
- ON2: Increase in the availability of selenium

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

No

Nature of Change:

This moderate scale action to restore 3,900 acres of tidal marsh and 900 acres of shallow subtidal habitat may change the environment on a regional scale but not to such an extent that our current understanding of boundary conditions (Harrell et al 2008), hydrodynamics, and ecological processes in the Delta would change.

Overview of Productivity Import-Export

See the Cache Slough evaluation (HRCM4) for complete discussion of productivity levels, import and export. Here we describe how conditions may differ from Cache Slough in order to provide the Conservation Measure evaluation appropriate specificity.

The primary difference with Cache Slough is that most of the eleven sites with the West Delta ROA are located along and directly connected to the margins of very high energy waterways – the lower Sacramento and San Joaquin rivers. Twitchell Island A and B and Dutch Slough area along lower energy waterways but not too far removed from the larger rivers. The result is that water in these restoration areas will exchange much more rapidly with the adjacent water bodies and that those adjacent water bodies will move marsh exports relatively great distances. Thus, the restored areas will have generally lower residence times than those of Cache Slough and exported productivity will reach farther afield.

Potential Positive Ecological Outcome(s)

Outcome P1: Increase rearing habitat (physical and biotic attributes) area for covered fish species.

As indicated at the beginning of this worksheet under the section entitled "Problems with Action", the team decided to merge two Intended Outcomes (rearing habitat and local food) into one outcome, P1, as shown below because rearing habitat for juvenile fish by necessity includes local availability of food. This outcome includes food (both primary and secondary production) produced within the vegetated marsh, within marsh channels, and within the subtidal areas adjacent to the vegetated marsh. General information that applies to salmon runs is provided in the worksheet for HRCM 4 – Cache Slough, Outcome P1c on page 15.

P1a. Spring Run Chinook Salmon

General Observations: Spring-run juveniles move through the Delta in the winter and spring (Williams and Rosenfield, In preparation, figure 3). The DRERIP Conceptual model (Williams and Rosenfield, In preparation, page15) indicates value of estuarine rearing varies across runs. The scoring below assumes that this restoration action only occurs when/if other tidal marsh projects in the Sacramento "corridor" are "restored" as well.

Magnitude = 2 - Low

The salmon model (Williams and Rosenfield, In preparation, page16), states that "Spring Chinook, or at least the Butte Creek population, pass quickly through the Delta, so habitat restoration there seems unlikely to do much for them. The same is probably true for late fall Chinook, and for steelhead". This particular outcome assumes that "rearing habitat area" (quantity) and/or food is limiting. Spring-run will consume the types of fish and zooplankton produced in this restoration (under the assumed condition). Although the information presented in the DRERIP salmon model seems focused on one spring run population (Butte Creek), many juveniles from other populations migrate at a smaller size than Butte Creek juveniles (Williams 2006). They migrate at about the same time as fall-run and thus may experience competition with fall run (Figure 3, in Williams and Rosenfield, In preparation – estuarine growth). So, this restoration may alleviate competition for a segment of the population. The model indicates moderate benefits of increasing rearing habitat.

Spring run may migrate past this restoration site from winter through spring. Average daily water temperatures in the vicinity of this restoration (as indicated by those at IEP monitoring station RSAC 101) regularly exceed 20-21 degrees C, beyond which sublethal effects accumulate (Marine and Cech 2004; Myrick and Cech 2004; Richter and Kolmes 2005) from May-September. With warming that may occur under climate change, these temperatures will occur in this area with some frequency during April and October as well. Thus, spring-run rearing in this proposed restoration site during May, June, and July will probably be impacted by high temperatures.

Benefits are limited to those emigrants rearing in this habitat in the early-mid spring, before temperatures in this region increase above optimal rearing threshold (12-16 degrees C, Marine and Cech 2004).

Upstream habitats are more likely to be important to the productivity of this run. Stressors in the Estuary may be related to competition with hatchery and wild production of fall run Chinook salmon (Williams and Rosenfield, In preparation).

Juvenile spring-run from two of important watersheds (Deer and Mill Creek) appear to migrate at a small size and these fish may benefit from rearing habitat restoration at lower elevations. Spring-run that migrate at small body size must compete with more abundant fall run Chinook salmon migrants. Thus, creation of suitable rearing habitat may alleviate an important bottleneck for this species. Given the moderate size of this restoration and the implicit assumption that it is implemented along with other, larger tidal marsh restorations, the marginal impact of this restoration is low.

Certainty = 1 - Minimal

There are no direct studies of spring-run Chinook salmon habitat use in this ecosystem. There is variability (inter-population and inter-annual) in the relationship between habitat volume-density-competition-and growth (Williams and Rosenfield, In preparation). Given the temperature limitations and differences in life history among spring-run populations, the Evaluation Team has low certainty that the magnitude of this impact from this action is low. Also, some of this restoration (e.g. Dutch slough) is proposed out of the most likely migration corridor for spring run, therefore the magnitude of this impact is less certain.

Establishment of *Corbicula*, could limit, if not eliminate the productivity benefits of the restoration to Chinook salmon. See Negative Outcome N1b. Similarly, colonization by invasive predators could result in added mortality that would counteract any benefits of restoration (especially if SAV invasion facilitates predation success).

P1b. Fall run Chinook salmon

General Observations: Fall-run juveniles move through the Delta in the winter and spring (Williams and Rosenfield, In preparation, figure 3). The salmonid model indicates value of estuarine rearing varies across runs: (page 15). The scoring presented below assumes that this restoration action only occurs when/if other tidal marsh projects in the Sacramento "corridor" are "restored" as well.

Magnitude = 2 - Low

Fall run Chinook salmon are the most abundant Chinook salmon in this Estuary. They are produced in hatcheries and they migrate at the same time as spring-run Chinook salmon. They also migrate during times when potential rearing habitats may be inaccessible due to high temperatures or reduced inundation of habitat. Thus, they are more likely to be exposed to competition for habitat than some other salmonid populations in this Estuary. This particular outcome assumes that "rearing habitat area" (quantity) and/or food is limiting. "Fall Chinook […] could benefit strongly from tidal marsh restoration" (Williams and Rosenfield, In preparation, page 16). Fall Chinook enter estuarine habitats at a small size and the model anticipates benefits from additional rearing/growth opportunities. Fall-run Chinook from the San Joaquin River basin may utilize some of the restored habitat (e.g. Dutch Slough). Most fall-run Chinook migrate as fry and these fish may benefit from restoration of rearing habitat at lower elevations. The creation of suitable rearing habitat may alleviate a bottleneck for this species. The magnitude of the impact will not be more than "low" because fall run Chinook face serious challenges in their upstream spawning and rearing habitat.

Fall-run salmon will consume the types of zooplankton produced in this restoration (under the assumed condition). Average daily water temperatures in the vicinity of this restoration (as indicated by those at IEP monitoring station RSAC 101) regularly exceed 20-21 degrees C, beyond which sublethal effects accumulate (Marine and Cech 2004; Myrick and Cech 2004; Richter and Kolmes 2005) from May-September. With warming that may occur under climate change, these temperatures will occur in this area with some frequency during April and October as well. Thus, fall run rearing in this proposed restoration site during May, June, and July will probably be impacted by high temperatures.

Fall run are impacted by severe stressors and limitation in their upstream spawning and rearing habitats (water temperatures, spawning gravel availability). Given these other stressors, the moderate size of this restoration, and the implicit assumption that it is implemented along with other, larger tidal marsh restorations, the marginal impact of this restoration is very likely to be low.

Certainty = 2-Low
Fall run Chinook use of fresh water tidal and sub-tidal environments is documented in other systems but is not well studied in this system – possibly because this kind of habitat is limiting in this system. The effect of global climate change on water temperatures in this area during the time period of fall run migration also decreases the window of time during each year when restoration will produce benefits.

Establishment of *Corbicula*, could limit, if not eliminate the productivity benefits of the restoration to Chinook salmon. See Negative Outcome N1b. Similarly, colonization by invasive predators could result in added mortality that would counteract any benefits of restoration (especially if SAV invasion facilitates predation success).

Outcome P2: Provide a continuous corridor of habitat and food productivity linking current and future restored habitat in the Cache Slough Complex with habitat in Suisun Marsh and Bay.

P2a. Splittail

General Observations: The relationship between the drivers and outcomes is described in Kratville, 2008 on pages P1h Pg 12, 13, 14, 15.

Magnitude = 3 - Medium
While more tidal marsh will help rearing of <u>juvenile</u> splittail, the expected benefit to the population as a whole (including all life stages) is medium. For Sacramento splittail, the limiting factor for population abundance is floodplain inundation that provides spawning

habitat. When large scale inundation occurs, splittail populations increase to high abundance numbers for several years following an event. Long periods without floodplain inundation reduce splittail population abundance. Splittail do not appear to be habitat limited at other life history stages.

Certainty = 3 - Medium
The uncertainty lies in whether these new rearing areas will increase the abundance of splittail populations. The West Delta ROA will increase opportunities to find sufficient rearing habitat for juveniles; however this does not appear to be a limiting factor in splittail abundance compared to floodplain inundation. The bulk of the adult splittail population resides in brackish areas of Suisun Marsh. If the western Delta becomes brackish to the extant that Suisun Marsh is today, this may change.

P2b. Green sturgeon

General Observations: The basic relationship between drivers and outcomes is described in Israel and Klimley, 2008, pages 1i, 4, 8, and 9.

Magnitude = 2 - Low
Information on juvenile sturgeon diets and physical habitat needs in the Delta is limited. Juvenile sturgeon of other species located in other systems do feed on drifting insects (Radtke 1967 and McCabe, G et al. 1993). This area of the Delta will not provide extensive intertidal-mud bottoms as found in lower portions of the estuary. Soft bottom benthos are a food resource for the sturgeon. Most habitat limitations for sturgeon appear to occur outside of the restoration area (i.e. upstream and downstream), as described on pages 4, 8, 9 in Israel and Klimley, 2008 and pages 19-21 of Israel et. al., 2009. It is unknown to what extent adult sturgeon used fresh water tidal marsh for foraging. The impact to individual sturgeon may be low but the extreme loss of fresh water tidal marsh in the Delta may have lowered the carrying capacity of the entire system for sturgeon. See pages 4, 8, 9 in Israel and Klimley, 2008 and pages 19-21 Israel et. al., 2009 for more detail.

Certainty = 1- Minimal
There is minimal certainty about whether this proposed restoration will benefit sturgeon as described in this outcome. The minimal certainty is due to the lack of research on this aspect of sturgeon biology/ecology in the Delta. Most of the available information on sturgeon diets and predator/prey relationships is based upon other species of sturgeon, located outside of this system.

P2c. White sturgeon

General Observations: The basic relationship linking drivers to outcomes is described in pages 1j, 19, 20, and 21 in (Israel et. al., 2009, the DRERIP White sturgeon model).

Magnitude = 2 - Low
Information on white sturgeon diets and physical habitat needs as juveniles in the Delta is limited. Other species of sturgeon in other systems do feed on drifting insects as juveniles. This area of the Delta will not provide extensive mud bottoms as found in lower portions of the estuary and so benthic food items are expected to be limited in this

restoration (Siegel, personal communication, Feb. 2009). Habitat limitations for white sturgeon appear to occur upstream and downstream of the restoration area (i.e. outside this ROA).

Certainty = 1 - Minimal
There is minimal certainty about whether this proposed restoration will benefit sturgeon as described in this outcome. The minimal certainty is due to the lack of research on this aspect of sturgeon biology/ecology in the Delta. Most of the available information on sturgeon diets and predator/prey relationships is based upon other species of sturgeon, located outside of this system.

Outcome P3: Food resources (i.e. organic material from the marsh plain and organic carbon, phytoplankton, zooplankton, and other organisms from intertidal channels) produced on the restored marsh will be exported, via tidal flow, and contribute to food availability downstream in the western Delta and Suisun Bay.

P3a. All covered fish species

General Observations: The Tidal Marsh and Foodweb models [Kneib et. al., 2008, page 9 and Durand, 2008, section 2.16)] provide a general indication that there may be a linkage between tidal marsh habitat as a driver and increases in availability and production of food resources as an outcome, but that the mechanism for this linkage may be movement by fish. The tidal marsh conceptual model also states that freshwater tidal marshes are net exporters of high-quality organic production (page 2 in Kneib et. al., 2008). See also Dame et al. 1986, Kimmerer and McKinnon 1989, Kneib 1997, Lucas et al. 2009. Please see the evaluation worksheet for action # HRCM4-Cache/Yolo for more details about **Tidal Marsh Contributions to Exported Production.**

There was disagreement within the evaluation team regarding the magnitude and certainty of expected benefits of tidal reintroductions with regard to the export of food (phytoplankton, zooplankton, insects, and small fish) to areas downstream of Rio Vista and the likely benefits to covered fish species. In the spirit of presenting the scientific discourse, both points of view are captured below.
Two key questions discussed were: (1) can we predict the sign of the flux of productivity (i.e. will the restoration area be a source or a sink for primary and secondary productivity); and (2) will there be adequate advection to move material out of the restoration area and downstream to Rio Vista (assuming the restoration area is a source of productivity, as opposed to a sink). Additional information and analyses is needed to better answer these key questions. To develop this additional information, the team recommends future development of a Tropho-dynamic model as described in the section on page 41 entitled "Research Needs".

Viewpoint #1

Please see the text of Outcome P3 in worksheet HRCM4 – Cache Slough for additional background information about Viewpoint #1.

Magnitude = 3-4 – Moderate to High
Without advective connection, restoration will still have significant productivity benefits to covered fish species and to many other species due to providing areas of highly functional habitat in conjunction with restoration elsewhere that collectively provide fish species a range of options that spread risk through exploiting available resources when they are present. Refer to Ted Sommers, IEP Estuarine Ecology Team or CAERS poster. In addition, these areas would export that productivity through the "trophic relay" concept described in the tidal marsh conceptual model (fish export the productivity).

Certainty = 3 – Moderate
Certainty is reduced by the potential for establishment of invasive clams that could consume substantial portions of phytoplankton and hinder zooplankton productivity.

Viewpoint #2

Please see the text of Outcome P3 in worksheet HRCM4 – Cache Slough for additional background information about Viewpoint #2.

Magnitude = 1-2 (Minimal to Low)
The implied relationship is that restored tidal marsh will export nonliving and living organic matter including plankton and fish, thereby supporting foodwebs of the upper estuary. An implicit assumption is that any increase in the area of shallow habitat would result in enhanced plant productivity some of which would be exported.

Certainty = 1 - Minimal
The sign of the signal is difficult to determine, except for total organic carbon, most of which is dissolved. Although dissolved organic carbon (DOC) will likely flow out of the marsh, fluxes of other components may be in or out (Kneib et. al., 2008, page 9). Colonization by invasive clam species can wipe out the food web production effect entirely. We have no certainty at all that they will not colonize. In addition, colonization of the site by vertebrate consumers (e.g, inland silverside) can also significantly reduce the amount of food available for export beyond the site boundaries (Moyle 2002). There is evidence from within this system (Dean et al. 2005) that restored marshes can act as sinks for certain zooplankters; in this case, the sign of the signal would be negative

Outcome P4: Provide local areas of cool water refugia for Delta smelt and salmonids.

The cause and effect relationship associated with this outcome is described in Stacey and Monismith 2008, Malamud-Roam 2000, and Enright 2008. Considering the landscape scale (medium) of the action, the relationship between tides, physiography, and water temperature could be moderate. The relationship between drivers (wind, insolation, fetch, tides, currents) and linkages (long-wave, short wave, latent, and sensible heat flux) is complex and may produce both warmer and cooler water on a variety of time and space scales. Larger spatial gradients of water temperature will likely occur. The frequency of threshold temperatures for various species is uncertain. See Stacey and Monismith (2008), Malamud-Roam (2000), Enright (2008).

For more details, please see the introductory text in the HRCM 4- Cache Slough action worksheet and the Suisun Marsh Tidal Marsh Restoration Worksheet, specifically, Outcome P4.

P4a. Delta smelt

Magnitude = 2- Low
The spatial extent of cool water refugia could be relatively limited. However, in some cases a large effect could be felt across relatively large area across the range. Please refer to the discussion located in HCRM4 – Cache Slough Restoration Action, Outcome P4, page 25 for more details.

Certainty = 1 - Minimal
The basis for our understanding is a single unpublished study in Suisun Marsh. The extent to which this effect may transfer to the restoration site, and to which Delta smelt and salmon will take advantage of it, cannot be predicted. Please refer to the discussion located in HCRM4 – Cache Slough Restoration Action, Outcome P4, page 26 for more details.

P4b. Salmonids

High temperatures are currently rare during May (as indicated by IEP gauges rsac075 and rsac054; Enright *pers. comm.*). Temperatures exceeding 20-21^{o}C (beyond which sublethal effects accumulate; Reese and Harvey 2002 *and see* Richter and Kolmes 2005) are more common and widespread in June, July, and August (as indicated by IEP gauges rsac075 and rsac054; Enright pers. comm.). With warming that may occur under climate change projections, high temperatures may become more frequent and extreme. Thus, Chinook salmon (spring-run and fall-run) and steelhead rearing in this proposed restoration site during June and July will probably be impacted by high temperatures. Forces that reduce those temperatures may improve survival, growth and smoltification success.

Benefits are limited to those emigrants rearing in this habitat after May, when temperatures in this region increase above optimal rearing threshold of 12-16^{o}C (Marine and Cech 2004). These benefits are expected to be transient (on annual and decadal time scales) and will never effect more than a small fraction of populations for any of the covered species (unless there is a cumulative impact from numerous restorations that produce the same cooling effect. Also, as mentioned in the description, this phenomenon is transient over time as the timing of tidal cycle shifts. Complexity of thermodynamics in conjunction with local geomorphology and long-term climate change and sea level rise introduce considerable uncertainty.

In addition to the runs listed below, please see Appendix B for winter-run etc.

P4b1: Spring run salmon

Magnitude = 2- Low.

This outcome modifies Outcome P1 (creation of habitat). In evaluating that outcome, benefits of this action were interpreted in the light of unfavorable temperature conditions that occur in the area during late-spring and Summer. To the extent that the tidal flooding/cooling phenomenon occurs on this restoration site (a function of geography and restoration design and site elevations) during the period of potential thermal stress (May through end of summer), it may provide some relief from the effects of thermal stress *for those salmon runs that migrate through this region at this time (fall and spring run and steelhead).* That benefit impacts only the proportion of the population that migrates at this time and only the proportion of the population that migrates through this area.

Certainty = 1-Minimal

Certainty is minimal for reasons similar to that described in P3a, above. This outcome is highly dependent upon highly variable ecosystem processes. Although scientists have a reasonable understanding at the general level, the range of data needed to evaluate at the action scale is lacking.

P4b2: Fall run salmon

Magnitude = 2- Low.
As noted above, the beneficial effect occurs for only a portion of the salmonid population passing through this region during a particular and narrow window of time.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

P4b3: Steelhead

Magnitude = 2- Low.
Beneficial effect occurs for only a portion of the salmonid population passing through this region during a particular and narrow window of time.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

Potential Negative Ecological Outcome(s)

Outcome N1: Establishment of harmful invasive species that will prey or compete or alter habitat conditions for covered fish.

Harmful invasive species have the potential to cause two types of adverse effects. First is to worsen conditions relative to the existing baseline; i.e., creating an attractive nuisance. Second is to detract from achieving the positive benefits the action could provide. The magnitude and certainty scores below are based upon an assessment relative to baseline conditions. The scores below for N1a to N1d do not represent the potential to distract detract from the positive benefits of the action because these deductions were considered by reducing the certainty scores for positive outcome # P1. Where appropriate, the impacts associated with the establishment of harmful invasive species on the restored marsh are discussed below.

N1a: Submerged Aquatic Vegetation (SAV) (including *Egeria*)

General Observations: As described in the conceptual model, the establishment of SAV is controlled by local flow conditions and substrates (Anderson, In Preparation). Many aspects of SAV physiology are influenced by local flow conditions including turbidity and to some extent flow velocity which if too high can scour suitable substrate precluding SAV establishment. The initial establishment of SAV is an intermediate outcome and the development of a large sustainable SAV population is the final outcome. The basic relationship between drivers and outcomes is described in the DRERIP aquatic vegetation conceptual model on pages 8, 9 10 and Figure 2 (Anderson, In preparation). Please note that establishment of SAV reduces the certainty that the positive outcome, P1 will occur. This has been noted in the scoring for P1.

Magnitude: 3 - Medium
The establishment of SAV in general is controlled by local flow conditions and substrates. Local flow conditions control many aspects of SAV physiology, most importantly in this location, turbidity. In nearby Liberty Island where turbidities are generally higher due to wind wave action SAV is restricted to shallow near shore areas (Ustin et al. 2008). If turbidities are high in the restoration area then SAV establishment and growth may be reduced to levels similar to Liberty Island. If not, there is the potential for SAV amounts similar to Franks Tract. The substrates in this area would be expected to support establishment of SAV (Anderson, In preparation). If the western Delta becomes brackish to the extant that Suisun Marsh is today, this may change. Small to moderate fractions of all the covered fish species may experience highly significant but localized effects due to SAV and therefore the net effect is medium.

For this outcome, the baseline condition is that much of the existing 21,600 acres of Delta tidal marsh is infested with submerged aquatic vegetation (Ustin, 2008). The restoration of a tidal marsh that eventually becomes infested with SAV is significant. Large, sustainable populations of SAV will produce significant changes in water quality (turbidity, pH, DO and temperature), or water flow characteristics (velocity and direction), which in turn can affect the quantity and quality of sediments (Anderson, In Preparation).

Eventually, the clarity of water entering the site from upstream will increase by lowering velocities and allowing particulates to settle out of the water column. This increased water clarity could increase predation of fish entering the site from outside areas (i.e. predators now have greater visual range). One type of predator, Centrarchid fish, is strongly associated with SAV and increased Centrachid populations may create a population sink for native fish at this location, as discussed in N1b, below. In summary, this action will worsen conditions beyond that of baseline conditions and small to moderate fractions of all the covered fish species may experience highly significant but localized effects due to SAV.

Certainty: 2- Low
There is high uncertainty about the initial colonization and ultimate patch distribution of SAV on the substrate. As the substrate softens over time, it may be more conducive to SAV establishment and growth (i.e. bed characteristics are described as a driver in the conceptual model). It is well documented that the physical structure of SAV facilities slower water velocities which allows sediment particles to settle, thereby reducing turbidity, locally and creating a positive feedback loop for more SAV establishment (Anderson, In Preparation). The effect of specific restoration site substrate, how those substrates may change over time after restoration, and the role of flow velocity at these locations is not well understood. The uncertainty of this outcome is largely dependent on how the final marsh system functions (Anderson 2007). If the western Delta becomes brackish to the extant that Suisun Marsh is today, this may change.

N1b: Non-native Centrarchids

General Observations: Centrarchid fish, as an assemblage, cover a range of ecological niches in the Delta. They are competitors for resources as well as predators on native fish. The magnitude of this effect is dependent on the assemblage of centrarchids that invade and the size of the populations. This is in turn partially dependent on the amount of SAV invasion into the restored system.

Please note that establishment of centrachids reduces the certainty that the positive outcome, P1 will occur. This has been noted in the scoring for P1. The relationship among drivers and outcomes is described by Brown and Minchniuk 2007, Grimaldo et al 2004, Nobriga and Feyrer 2007, and Nobriga et al 2005.

Magnitude: 4 - High
For this outcome, the baseline condition is that much of the existing 21,600 acres of tidal marsh are excellent habitat for Centrarchid fish where they are associated with adjacent deeper water. This is illustrated by the large number of Bass Tournaments that occur in the Delta. The Delta is a stop on the national professional bass fishing circuit with $100,000 prizes. This action could worsen conditions beyond that of baseline. Centrachids are a concern because they prey upon and compete for food and other resources with native covered fish.

The establishment of Centrarchids in conjunction with SAV is well documented in the Delta (Brown and Michniuk 2007; Grimaldo et al. 2004; Nobriga and Feyrer 2007; Nobriga et al. 2005). Centrarchid fish, as an assemblage, cover a range of ecological niches in the Delta. They are competitors for resources as well as predators on native fish. The magnitude of this effect is dependent on the assemblage of Centrarchids that invade and the size of the populations. This is in turn partially dependent on the amount of SAV invasion into suitable habitat areas of the restored system. The extent of their impact on the native ecology of the restored marsh is partially dependent on the extent of SAV establishment and patch size. Centrarchid fish will become established in this area as they have everywhere else in the Delta. If the western Delta becomes brackish to the extant that Suisun Marsh is today, this may change.

Certainty: 2 - Low
It is highly probable that Centrarchid fish will become established on this restoration site. However, once established, the ultimate size of the centrachid population and their impacts to local native fish are less certain. In areas with low SAV patch size the numbers of Centrarchid fish and their presumed impact on native fish are lower then where the opposite is true (Brown and Michniuk 2007). If the western Delta becomes brackish to the extant that Suisun Marsh is today, this may change.

N1c: *Corbicula*

General Observations: The relationship between drivers and outcomes is described in the DRERIP *Corbicula* Conceptual Model (Thompson et. al., In revision).

Consequences of *Corbicula* establishment. If established, *Corbicula* would likely have a significant effect on food web dynamics because it consumes phytoplankton in shallow areas and/or consumes the productivity of shallow areas exported to channels to such a high extent that it exhibits top-down trophic control. *Corbicula*'s consumption of primary productivity represents a significant limiting factor throughout the Delta that could greatly reduce productivity benefits of restoration efforts (Thompson et. al., In revision). According to the *Corbicula* model (Thompson et. al., In revision page 11), no local studies have been undertaken to indicate whether *Corbicula* feeding has reduced zooplankton populations either through competition or direct predation. In this case, the baseline condition is that much of the Delta is infested with *Corbicula*. The restoration of tidal marsh which may also become infested with *Corbicula* at some future time would not represent a significant change above baseline conditions. Establishment of *Corbicula* would however, consume much of the positive benefits that were previously discussed above under positive outcomes.

Potential Control Options. There are no stressors identified that can limit the success of Corbicula in a significant manner. However, salinity can limit the spatial distribution of this species and food limitation is a source of stress. (Thompson et. al., In revision, pages 8 and 13). The *Corbicula* conceptual model indicates that the only meaningful method to control their presence/abundance is salinity. This control method would require salinity intrusions into the restoration area of sufficient duration and at the appropriate times of year to have a meaningful effect. The conceptual model does not specify the duration and timing which might be most effective during recruitment. Water temperatures may influence the effectiveness of both recruitment and control measures.

Magnitude: 1- Minimal
Corbicula can control phytoplankton biomass development in shallow areas, or consume the productivity of shallow areas exported to channels. Corbicula is a significant limiting factor throughout Delta (Thompson et. al., In revision).

Certainty: 2 - Low
The timing and extent of colonization by *Corbicula* cannot be predicted for specific restoration sites due to lack of data.

Corbicula are prolific reproducers and colonizers of newly available habitats in salinities below 2 ppt. Source populations can come from elsewhere within the Delta or from upstream tributary populations. *Corbicula* can establish on soft and hard substrates and on vegetation and they can colonize intertidal zones as well as deeper water. (*Corbicula* model). Based upon the biology of the species and the physical setting of the restoration site, the probability of *Corbicula* establishment in the West Delta restoration areas appears to be high, but ultimately cannot be predicted, partially due high variability in environmental conditions. The low certainty score considers the probability and extent of potential establishment.

Corbicula monitoring data from previous restoration sites in the Delta, such as Liberty Island or Little Holland Tract, would provide greater information about the probability of colonization on these west Delta sites. More information would improve the certainty rating. However, such data and analysis was not made available to the evaluation team.

N1d: Inland Silversides

General Observations

Inland silversides (*Menidia beryllina*) are highly tolerant of warm water, salinity variability and are trophic generalists compared to Delta smelt (Moyle 2002). Inland silversides are the most numerous fish in Suisun Marsh shoreline habitats (Matern et al. 2002), and the most numerous fish in shallow Delta habitats (Nobriga et al. 2005, Brown and May 2006). The Delta smelt model (Nobriga and Herbold, page 3) includes intraguild competition with inland silversides as one of the top five in-Delta stressors to Delta smelt. Inland silversides are thought to be a major predator of Delta smelt eggs (Bennett and Moyle 1996 and Bennett 2005 in the Delta smelt Conceptual Model pg 12). In the laboratory, inland silversides reduce Delta smelt size relative to controls when they are reared together (Bennett 2005).

Inland silversides are also treated in the longfin smelt model. Moyle (2002, in Rosenfield, 2008) suggested that based on timing of arrival in the Estuary and subsequent longfin population response, inland silverside might have had a major impact on longfin population dynamics. However, the model states that inland silverside prefer shallow water habitats where juvenile and sub-adult longfin are rare, thus, their impact as predators of juvenile and sub-adult longfin is probably slight (Rosenfield, 2008, pg. 17). Spawning locations for longfin are unknown, so it is not known whether competition from inland silverside for spawning territory is a factor in their decline.

However, Delta smelt evolved with other intraguild competitors, including longfin smelt, and have survived with striped bass (introduced in 1879). Interaction between silversides and Delta smelt in the wild may be limited because Delta smelt typically inhabit offshore environments, while inland silversides typically inhabit shoreline habitats. Increased shoreline habitat would presumably increase the carrying capacity for inland silversides. However, predator-prey interaction between Delta smelt and inland silversides in the wild is speculative. Silversides may eat Delta smelt eggs or larvae if the eggs and larvae occur on the shorelines. It has not been shown that inland silversides reduce calanoid copepods (Norbriga and Herbold, 2008, page 32), so they may not effectively compete with Delta smelt for prey.

Williams and Rosenfield, In preparation; Israel and Klimley, 2008; Kratville**,** 2008); and Israel et. al., 2009 do not mention inland silversides so this evaluation assumes no adverse effects and focuses its evaluation on Delta smelt and longfin smelt.

Magnitude = 2 -Low
Inland silversides are the most abundant fish in shallow-water habitats in many areas of the Delta and may currently contribute to local depletions of zooplankton otherwise available to native fishes within these areas. Additionally, they may prey on embryos of species that lay eggs in these shallow areas (Moyle 2002). The crash of Delta smelt populations coincided with invasions of inland silversides into the estuary (Bennett and Moyle 1996). This action may change conditions relative to baseline by attracting (via restored marsh) a nuisance (inland silversides). This conservation measure will increase the local inland silverside population by providing additional shoreline breeding habitat. Because of the high existing abundance of inland silversides, the incremental increase in breeding habitat and thus population size above current conditions is considered small and the magnitude of this effect is considered to be low relative to baseline. Further, differential habitat selection (offshore environments for inland silverside) is expected to reduce the interspecific competition effects.

Certainty = 2 – Low
Understanding of interaction between inland silversides and Delta smelt in the wild is low, particularly in regards to egg predation by inland silversides. Better data on where and when Delta smelt lay their eggs would better allow us to assess the potential impact of inland silverside predation. Spatial interactions with longfin smelt are also uncertain.

Outcome N2: Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A – Covered fish species, N2-B, Non-covered wildlife species, N2-C, Human health.

N2a: Covered fish species

General Observations: methyl mercury: The relationship between drivers and outcomes is supported by (Alpers et. al., 2008, Table 2 and associated text). Although current methylmercury levels on Liberty Island (analogue for future state of areas to be restored) are relatively low (Slotton et al. 2002, (Alpers et. al., 2008, figure 5), there is potential for enhanced production of methylmercury in areas of high marsh that will be inundated infrequently (only during highest tides). The process of drying out between wetting events tends to oxidize species of sulfur, iron, carbon, and mercury, leading to higher potential to form methylmercury upon rewetting. Once formed, methylmercury biomagnifies in the aquatic food web, and ecological effects may occur in some sensitive species. Thus, the specific geomorphology of restoration sites and in particular the degree to which shallow depressions and poorly drained areas of high marsh are part of the restoration projects directly influences the degree of mercury methylization.

General Observations, other contaminants

Past land use determines risk of other contaminants: lead risk in areas with significant hunting, e.g., pheasant farms or duck clubs. Risk of residual pesticides (e.g., pyrethroids) in areas used for agriculture in past 2 years, which suggests that if these pesticides were used, allowing for a 2 year lag period between application and tidal restoration would be a prudent mitigation measure. Selenium contamination from the San Joaquin Valley and other sources is also a concern, however it was not evaluated in this worksheet.

Magnitude: 1 - Minimal

No toxicological studies have been conducted with any of the covered species regarding acute toxicity. Mercury concentrations in target fish are compared here against concentrations producing mortality in other fish species. Mercury concentrations in covered fish species are compared here against concentrations producing mortality in other fish species. Mercury concentrations in ppm-wet weight for white sturgeon, Chinook salmon and Steelhead collected during 2006 were 0.165-0.279, 0.094-0.396 and 0.06-0.13, respectively (Melwani et al. 2007). No tissue data for either longfin or Delta smelt was found. It is assumed that both species will have tissue concentrations similar to other fish taxa living one year and feeding primarily on zooplankton. Mercury concentrations in juvenile threadfin shad and juvenile largemouth bass in the Delta are 0.012-0.076 and 0.035-0.230, respectively (Slotton et al., 2006). In comparison death in rainbow trout in laboratory studies occurred at 4-ppm wet weight and the NOAEC for death in Brook trout at 2.7 ppm (in Wiener and Spry, 1996). In conclusion, there exists about a 10X safety factor between fish tissue concentrations in the Delta and values reported to cause mortality in lab studies.

Regarding chronic toxicity, again no toxicological studies with any of target species. Therefore, have compared reported tissue concentration for individual species against known laboratory effects in other taxa. Decreased feeding efficiency and some hormones response changes observed at 0.25-0.27 ppm wet weight (page 30 of (Alpers et. al., 2008). Decreases in growth occurred in fathead minnows at 0.6-0.7 ppm Hammerschmidt et al., 2002) and in juvenile walleye at 2.4 ppm (Friedmann et al., 1996). In conclusion, some up/down regulation of genes and alterations in feeding behavior are possible in the most contaminated individuals.

Certainty: 2 - Low

Scientists have a low certainty that the magnitude of this outcome is minimal (i.e. magnitude may be higher). The uncertainty is due to the limited amount of tissue data that is currently available for most target species (large safety factor regarding acute toxicity), which makes it impossible to determine the proportion of population potentially at risk. Additionally, only limited toxicological data is available for most of the important sub-lethal processes and none of this has been collected on species of interest.

N2b: Methyl mercury, non-covered species

General Observations: The relationship between drivers and outcomes is described in the DRERIP Mercury Conceptual model (Alpers et. al., 2008, Table 2 and associated text).

Magnitude: 3 - Medium
Fifty-eight percent of Forster's terns in San Francisco Bay are at risk of reproductive impairment from consuming fish with elevated mercury levels (Ackerman *et al*., 2008). No Forster's Terns nest in the Delta. However, mercury levels in small fish consumed by terns are higher in parts of the Delta such as the Yolo Bypass than in San Francisco Bay suggesting that other bird species filling the Forster's tern niche in the Delta may be at risk. Mercury contamination may result in a possible sustained, minor population effect on a large area.

In laboratory studies, mink have reproductive failure and die when fed fish diets of 0.5 and 1-ppm mercury, respectively (Dansereau *et al*., 1999). For comparison, mercury concentrations in 64% of largemouth bass, 23% of white catfish, and 35% of channel catfish caught in the Bay-Delta watershed have between 0.23 and 0.93 ppm mercury (Davis et al., 2006). Expected sustained minor population effect or effect on large area.

Additional studies on rails and other species are described in the evaluation worksheet for Cache Slough #HRCM 4, page 36.

Certainty: 2-3 Low-Medium
Scientific understanding of methylmercury effects on some bird and mammal species is high, based on peer-reviewed studies in the San Francisco Bay Area and elsewhere. However, methylmercury effects on other bird, reptile, and mammal species is unknown. The nature of this outcome is greatly dependent on highly variable ecosystem processes.

N2c: Methyl mercury, Human Health

General Observation: See also results from water quality team.

Magnitude: 2 - Low
Fish consumption advisories for the Delta recommend that children under the age of 17 and women of child bearing age consume no largemouth bass or smallmouth bass, spotted bass or Sacramento pikeminnow, and others should limit their consumption of these species to one meal a month (OEHHA, 2006, 2008a,b). Between 10,000 and 20,000 fishermen in the Delta are presently eating fish with more than 10X the recommended methylmercury and could experience some sublethal mercury poisoning (personal communication, Dr Fraser Shilling). Action could increase mercury content of sport fish.

The probability of increased methyl mercury production and export into the food web is the same as that described above for target and non-target species.

Certainty: 3 - Medium
Uncertain magnitude and direction of change in mercury content of sport fish, although levels are more likely to increase than decrease. For a given increase in mercury content of sport fish, risk to human health is quantified based on peer-reviewed studies (OEHHA, 2008a,b). The number of anglers that would access the project area and what fish they would consume is unknown.

The role of restoration projects under this Conservation Measure in contributing to mercury levels in fish species consumed by humans needs to be explored in relation to other mercury sources for those fish species.

Outcome N3: Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids.

N3a: Covered fish species

General Observation: The relationship between drivers and outcomes is described by the DRERIP Pyrethroids conceptual model (Werner and Oram, 2008, Figure 1).

Magnitude: 1-2 – Minimal - Low

To the extent that pyrethroids or pyrethrins were used in the area to be flooded, significant toxicity could occur within 1-2 years of application. After ~2 years, near-total degradation should occur. DDT and metabolites could cause reduction of insect populations and bioaccumulation in target fish species (and some non-target bird species). Possible presence of legacy pesticides from 1960s (e.g. DDT) is unknown.

Certainty: 1 - Minimal

The toxicity of various pesticides is not completely understood. Although some peer-reviewed studies for selected life stages of certain fish exist, there is not much data for covered fish species. The nature of this outcome is highly dependent on highly variable ecosystem processes affecting the fate (degradation) and transport of pesticides.

N3b: Non covered wildlife species

General Observation: The relationship between drivers and outcomes is described in Werner and Oram, 2008, Figure 1.

Magnitude: 1-2 Minimal - Low
To the extent that pyrethroids or pyrethrins were used in the area to be flooded, significant toxicity could occur within 1-2 years of application. After ~2 years, near-total degradation should occur. DDT and metabolites could cause reduction of insect populations and bioaccumulation in target fish species (and some non-target bird species).

Certainty: 1 - Minimal

The toxicity of various pesticides is not well understood. A limited number of peer-reviewed studies for certain life stages of selected fish species exist. However, there is not much data for covered fish species available (Werner et. al., 2008). The effect that tidal marsh restoration will have on the availability of residual pesticides is greatly dependent on highly variable ecosystem processes affecting the fate (degradation) and transport of pesticides. Additionally, legacy pesticides from 1960s (e.g. DDT) may be present on the restoration site and more recent (illicit) use is unknown.

Outcome N4: Resuspension and export of contaminants to downstream areas (A) mercury and methylmercury, (B) pesticides and herbicides (e.g. pyrethroids

N4a: Covered fish species

Analysis of resuspension affects considers two separate physical settings: the restoration marsh sites and the adjacent tidal sloughs. The restored marsh sites are not likely experience much scour, since the adjacent tidal channels would be excavated as part of construction and the hard farm fields are not expected to scour easily. Adjacent tidal sloughs, which are typically comprised of more erodible substrate, may experience more scour both the bed and banks.

General Observations: The relationship between drivers and outcomes is described in Alpers et. al., 2008 (Figures 4, 7, and 8 and associated text) and Werner and Oram, 2008, Figure 1.

Magnitude: 1 - Minimal

The degree of scouring of pre-project soils depends on hydrodynamics. Scour could be a short-term phenomenon as channels reach geomorphic equilibrium. There is potential for increasing methylmercury concentrations in high-elevation marsh (infrequently wetted zone) and possible export of this to downstream environments.

Certainty: 2 - Low

The nature of this outcome is greatly dependent on highly variable ecosystem processes affecting fate (e.g.photodegradation of methylmercury) and transport.

Outcome N5: Movement of fish and food resources to areas in central Delta with high predation.

N5. All covered Species

General Observations: Current water operations move fish into the central Delta (not just the pumps) and this indicates this West Delta ROA could become a population sink resulting in the movement of fish and food resources to areas with high predation. A logical train of thought links the DLO relationship here. This issue is beyond the scope of the current DRERIP conceptual models.

Magnitude = 2 to 3; Low - Medium

Salmon fry do enter the central Delta through the Delta Cross Channel and Georgiana Slough and salmon smolt survival in the Central Delta is lower than in the mainstem of the Sacramento River (Brandes and McLain 2001). Currently, juvenile Chinook salmon that enter the central Delta show lower survival rates than juveniles that stay in the main stem of the Sacramento River (Brandes and Mclain 2001). The exact reasons for this are unknown: however local conditions (e.g. changed hydrology, predatory fish) are the most likely causes. Vogel (ERP 2004) showed that predation rates on Chinook salmon in Georgiana Slough were 82.1% verses the lower Sacramento main stem at 25%. Increased temperature in the Central Delta where flows are low may also be a contributing factor in lowered survival of both salmon and Delta smelt during certain times of the year. How this will change under proposed operations is unclear. If predation remains the same or worse under post-restoration conditions, if altered hydrological conditions continue, and if covered fish are attracted to this area, than lower populations of covered fish may result (as opposed to the hoped for higher populations of covered fish).

Certainty = 1 - Minimal

Certainty is minimal because it is difficult to predict in advance future predation levels in this ROA, future hydrological conditions, and behavioral patterns of covered fish.

Important Gaps in Information and/or Understanding

Data needed to more fully evaluate tidal marsh restoration actions

- Residence times (average and spatial variance in that value) are necessary to determine how much and what kind of food would be produced on site and exported from the site. Residence time projections also affect temperature and dissolved oxygen conditions and these are important attributes of physical habitat. Finally, residence times for particles of water could inform assessment of "residence" times for fish. There is a non-linear relationship between fish "residence time" and the benefit of the rearing habitat as, at high "residence times" new habitat may serve to delay important migratory activities whereas at very low residence times, the new habitat will have reduced benefit because fish (or at least those that behave like particles) will experience the habitat for only a short period.
- Centrarchid models to understand predator-prey-habitat interactions.
- Striped bass model to understand predator-prey-habitat interactions.
- Expected retention time on restored tidal areas to understand likely productivity and food export potential to local sloughs.
- More spatially comprehensive hydrodynamics to understand whether changed flow patterns will reduce or simply redistribute predator pressure.
- Hydrologic and sediment information about turbidity levels, duration, and consequences on species as related to the following: Increased ability for Delta smelt to locate food due to increased turbidity from increased velocities in larger channels.
- *Corbicula* monitoring data from previous restoration sites in the Delta, such as Liberty Island or Little Holland Tract, would provide greater information about the probability of colonization on this site.
- Better data on where and when Delta smelt lay their eggs would better allow assessment of the potential impact of inland silverside predation.
- Analysis of factors contributing the success or failure of other past tidal marsh restoration actions in the Delta.
- Liberty Island is often referred to as a model of a successful restoration project. Monitoring data and new bathymetric data from Liberty Island should be fully analyzed to determine the features that makes it successful and to consider how to apply those features to other restoration projects in the Delta. Specifically, the bathymetric data could be turned into a Digital Elevation Model (DEM) and combined with the habitat type mapping (i.e. vegetation and open water) to illustrate how the restoration provides habitat for covered and other species. This would include documenting the quality of existing LiDAR data for the vegetation mapping.

Research Needs

- Restoration techniques that will prevent colonization by invasive species.
- Management practices that can control invasive vegetation, clams, and predators (centrarchids and inland silversides) and limit colonization of these sites.
- Run (and life-history) specific studies of Central Valley Chinook salmon and studies of steelhead use of tidal marsh habitats would be extremely valuable to defining magnitude of impacts to these populations and increasing certainty. Various tools (including genetic markers and otolith signatures of population origin) could be used to asses both growth and survival of salmonids in these habitats as well as changes in life history

characteristics (survival and fecundity) over the course of the life cycle that arise from residence in tidal marsh habitats. Currently, all of the evidence for benefits of tidal marsh on salmonids comes from steelhead and fall run populations well to the North (where high temperatures and invasive predators are not as problematic). Translating these results to all CV salmonid populations is unwarranted and could lead to disastrous "restoration" projects. In addition, data on nutrient flow from the marsh plain to juvenile fish rearing in the adjacent channels, is essential to determining the value of restored marshes as a food source for larvae of pelagic fish (like longfin and Delta smelt).

- Future research should generate simulations of generic "applications" of the DRERIP Conceptual Models. For example, the temperature model could be "applied" to generic landscape characteristics, such as a restoration site with specific shapes (bowl or gradation), to consider how temperature dynamics are affected on various spatial and temporal scales. This exercise would help managers understand where further detail is needed by taking the conceptual models to the next level by conducting simulations to apply the concepts to a landscape.
- Data on nutrient flow from the marsh plain to juvenile fish rearing in the adjacent channels, is essential to determining the value of restored marshes as a food source for pelagic fish larvae (i.e. longfin and Delta smelt).
- Evaluate the effectiveness of water management strategies on managed wetlands to reduce the production of low dissolved oxygen events associated with managed wetlands operations and transfer what is learned into best management practices for the broader managed wetlands community in this region. In addition, it is likely the reduction of low DO events will result in conditions less favorable for MeHg production and thus reduce MeHg loading to the surrounding aquatic environment. This hypothesis needs testing.
- Greater understanding and more research is needed about the availability and production of food in tidal marshes. Export of organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta has not been studied.
- Potential negative effects of methylmercury exposure on covered fish species remain largely unknown. Based on published studies involving other (non-targeted) fish species, there is reason for concern regarding possible chronic effects caused by methylmercury exposure, including: endocrine disruption, reduced reproductive success, reduced predator avoidance, and reduced feeding efficiency. (See Mercury Conceptual Model, Alpers et al. 2008, Table 4, page 30). Research is especially needed to determine possible effects caused by exposure during early life stages.
- A better understanding is needed regarding the relationship of mercury methylation to the duration of wetting and drying events in areas that are intermittently inundated (i.e. tidal marsh and floodplain). Laboratory and field studies of mercury cycling involving sediments in tidal marsh and floodplain environments should quantify the duration of drying time and the extent of dryness necessary to change the oxidation-reduction character of iron, sulfur, carbon, and mercury in sediments such that microbial activity associated with mercury methylation is enhanced.
- Tropho-dynamic model of ecological interactions linking primary production to the food web structure and production flows into, through, and out of the tidal marsh system.
- Landscape-level models that address the effects of variation in structural features of the tidal marsh environment (e.g., tidal channel complexity, channel width, channel length, edge: area ratios, etc.) on the population or production dynamics of specific plants and animals.

Assess Reversibility and Opportunity for Learning

Reversibility

No/Hard. The following on-the-ground actions would be needed to reverse this action:
1) levees would need to be reconstructed
2) newly created tidal sloughs would have to be regraded
3) sites would have to be dewatered
4) wetland vegetation would have to be removed
5) newly installed levees would need to be removed as necessary
6) monitoring pre, during, and post construction

Although this reconstruction is technically possible, there would be significant financial and regulatory costs. Prior to action reversal, the following planning activities would be needed:
1) geotechnical evaluations for levee reconstruction
2) engineering design
3) evaluate land use options for areas subject to subsidence reversal actions
4) environmental permitting and associated agency ESA consultation
5) Mitigation planning

Opportunity for Learning

High: Implementation of this project can be designed such that different engineering designs can be compared. Numerous physical and biological components can be monitored and ideally, the monitoring data would be used to assess and refine modeling simulations of the restoration as a part of a comprehensive adaptive management program.

See text in the Evaluation Worksheet for HRCM 4 –Cache Slough Tidal Marsh Restoration for details.

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Appendices

Appendix A: Summary Tables Organized by Outcome

Table 3. Positive Outcomes

Outcome	Magnitude	Certainty
P1a. Increase rearing habitat (physical and biotic attributes) area – spring run	2	1
P1b. Increase rearing habitat (physical and biotic attributes) area. – Fall run salmon.	2	2
P2a: Provide a continuous corridor of habitat and food productivity… Splittail	3	3
P2b: Provide a continuous corridor of habitat and food productivity … Green Sturgeon.	2	1
P2c: Provide a continuous corridor of habitat and food productivity … White sturgeon.	2	1
P3: Increase the availability and production of food in the western Delta and Suisun Bay by exporting, via tidal flow, organic material from the marsh plain and organic carbon, phytoplankton, zooplankton, and other organisms from intertidal channels into the Delta.	Viewpoint 1: 3-4 Viewpoint 2: 1-2	Viewpoint 1: 1-2 Viewpoint 2: 1
P4a: Locally provide areas of cool water refugia for Delta smelt.	2	1
P4b1: Provide local cool water refugia for Spring-run (Feb-Jun).	2	1
P4b2: Provide local cool water refugia for fall-run (Feb-Jun).	2	1
P4b3: Provide local cool water refugia for steelhead.	2	1

Table 4. Negative Outcomes

Outcome	Magnitude	Certainty
N1a: Establishment of undesirable species …. Egeria and SAV	3	2
N1b: Establishment of undesirable species …….. Non-native Centrarchids.	4	2
N1c: Establishment of undesirable species …….. Corbicula	4	2
N1d: Establishment of harmful Inland silversides	2	2
N2a: Potential for mercury methylation and local bioaccumulation … Covered fish species.	1	2
N2b: Potential for mercury methylation and local bioaccumulation Other species (not covered).	3	2 to 3
N2c: Potential for mercury methylation and local bioaccumulation … Human health.	2	3
N3a: Local effects of contaminants including toxicity from residual pesticides and herbicides …. Covered fish species	1 to 2	1
N3b: Local effects of contaminants including toxicity from residual pesticides and herbicides … Other species (not covered).	1 to 2	1
N4a: Resuspension and export of contaminants to downstream areas … covered fish species.	1	2
N5: Movement of fish and food resources to areas in central Delta with high predation creating a population sink.	2 to 3	1

Appendix B - Outcomes With Zero Magnitude

OP3a: Increase rearing habitat (physical and biotic attributes) area – Steelhead.

General Observations:
Steelhead juveniles move through Delta from Jan-Jun, but mostly from late March-June. Salmonid model Fig 27. Steelhead Conceptual model figure. The salmonid model indicates value of estuarine rearing varies across populations: (p15).

Magnitude = 0 (zero).
Outcome assumes that "rearing habitat area" (quantity) and/or food is limiting. Model txt (p16)"Spring Chinook, or at least the Butte Creek population, pass quickly through the Delta, so habitat restoration there seems unlikely to do much for them. The same is probably true for late fall Chinook, and for steelhead." In other systems, steelhead use this kind of habitat but, the text notes, steelhead smolt in this system are large compared to other systems so research there is not likely to apply here.

Steelhead will eat the types of food produced in this habitat. Conceptual model (Estuarine – growth) shows a low impact of this kind of habitat on competition – competition may have a moderate impact on growth.

Steelhead migrate through this area "mainly in April and May" (Salmonid model P 34.) Average daily water temperatures in the vicinity of this restoration (as indicated by those at IEP monitoring station RSAC 101) regularly exceed 20-21oC (beyond which sublethal effects accumulate; Reese and Harvey 2002 *and see* Richter and Kolmes 2005) from May-September. With warming that may occur under climate change, these temperatures will occur in this area with some frequency during April and October as well. Thus, steelhead rearing in this proposed restoration site during May, June, and July will probably be impacted by high temperatures and negative impacts could become more common with global warming. Restoration will impact only steelhead from Sacramento Basin.

Certainty = 3 - Medium
No direct research on use of shallow estuarine habitat by steelhead in this system. Any effect will be limited to the Sacramento population and to those times of year when temperatures are not too high in the target area. This is relatively small restoration and presupposed the restoration of larger habitats nearby (as in the habitat "corridor" concept identified in the initial outcomes) – thus, it's marginal value as habitat for emigrating steelhead is likely nil. We can be moderately certain that this outcome will have a negligible or zero impact on the steelhead population as a whole.

In summary, steelhead in this system are not believed to be limited by availability of estuarine rearing habitat, except for the impact of high temperatures, which this restoration will do nothing to alleviate.

OP3b: Increase rearing habitat (physical and biotic attributes) area - Winter-run Salmon

General Observations:
Winter-run juveniles move through the Delta in the winter and early spring (figure 3). The salmonid model indicates value of estuarine rearing varies across runs: (p15). The scoring presented below assumes that this restoration action only occurs when/if other tidal marsh projects in the Sacramento "corridor" are "restored" as well.

Magnitude = 0.
Outcome assumes that "rearing habitat area" (quantity) and/or food is limiting. Model txt (p16)"Spring Chinook, or at least the Butte Creek population, pass quickly through the Delta, so habitat restoration there seems unlikely to do much for them. The same is probably true for late fall Chinook, and for steelhead. The case for winter Chinook seems equivocal.".
Winter-run will consume the types of zooplankton produced in this restoration (under the assumed condition). All winter-run migrate through this area when temperatures are cool enough to support rearing.

The DRERIP Conceptual model shows a moderate impact of this kind of habitat on competition – competition may have a moderate impact on growth – but both of these impacts are speculative. Food limitation is not considered a major limitation on survival in this part of the life cycle. Winter-run have the smallest population of any Chinook salmon run in this system. They have access to the same estuarine habitats as the other runs. Thus, competition and growth limitation due to habitat limitation in the Estuary is least likely for this run among all the Central Valley Chinook populations. In addition, this run rears upstream and probably enters the Estuary at a size where rearing in the Estuary is less important (p. 12, Figure 9).
Finally, the figure depicting relative impact of stressors across habitats indicates that upstream impacts are more likely to be important and that stressors in the Estuary are related to stressors other than limitation of habitat. Given the limited size of this restoration and the implicit assumption that it is implemented along with other, larger tidal marsh restorations, the marginal impact of this restoration is probably neglible or zero.

Certainty = 3 - Medium
Winter run represent a unique life history strategy for the species as a whole. No direct studies of this run's habitat use in estuarine habitats has been published meaning that their use and benefit from tidal marsh habitats is uncertain. However, unless access to additional spawning/rearing habitats (with adequate cold water and spawning gravel) is created upstream, rearing habitats in the Delta will be of little value to this species. Given this CM's small size and assumed (by the Proponents) positioning among other CM habitats and the lack of evidence of food limitation in this part of the life cycle, we are moderately certain that the magnitude of the outcome for this run will be negligible.

In summary, the most important actions necessary to conserve and restore winter run lie outside of the Delta. The small scale of this restoration combined with the lack of evidence that this run is limited by habitat in the estuary mean it is not likely to have a measureable impact on the short, medium, or long-term prospects for this species.

OP3c: Increase rearing habitat (physical and biotic attributes) area. - Late Fall-run Salmon

General Observations:
Late-fall-run juveniles move through the Delta in the fall and winter (figure 3). The salmonid model indicates value of estuarine rearing varies across runs: (p15). The scores presented below assumes that this restoration action only occurs when/if other tidal marsh projects in the Sacramento “corridor” are “restored” as well.

Magnitude = –0.
Outcome assumes that “rearing habitat area” (quantity) and/or food is limiting. Model txt (p16)”Spring Chinook, or at least the Butte Creek population, pass quickly through the Delta, so habitat restoration there seems unlikely to do much for them. The same is probably true for late fall Chinook, and for steelhead”.

Late fall-run will consume the types of zooplankton produced in this restoration (under the assumed condition). Most late-fall run migrate through this area when temperatures are cool enough to support rearing. {See Salmon Model Williams and Rosenfield version dated November 2008 Figure 2d entitled “Sacramento Late-fall run life history – Late Fall Run located on page 108 of the pdf file. See also graph called “Late-fall run growth and emigration rate -- estuarine habitats” on page 115 of pdf file. Graph formerly called (General Model figure 3) of Rosenfield 2007.}

Conceptual model indicates that estuarine growth shows a low impact of this kind of habitat on competition and of competition on growth. This is because the late fall run migrates at larger size than many other runs, its migration coincides with winter run (See Salmon model graphs described above), and temperatures and flows during this period increase accessibility to potential rearing habitat meaning these fish do not need to compete (e.g. with the much more populous fall run) for rearing habitat in the estuary.

The figure depicting relative impact of stressors across habitats indicates that upstream impacts (e.g. access to spawning habitats) are more likely to be important and that stressors in the Estuary are uncertain.

Certainty = 3 - Medium
The importance of growth in estuarine environments is unstudied for this run but is likely to be small. Conceptual model indicates low certainty of impact. Given the limited size of this restoration and the implicit assumption that it is implemented along with other, larger tidal marsh restorations, the marginal impact of this restoration is probably negligible or zero.

In summary, the most important actions necessary to conserve and restore late-fall run lie outside of the Delta. The small scale of this restoration combined with the lack of evidence that this run is limited by habitat in the estuary mean it is not likely to have a measurable impact on the short, medium, or long-term prospects for this population.

Salmonids migrate through the Sacramento River corridor on their way to and from marine environments (Salmonid conceptual model).

OP4. Provide a continuous corridor of habitat and food productivity linking current and future restored habitat in the Cache Slough Complex with habitat in Suisun Marsh and Bay. - Salmonids

Salmonids migrate through the Sacramento River corridor on their way to and from marine environments (Salmonid conceptual model).

There is no mention of (or a conceptual model to support) the benefit of a "corridor" or rearing habitat. Rearing habitat has benefit but the benefits of providing a "continuous corridor" of productive rearing habitat are unsupported in the conceptual model or the literature. The concept of a corridor (which implies habitat beneficial for the movement of organisms between valuable habitats) is misapplied here because the idea is to provide "rearing habitat" not to facilitate movement between habitats. Therefore, this proposed outcome cannot be vetted for salmonids– the anticipated magnitude of the "corridor" or rearing habitat is zero.

Emigrating salmon are trying to achieve two goals – growth and migration. Growth is valuable only up to a certain point, then migration rate is of paramount importance because salmon reach a size where they will have more productive growth in the ocean than in freshwater. A conceptual model of growth: migration trade-offs of this type is supported by evidence on growth of salmon in this estuary (Macfarlane and Norton 2002 – which found a relatively consistent size of salmon smolt entering the ocean over the time period of sampling) and other sources on growth-migration tradeoffs in salmon LH (e.g. Williams 2006 and Quinn 2005). Under this conceptual model, salmon would be expected to grow as rapidly as possible until a size or time threshold (whichever came first) prompted them to migrate. Salmon do not require continuous rearing habitat throughout the migration process – indeed, presence of this habitat may impede migration rates. It is only beneficial to find a rearing habitat, rear in it until the time or growth threshold is reached, and then migrate as rapidly as possible to the more productive marine environment.

In summary, even if the continuity of rearing habitats provides benefits, such continuity would be at the margin of priority (compared to the potential value of the habitat itself and other needs of these species). No future studies or research is recommended for this issue.

OP5a: Locally provide areas of cool water refugia for winter-run salmon.

Magnitude = 0- Zero.
There will be no benefits of this restoration to winter-run salmon because this run passes through the region during a window of time when temperatures are not believed to be highly stressful to salmonids.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

OP5b: Locally provide areas of cool water refugia for late fall-run salmon.

Magnitude = 0- Zero.
There will be no benefits of this restoration to late fall-run salmon because this run passes through the region during a window of time when temperatures are not believed to be highly stressful to salmonids

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

Appendix C - General Information about the West Delta Sub-Areas

Sub-Area Name	***Total size of Island***	***Location and Existing Conditions***	***Previous Restoration Nearby***
1. Decker Island	470 acres	Island is surrounded by the Sacramento River to the northwest and Horseshoe Bend, a former meander of the Sacramento River, to the east, south, and west. Decker Island is the only high-elevation island in the Delta, as it was built by sediment dredged to straighten the Sacramento River at this location.	Yes. For more details see: http://www.water.ca.gov/floodmgmt/dsmo/ecb/maep/deckerisland/ Has exhibited some of the most undesirable restoration outcomes – large channels with minimal tidal floodplain area resulting in very low velocities which support thick SAV beds and their associated problems.
2) Sherman Island (north end)	1,000 + acres. DWR has plans to acquire most of the property on this island.	Northern end of Sherman Island, bordered by Horseshoe Bend on the west, Three Mile Slough on the north and east, and remainder of Sherman Island to the south. The northern extent of Sherman Island is subsided in the interior portions away from the levees by up to roughly 20 feet, with the levee interior slopes being much higher and more gradually sloping down to the deep interior than at many Delta islands.	Yes. (1) DFG owns the tidal western 3,115 acres at the confluence of the Sacramento and San Joaquin Rivers that breached in the 1920s. (2) DWR funded 4,500 feet of levee setback via RD 341 and restored intertidal channel margin and wetland, Mason's lilaeopsis, and augment existing riparian vegetation. For more details see: http://www.water.ca.gov/floodmgmt/dsmo/ecb/maep/shermanisland.cfm. See also: http://www.water.ca.gov/floodmgmt/dsmo/ecb/maep/mayberry.cfm
3) Bradford Island (west side		Bradford Island lies about 10 miles east of the confluence of the Sacramento and San Joaquin rivers. Bradford Island has 7.4 miles of levees. Located South of Twitchell Island. Fisherman's Cut splits Bradford Island from Webb Tract.	Tract 19 was previously restored by reclamation district as riparian floodplain on subsided lands behind a levee. For more details see: http://www.water.ca.gov/floodmgmt/dsmo/ecb/maep/bradfordisland.cfm and see:

		The restoration site has a mix of higher and lower elevation lands down to about -20 ft and includes what appears to be older mineral deposits from riverine conditions extending in fingers quite a distance to the east onto Webb Tract.	http://www.stillwatersci.com/case_studies.php?cid=44 Aerial Photo at: http://www.water.ca.gov/floodmgmt/dsmo/ecb/maep/bradford.cfm and at: http://www.sacbee.com/1276/gallery/1462198.html?mi_rss=Delta%20Galleries Photos available at: http://www.water.ca.gov/floodmgmt/dsmo/docs/Apx_F-1_Bradford_photo_log.pdf
4, 5, and 6) Twitchell Island	300-400 acres of the island; about 85% owned by DWR.	Located on the San Joaquin River just east of Sherman Island. Three Mile Slough borders to west. Seven Mile Slough border north and east. ROA focuses on the least subsided bench along the levee interior, where elevations are in the medium subtidal to lower intertidal range.	Yes. . For more details see: http://www.water.ca.gov/floodmgmt/dsmo/ecb/maep/twitchellisland.cfm See also: http://www.geiconsultants.com/content505.html See Aerial Photo at: http://www.water.ca.gov/floodmgmt/dsmo/ecb/maep/twitchell.cfm
7, 8, and 9) Brannan Island – A (north shore, across Sacramento River from Grand Island) and Brannan Island – B (west shoreline), Brannan Island – C (between Three Mile Slough and		Located on the southern bank of Sacramento River where it meets Cache Slough and extends south to Three Mile Slough. As above, ROA focuses in strip of levee interior bench that is less subsided than levee interior. Brannan C is the Brannan Island State Recreation Area with campgrounds and boat	? Part of Island is a state recreation area. For more details see: http://www.parks.ca.gov/?page_id=487

Sacramento River.		launch ramp, not a likely restoration candidate.	
10) West Bank of Sacramento River (across from Brannan Island and Decker Island	~200 acres	South of Rio Vista and extending southwest across almost from the western confluence of Sacramento River and Horseshoe Bend. Lands are diked historic margins of the lower Sacramento River. Long, narrow strips of landscape. Elevation data not readily available.	
11) Grand Island (southwestern tip	~150 acres	Located at the confluence of Steamboat Slough and Sacramento River near Rio Vista. Lands appear to be out of agricultural production and coarse elevation on ROA map (Figure 1) indicates in or near to intertidal elevation ranges. Grand Island Road forms natural eastern boundary and location for setback levee (road may already be raised).	
12) Dutch Slough	1,100 acres	Along southern bank of Dutch Slough between Big Break to the West and Jersey Island Road to the east, in Oakley. Site topography ranges from upland, intertidal, shallow subtidal, and some medium subtidal.	The Dutch Slough Tidal Wetland Restoration Project has been in the planning phase for several years. CALFED funds purchased the property in the early 2000s. Draft EIR for restoration project released December 2008. Planned to be an adaptive management restoration experimental site, applying designs to test selected restoration approaches of value for other Delta restoration efforts. May go to construction in 2010.

Appendix D - Excerpt From BDCP Steering Committee November 21, 2008, Handouts #2 and #3

BDCP Steering Committee
November 21, 2008

HANDOUT HABITAT #2

PRELIMINARY DRAFT—FOR DISCUSSION ONLY
Estimated Extent of Lands within Restoration Opportunity Areas that may be Suitable for Tidal Marsh Restoration Area by Elevation Class

Restoration Opportunity Area (ROA)	Area by Elevation Class (acres)										Total
	Upland (>+15 feet)[1]	Transitional Upland 2 (>+3-15 feet)[2]	Transitional Upland 1 (>+3-6 feet)[2]	Sea level Rise Accommoda-tion (>0-+3 feet)[2,3]	Tidal Marsh[4]	Subtidal 1 (<0-3 feet)[4]	Subtidal 2 (>-3-6 feet)[4]	Subtidal 3 (>-6-9 feet)[4]	Subtidal 4 (>-9-12 feet)[4]	Subtidal 5 (>-12 feet)[4]	
West Delta ROA											
Sherman Island A	N/A	7	8	18	94	83	11	3	0	0	224
Sherman Island B	N/A	10	14	13	132	127	15	8	2	0	321
Decker Island	467	13	21	80	40	14	4	1	0	0	640
Dutch Slough A	N/A	62	155	246	271	269	173	51	1	0	1,228
Grand Island	95	24	38	34	31	7	3	1	0	0	233
Brannan Island A	N/A	28	44	43	98	96	45	9	0	0	363
Brannan Island B	N/A	8	16	24	43	47	46	19	3	0	206
Brannan Island C	268	8	10	5	5	3	1	0	0	0	300
Bradford Island	N/A	11	16	24	47	36	28	20	16	11	209
Twitchell A	N/A	0	3	4	25	11	4	2	0	0	49
Twitchell B	N/A	2	4	6	18	47	139	70	30	12	328
Twitchell C	N/A	1	2	4	4	3	4	61	157	16	252
Sacramento River North	423	18	11	8	11	16	9	2	1	2	501
Subtotal	1,253	192	342	509	819	759	482	247	210	41	4,854

HANDOUT HABITAT #3

PRELIMINARY DRAFT—FOR DISCUSSION ONLY

Potential Opportunities for Tidal Marsh Restoration by ROA based on Implementability, Suitability, and Cost (Does not include assessment of covered fish species benefits.)

Restoration Opportunity Area and Land Units	Potential Opportunities for Tidal Marsh Restoration (acres) [1]					
	Very High[2]	High[3]	Moderate[4]	Low[5]	Very Low[6]	Total Potential
West Delta ROA						
Sherman Island A	0	200	10	0	0	210
Sherman Island B	0	0	0	270	20	290
Decker Island	600[7]	4	0	0	0	604
Dutch Slough A	0	0	790	170	0	960
Grand Island	170[7]	0	0	0	0	170
Brannan Island A	0	0	0	237	45	282
Brannan Island B	0	0	0	0	114	114
Brannan Island C	0	280[7]	0	0	0	280
Bradford Island	0	0	0	110	30	140
Twitchell A	0	0	0	40	0	40
Twitchell B	0	0	70	140	0	210
Twitchell C	0	0	10	0	0	10
Sacramento River North	460[7]	10	0	0	0	470
Subtotal	1,230	494	880	967	209	3,780

Appendix E - Background Information Proposed West Delta Restoration Opportunity Areas from BDCP

Excerpt from BDCP Steering Committee Meeting October 31, 2008. Handout #3: Third Draft Habitat Restoration Conservation Measures

Bay Delta Conservation Plan
Steering Committee Meeting
October 31, 2008

Handout #3

Third Draft
Habitat Restoration Conservation Measures

Note to Steering Committee: *This handout presents the third draft of habitat restoration conservation measures. A summary list of proposed habitat restoration conservation measures is presented in Table 1. This draft includes revisions proposed by SAIC—no comments were received from the Steering Committee to the second draft habitat restoration conservation measures presented to the Steering Committee on October 17, 2008. All new text added to this draft from the second draft is displayed in underlined red text; text in black is the same as delivered in the second draft. These draft conservation measures will be discussed at the October 31, 2008 Steering Committee meeting.*

Table 1. List of Proposed Habitat Restoration Conservation Measures

Conservation Measure FIMA1.3: Restore a mosaic of __ to __ acres of intertidal marsh and shallow subtidal aquatic habitat within the West Delta Restoration Opportunity Area. Restored freshwater intertidal marsh and shallow subtidal aquatic habitats would be designed to support the physical and biological attributes described in Attachment A. The mosaic of habitats would include at least __ acres of freshwater intertidal marsh habitat. Areas suitable for restoration include Decker Island, portions of Sherman Island, Jersey Island, Bradford Island, Twitchell Island, and Brannon Island, and along portions of the north bank of the Sacramento River where elevations and substrates are suitable. The purpose of restoring intertidal marsh in the west Delta is to provide a continuous corridor of habitat and food productivity linking current and future restored habitat in the Cache Slough Complex with habitat in Suisun Marsh and Bay and to provide intertidal marsh habitat within the anticipated future eastward position of the low salinity zone with sea level rise.

Design elements of this conservation measure are anticipated to include:

- placing fill material on shallowly subsided restoration sites to raise land surfaces to elevations suitable for restoration of intertidal marsh[3];
- planting tules, or other techniques, to raise ground surface elevations suitable for intertidal marsh restoration on shallowly subsided portions of islands and breaching levees when target elevations are achieved;
- breaching and setting back levees to provide for tidal exchange with restored habitats; and
- excavating channels and/or creating berms to encourage the development of dendritic channel networks within restored marshes.

Rationale: Restoring freshwater intertidal marsh and shallow subtidal aquatic habitats is expected to reduce the adverse effects of stressors related to food and habitat availability for the covered species by:

- increasing rearing habitat area for Chinook salmon, Sacramento splittail, and possibly steelhead (Healey 2001, Brown 2003);
- improving future habitat areas for delta smelt and longfin smelt within the anticipated eastward movement of the low salinity zone with sea level rise;
- increasing the production of food for rearing salmonids, splittail, and other covered species (Kjelson et al. 1982; Siegel 2007);
- increasing the availability and production of food in the western Delta and Suisun Bay by exporting organic material via tidal flow from the marsh plain and organic carbon, phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta (Siegel 2007);
- locally providing areas of cool water refugia for delta smelt (C. Enright pers. comm.);
- increasing the extent of habitat available for colonization by Mason's lilaeopsis; and
- increasing the extent of habitat for California black rail and tricolored blackbird.

Lands within the West Delta ROA (see Figure 1) represent the only location to implement intertidal marsh restorations within the anticipated future location of the low salinity zone with sea level rise. A substantial proportion of the suitable restoration sites in this area are in public ownership.

Recommended Implementation Timeframe: This conservation measure could be initiated in the BDCP near-term implementation period and continue to be implemented over the term of the BDCP as restoration opportunities are identified.

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[3] Sources of fill material could include dredge material from ongoing dredging operations and dredge spoils and sand deposits on Decker Island, Brannon Island, and other nearby suitable sites.

Implementation Considerations: Implementation considerations include:

- the availability of suitable fill material and feasibility for subsidence reversal;
- consideration for the effects of restoration-induced dampening of the tidal range on subsequent marsh restoration designs and local tidal hydrodynamics;
- the need to design levees and provide elevations suitable to accommodate future sea level rise;
- locating and designing levee breaches to maximize the development of intertidal marsh and minimize hydrodynamic conditions that favor non-native predatory fish;
- coordination with Delta levee programs to ensure that restored habitats are protected from adverse effects that could be associated with future levee failures;
- determining the appropriate allowable land uses and management activities on transitional grasslands conserved to accommodate future sea level rise;
- the need to incorporate design features and management strategies to preclude or minimize the establishment and abundance of undesirable non-native species;
- potential for increasing mercury methylation and resuspension of contaminants;
- the need to incorporate design features that will promote the natural establishment of marsh-associated covered plant species; and
- the likelihood for removal of food produced from restored intertidal marshes by non-native clams.

Resiliency to future changes: The resiliency of this conservation measure to accommodate future sea level rise is limited because of the extent of subsidence in the west Delta. It is expected, however, that, to the extent practicable, restoration designs would incorporate elements that would provide land surface elevations sufficient to accommodate the upslope establishment of marsh over time as sea level rises.

Uncertainties/risks: Restoration of subtidal aquatic habitats could result in establishment of *Egeria* and other non-native plants that reduce the ecological benefits for restored subtidal aquatic habitats to covered species. The abundance of non-native predators and competitor abundance could increase and the ability to control these species is uncertain. Methylation of mercury may occur in intertidal zones, making methylmercury bioavailable to plants, fish, and wildlife in and downstream of restored marshes (Alpers et al. 2006). Large scale levee failures, in the central Delta could reduce species and ecosystem benefits associated with restored marshes in the west Delta depending on the effects of changed hydrodynamic conditions on tidal range and salinity gradients in the west Delta. There could be a short-term risk associated with mobilizing pesticides, herbicides, and other contaminants into the Delta following initial introduction of tidal flow onto agricultural lands.

Monitoring and adaptive management considerations: *[Note to reviewers: this section is a general summary; more detail will be provided in future iterations.]* Opportunities for adaptive management are related to assessing the effectiveness of restored marshes to develop as functional covered species habitats and to produce food and organic carbon in support of food web processes. Results of monitoring the development of early marsh restoration projects would help inform improvements in the design and management of subsequent marsh restorations. Results of monitoring early restorations could also be used to develop cost effective management techniques, if needed, to control the establishment of non-native species in restored marshes. Some of the monitoring considerations include:

- type and extent of use by covered fishes;
- extent of phytoplankton, zooplankton, and macroinvertebrate production in marsh channels;
- load of phytoplankton, zooplankton, and macroinvertebrates exported into the Delta and Suisun Bay;
- extent of food produced from restored habitats that are consumed by non-native clams;
- extent of native vegetation relative to non-native vegetation in the restored marsh;
- extent of native relative to non-native submerged aquatic vegetation;
- change in abundance of non-native predatory fish species;
- effects of habitat restoration on salinity gradients in the west Delta;
- levels of mercury methylation and biological uptake;
- organic carbon production in restored marshes and export to the Delta and Suisun Bay; and
- growth and survival of rearing Sacramento splittail and Chinook salmon in shallow subtidal aquatic habitats.

Reversibility: This conservation measure would be difficult to reverse because reversing the measure would require construction of new levees to re-isolate restored habitat areas from tidal flow.

			Viewpoint 1		Viewpoint 2	
Outcome Code	**Covered Spp.**	**Description**	**Magnitude**	**Certainty**	**Magnitude**	**Certainty**
		Positive Outcomes				
P3a	All	INCREASE THE AVAILABILITY AND PRODUCTION OF FOOD IN THE WESTERN DELTA AND SUISUN BAY BY EXPORTING, VIA TIDAL FLOW, ORGANIC MATERIAL FROM THE MARSH PLAIN AND ORGANIC CARBON, PHYTOPLANKTON, ZOOPLANKTON, AND OTHER ORGANISMS FROM INTERTIDAL CHANNELS INTO THE DELTA	3-4	3	1-2	1
P4b	Chinook Salmon	LOCALLY PROVIDE AREAS OF COOL WATER REFUGIA FOR DELTA SMELT AND SALMONIDS.	2	1		
P4a	Delta smelt	LOCALLY PROVIDE AREAS OF COOL WATER REFUGIA FOR DELTA SMELT AND SALMONIDS.	2	1		
P1b	Fall-run Chinook Salmon	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	2		
P2b	Green Sturgeon	Provide a continuous corridor of habitat & food productivity linking current & future restored habitat in the Cache Slough Complex with habitat in Suisun Marsh & Bay	2	1		
P2a	Splittail	Provide a continuous corridor of habitat & food productivity linking current & future restored habitat in the Cache Slough Complex with habitat in Suisun Marsh & Bay	3	3		
P1a	Spring-run Chinook Salmon	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	2		
P2c	White Sturgeon	Provide a continuous corridor of habitat & food productivity linking current & future restored habitat in the Cache Slough Complex with habitat in Suisun Marsh & Bay	2	1		

Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
Negative Outcomes						
N4a	All	Resuspension and export of mercury and methylmercury to downstream areas	1	2		
N3a	All	Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids	1-2	1		
N2a	All	POTENTIAL FOR MERCURY METHYLATION AND LOCAL BIOACCUMULATION TO AFFECT WILDLIFE: N2-A - TARGET SPECIES, N2-B, NON-TARGET WILDLIFE SPECIES, N2-C, HUMAN HEALTH.	1	2		
N1c	All	ESTABLISHMENT OF UNDESIRABLE SPECIES (SUCH AS Corbicula) THAT WILL PREY OR COMPETE OR ALTER HABITAT CONDITIONS FOR COVERED FISH	4	2		
N1b	All	ESTABLISHMENT OF UNDESIRABLE SPECIES (SUCH AS Centrachids) THAT WILL PREY OR COMPETE OR ALTER HABITAT CONDITIONS FOR COVERED FISH	4	2		
N5a	All	Movement of fish and food resources to areas in central Delta with high predation	2-3	1		
N1a	All	ESTABLISHMENT OF UNDESIRABLE SPECIES (SUCH AS EGERIA,) THAT WILL PREY OR COMPETE OR ALTER HABITAT CONDITIONS FOR COVERED FISH	3	2		
N1d	Delta smelt	ESTABLISHMENT OF UNDESIRABLE SPECIES (SUCH AS Inland Silversides) THAT WILL PREY OR COMPETE OR ALTER HABITAT CONDITIONS FOR COVERED FISH	2	2		
N2c	Humans	POTENTIAL FOR MERCURY METHYLATION AND LOCAL BIOACCUMULATION TO AFFECT WILDLIFE: N2-A - TARGET SPECIES, N2-B, NON-TARGET WILDLIFE SPECIES, N2-C, HUMAN HEALTH.	2	3		
N3b	Others	Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids	1-2	1		
N2b	Wildlife	Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A - Target species, N2-B, Non-target wildlife species, N2-C, Human health.	3	2-3		

Viewpoint 1 Advective-driven transport of Cache Slough productivity will provide important and very substantial productivity contributions to larger regions of the northwestern Delta.

Viewpoint 2 Export from the restored marsh will be non-existent when Yolo Bypass is not flowing therby limiting productivity contributions beyond the restoration area.

HRCM 7:
South Delta ROA
Tidal Marsh & Shallow Subtidal Restoration

Incomplete Working Draft
Scientific Evaluation Worksheet

Note about this "Incomplete Working Draft": this document is not completed. The Tidal Marsh Evaluation Team had limited time for this evaluation. Much information has been replicated from the Cache evaluation and has not been revised throughout to reflect the specific restoration sites and geographies of this ROA.

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Action Description

HRCM7: South Delta ROA Tidal Marsh & Shallow Subtidal Restoration

Restore 3,650 acres of vegetated tidal marsh and 950 acres of shallow subtidal habitats on portions of Union, Upper Roberts, and Middle Roberts Islands in the South Delta ROA (see map).

Evaluation Team

Dave Harlow (Chair), Stuart Siegel (Coach), Jon Rosenfield, Wim Kimmerer, Chris Enright, Dan Kratville, Charlie Alpers, Amy Richey and Kateri Harrison (note taker).

Date of Last Revision: May 20, 2009

Approach

1. Plant tules or other techniques to raise currently subsided ground surface elevations suitable for intertidal marsh restoration on shallowly subsided portions of islands and breaching levees when target elevations are achieved.
2. Scalp higher elevation portions of islands to provide fill for placement on subsided portions of islands to raise surface elevations.
3. Breach and set back levees to provide for tidal exchange with restored habitats.
4. Construct cross levees where appropriate to protect property and preclude inundation of deeply subsided portions of islands.
5. Locate and design levee breaches to maximize the development of intertidal marsh and minimize hydrodynamic conditions that favor non-native predatory fish. Levee breaches will be of sufficient length to not limit water motion into and out of restored habitat.
6. Excavate channels to initiate development of dendritic channel networks within restored marshes.

Intended Outcomes as Stated in Conservation Measure

1. Increase rearing habitat area for Sacramento splittail, Chinook salmon produced in the San Joaquin River and other eastside tributaries, and possibly steelhead.
2. Increase the production of food for rearing salmonids, splittail, and other covered species.
3. Increase the availability and production of food in the Delta and Suisun Bay by export from the south Delta of organic material via tidal flow from the new marsh plain and organic carbon, phytoplankton, zooplankton, and other organisms produced in new intertidal channels.
4. Locally provide areas of cool water refugia for Delta smelt.
5. In conjunction with dual conveyance operations, marsh restoration in the south Delta could expand the current distribution of Delta smelt into formerly occupied habitat areas.

Conceptual Model Information Regarding Intended Outcomes

The basic drivers and outcomes discussed in this worksheet are described in the following DRERIP conceptual models Delta smelt, Salmonids, Temperature, Foodweb, Tidal marsh, Corbicula, Sediment, and Mercury.

Assumptions

Provided in BDCP Conservation Measure

1. Restoration would occur on portions of Union and Upper and Middle Roberts Islands
2. Dual conveyance

Added by Evaluation Team

1. Water output from the site, post-restoration, will meet water quality standards.

2. Restoring tidal marsh habitat on the different tracts of the South Delta ROA will have varying levels of both positive and negative effects. For example, some of tracts may be more efficient at the methylization of mercury and so may have a higher magnitude score for an associated negative outcome. Differences in hydrology, topography, soils, and land-use history will also manifest as distinctions in success of this action among the tracts. BDCP's estimated extent of restoration types based upon elevation for each sub-area is presented in Appendix C.

3. The time frame for realizing restoration benefits depends upon the approaches used. Reversal of subsidence on restored areas can take several years to a decade or more depending on starting elevations. The accretion rate depends on sediment supply and biomass accretion which depends on site-specific conditions. Sediment supply in the Delta is generally very low (Schoellhamer et. al., 2007).

4. Efforts to reverse subsidence before active restoration would be focused on the more deeply subsided portions of these landscapes, i.e., lands more than 6 feet below low tide. There is a hypothesis that shallow open water regions located contiguous to emergent tidal marsh provide enhanced ecosystem complexity and functions compared to those tidal marsh habitats located directly adjacent to deeper sloughs. Although this hypothesis has not been tested, preliminary information on current conditions at Liberty Island and Little Holland Tract suggest support. However, the details of these sites are not readily available to the broad research community at this time and so the information is anecdotal. This assumption also includes a time limit to allow for subsidence reversal so that restoration of an entire parcel is not delayed indefinitely. To speed up the subsidence reversal process, an alternative method would be to separate low-lying areas with new levees and reconnect those areas after subsidence reversal is accomplished.

5. Water output from the site, post-restoration, will meet water quality standards.

6. Source of fill material will be identified and use of all material, including dredge spoils, will be approved by the RWQCB.

7. Prior to implementation, a Phase I Environmental Assessment with on-site sampling to assess legacy and other soil contaminants (i.e. mercury and pesticides) will be completed.

Problem(s) with Action as Written:

1. Exporting primary production produced on this restored marsh to the Suisun Bay is not a realistic outcome, given the long distance between the two areas. If successful, this restoration site may export fish.
2. Approach #5 has some ambiguity.
3. The action does not describe how selenium issues will be addressed. Selenium is a concern on this restoration site.
4. Since rearing habitat for juvenile fish by necessity includes local availability of food, the evaluation team merged the Intended Outcomes 1 and 2 (tidal marsh, rearing habitat, and local food) into one outcome.
5. Loading of fill material on top of a shallow island may compress the underlying soils. This approach may not yield the intended result. A close study of existing soil conditions including analysis of the local soil map is needed to further evaluate this issue.
6. The conservation measure would benefit from an explicit recognition that restoration of tidal marsh functions on subsided landscapes, especially those subsided below emergent vegetation elevations, will take many years to many decades. In the interim, restoration sites below vegetation elevations will function as shallow subtidal habitat.
7. It is unlikely that intertidal mudflats will develop in the Delta because dominant intertidal emergent vegetation species in the Delta can grow throughout the tidal range and just into shallow sub tidal elevations (Brown 2003, Simenstad et. al., 2000 as cited in Schoellhamer et. al., 2007, p.26).

Scale of Action:

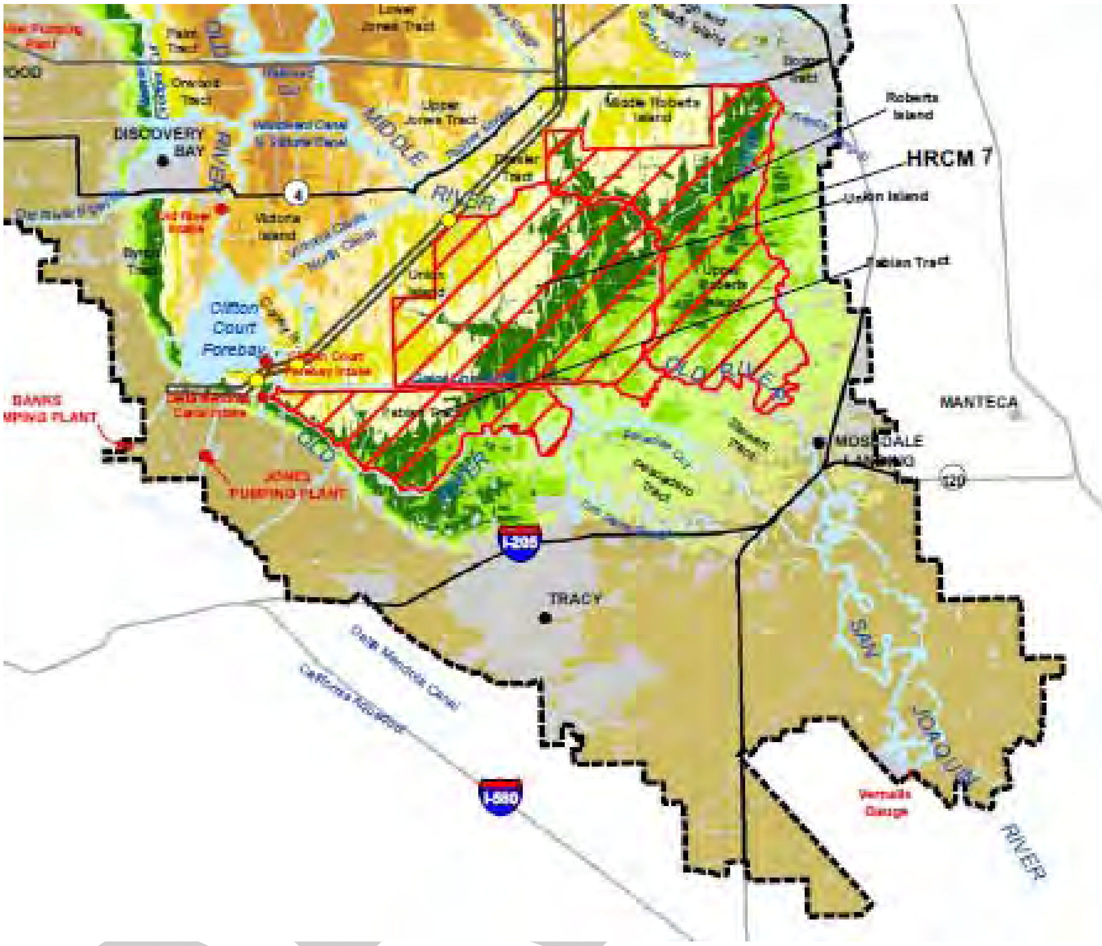
Medium

Rationale:
This is a medium scale restoration action due to its spatial extent. As listed in Table1 below, the Delta currently has approximately 21,600 acres of tidal marsh habitat (baseline). Additionally, 67,000 acres of diked and other lands have been identified as potentially restorable to tidal marsh (neglecting effects of restoration on reducing tidal range). The proposed 3,650 of tidal marsh plus 950 acres of shallow sub-tidal restoration options would increase marsh acreage 16% above current conditions. Significant amounts of the 67,000 acres of identified restorable lands are highly constrained such that they could not be restored in the near term (South Delta and Netherlands alone account for 31,000 acres of the 67,000 acres). Therefore, this action also represents an important part of the potentially restorable tidal marsh lands.

Table 1. Summary of Tidal Marsh Acreages

Area	Acreage	Source
Delta (entire Delta proper)	738,000	DWR, 2009
Historic tidal marsh/wetlands in Delta	525,000	TBI, 2002
Current extent of tidal marsh/wetlands in Delta.	21,600	TBI, 2002
Restorable intertidal lands within Delta.	67,000	CA DVSP, 2008, Table 1, p.77.
Proposed South Delta tidal marsh restoration (this action)	3,650 tidal marsh 950 sub-tidal	BDCP, 2009

Figure 1: South Delta Restoration Areas



Evaluation Summary

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Note: Negative outcomes are scored relative to baseline conditions. These negative mechanisms may also decrease the certainty that positive effects of site restoration will be realized. Appendix "A" contains the above information in summary tables that are organized by the numerical order of the outcomes, rather than species.

Outcomes with Direction of Change Uncertain

The outcomes listed below could be either positive or negative (the direction of change is not certain).

- Organic carbon levels are increased and may affect drinking water supplies. This outcome was not evaluated. The Evaluation Team believes there is a relationship but lack of data precludes evaluation at this time.

Outcomes with Zero Magnitude

During the Evaluation process, several of the outcomes identified by BDCP early in the process, were found to have a zero magnitude. These outcomes are listed below and their evaluation is provided in Appendix B.

- OP1a: Increase rearing habitat area (including physical and biotic attributes) for longfin smelt.
- OP1b: Increase rearing habitat area (including physical and biotic attributes) for steelhead.
- OP2a: Locally provide areas of cool water refugia for winter-run salmon.
- OP2b: Locally provide areas of cool water refugia for late fall-run salmon.
- OP2c: Locally provide areas of cool water refugia for late spring-run salmon

Other Potential Positive Outcomes Identified, Not Evaluated

When BDCP originally crafted this action, they identified the potential positive outcomes listed below. The Evaluation Team ran out of time and funding before it could fully evaluate this outcome. Although this outcome likely has merit, the team was not able to evaluate this outcome.

- OP3: In conjunction with dual conveyance operations, marsh restoration in the south Delta could expand the current distribution of Delta smelt into formerly occupied habitat areas.

Other Potential Negative Outcomes Identified, Not Evaluated

During the course of this evaluation, the team identified one potential negative outcome that it did not evaluate due to lack of time. It is recommended that this potential outcome be evaluated at some point in the future when additional time is available.

- ON1. Pesticide use for mosquito control. Tidal marsh provide habitat for mosquito larvae and adults. Since this restoration action will increase tidal marsh habitat, it will also increase the availability of habitat for mosquitoes. County environmental health departments are authorized to utilize pesticides to the extent necessary to manage mosquitoes in order to protect public health and prevent west Nile and other viruses. Sacramento, San Joaquin, and other Delta counties have active mosquito management programs that include the application of pesticides on marsh habitats. The effect such pesticide use may have on the flora and fauna in the restored marsh and connected areas have not been evaluated in this worksheet.

- ON2: Increase in the availability of selenium. This negative outcome may affect all covered fish species. This restoration site is located close to the selenium source and in proximity to the pumps.

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

No

Nature of Change:

This moderate scale action to restore 3,650 acres of tidal marsh and 950 acres of shallow subtidal habitat may change the environment on a regional scale but not to such an extent that our current understanding of boundary conditions (Harrell et al 2008), hydrodynamics, and ecological processes in the Delta would change.

Overview of Productivity Import-Export

The Cache Slough evaluation worksheet (HRCM4) provides a complete discussion of productivity levels, import and export. Here we describe how conditions may differ from Cache Slough in order to provide the Conservation Measure evaluation appropriate specificity.

The South Delta ROA has less tidal exchange and may have lower residence time compared to Cache, due to its geographic location (farther away from a river channel etc).

Although the scale of the action is moderate in size, its southerly location offers warmer temperatures which will increase primary production compared to other restoration sites. However, it is highly uncertain whether any of this production will be exported or will benefit covered fish species.

Potential Positive Ecological Outcome(s)

Outcome P1: ***Increase rearing habitat area (including physical and biotic attributes) for covered fish species.***

As indicated at the beginning of this worksheet under the section entitled "Problems with Action", the team decided to merge two Intended Outcomes (rearing habitat and local food) into one outcome, P1, as shown below because rearing habitat for juvenile fish by necessity includes local availability of food. This outcome includes food (both primary and secondary production) produced within the vegetated marsh, within marsh channels, and within the subtidal areas adjacent to the vegetated marsh. General information that applies to salmon runs is provided in the worksheet for HRCM 4 – Cache Slough, Outcome P1c on page 15. Please note that green and white sturgeon are not known to utilize the Cosumnes and Molkemne River systems and so these species are not listed in the analysis below.

P1a. Delta smelt:

General Observations: The aquatic food web supporting Delta smelt production is a primary component of habitat suitability that affects Delta smelt growth rates, health, fecundity, and mortality (page 21 in Nobriga and Herbold, 2008). The food web supporting Delta smelt is based on the production of pelagic zooplankton.

Delta smelt historically spawned in the South Delta (Nobriga and Herbold, 2008, p. 11).

Delta smelt are believed to be food limited for at least some life stages (Herbold and Nobriga 2008, page 9). In summary, food resources for Delta smelt would be produced within the restored marsh habitat, and the combination of physical space and food production would constitute habitat for Delta smelt.

Food generated on this site might be lost to invasive clams. This phenomenon is described in detail in Negative Outcome N1b. Predation (especially if it is facilitated by colonization of SAV) may also eliminate any beneficial effect of this action.

Magnitude = 1 - Minimal
Delta smelt were historically found in the South Delta (Bennett 2005, Figure 1) but they are infrequent or absent from this area in recent years (Nobriga and Herbold, 2008 Figure 3). Delta smelt eat food produced on tidal marshes; but, the smelt model (p. 27 and elsewhere, and pers. comm. with B. Herbold, US EPA) indicates that Delta smelt do not forage ***in*** shallow environments. Delta smelt will not benefit from the physical habitat structure to be created on shallow parts of this restored landscape. Food consumed in the shallow tidal areas is likely to be nil.

The food consumed in directly adjacent pelagic habitats depends entirely on how much of the zooplankton produced in the shallow areas is consumed by fish that actually forage in shallow environments where the food is produced.

This outcome assumes that Delta smelt are limited by food production in this area. The Model indicates that Delta smelt rearing in open water habitats may have, in the past, relied on export of food from a vast network of tidal marshes (p12). However, today, it is more likely that water quality, flow conditions, and non-native species in this area limit native fish productivity than that productivity is limited by lack of tidal marsh habitat. (e.g., Jassby and Van Nieuwenhuyse, Brown and May 2006, Presser et. al., in revision and Werner and Oram, 2008).

Certainty = 2 - Low
The value of food produced on site is related to how much of that food makes it into the adjacent channels and bays and to the nature and extent of food limitation in this region currently. Both of these factors are uncertain. The magnitude of food production depends on physical aspects of the restoration (e.g. those that contribute to retention time) and biological outcomes (e.g. the amount of food consumed in shallow areas that is then not exported to adjacent deep habitats).

Corbicula establishment could limit, if not eliminate, the productivity benefits of the restoration to Delta smelt. See Negative Outcome N1b. Similarly, establishment of SAV and centrarchid (or other) predators could lead to predation rates on the site that eliminate any net benefits at a population level.

P1b. Fall-run Chinook salmon - San Joaquin or eastside tributaries.

General Observations: Fall-run juveniles move through the Delta from in the winter and spring (Williams and Rosenfield, In preparation, figure 3 and see also page 15 that shows the value of estuarine rearing varies across runs).

Magnitude = 2 - Low
Outcome assumes that "rearing habitat area" (quantity) and/or food is limiting. Page 16 of Williams and Rosenfield, In preparation, states that : "<u>Fall Chinook […] could benefit strongly from tidal marsh restoration</u>". Fall Chinook generally enter estuarine habitats at a small size and the text anticipates benefits from additional rearing/growth opportunities. Fall run will eat the types of food produced in this habitat. San Joaquin River and eastside fall-run migrate through this area from January and into June, with a pulse in May (Williams and Rosenfield, Figure 3).

High temperatures are common in this area during May (as indicated by an IEP gauge, rsan058, in the vicinity). Average daily temperatures exceed 20-21^{o}C (beyond which sublethal effects accumulate; Reese and Harvey 2002 *and see* Richter and Kolmes 2005) during May in approximately 1/3 of years. In June, average daily temperatures exceed this critical threshold in almost every year. With warming that may occur under climate change projections, high temperatures may become more frequent and more extreme, even during April. Fall-run rearing in this proposed restoration site during May will probably be impacted by high temperatures and negative impacts could become more common, and occur earlier in the year, with global warming.

This region has been highly altered by anthropogenic chemical inputs, channel modification, and invasive species (Brown and May 2006). Water quality in this area is notoriously poor: lethally low DO conditions occur throughout the year (including, occasionally, during the fall-run juvenile emigration period; http://www.sjrdotmdl.org/concept_model/bio-effects_model/lifestage.htm). In addition, the area is dominated by SAV and associated Centrarchid predators. Without action to correct water quality and flow problems in this area, construction of tidal marsh habitat is not likely to be successful in restoring native fish. This action will not benefit Sacramento River fall run and will not benefit fall-run that migrate into the lower San Joaquin River after mid-April.

Certainty = 2 - Low
Restoration of Chinook salmon to the San Joaquin River drainage will probably require restoration of flows to the lower San Joaquin River (to create passage for adults and juveniles and to dilute and disperse contaminants). Restoration of these flows will impact the value of "rearing" habitat in the Southern Delta.

P1c. Splittail

General Observations: The relationship between the drivers and outcomes is described in Kratville, 2008 on pages P1h Pg 12, 13, 14, 15.

Magnitude = 2 - Low
While more tidal marsh will help rearing of juvenile splittail, the expect population benefit is medium. Sacramento splittail population abundance is limited the lack of floodplain inundation to provide spawning habitat (Kratville 2008). When large scale inundation occurs splittail population abundance is high for several years following an event. Long periods without floodplain inundation reduce splittail population abundance. Splittail do not appear to be habitat limited at other life history stages. Tidal Marsh in this area may provide similar benefits as the Cosumnes tidal marsh areas in terms of adding resiliency to the population. Future floodplain restoration on the San Joaquin River at a major scale may increase the value of this proposed tidal marsh.

Splittail are benthic fish which forage during the day. Adult splittail typically consume detritus (60-79%), mysid shrimp (2-24%), Corbula (6%), salmon eggs, worms, and invertebrates. Larval and juvenile splittail are typically found on the floodplain and while there they consume small rotifers, cladocerans, chironomid larvae, zooplankton, and copepods (Kratville 2008). To the extent that tidal marsh supports the production of these types of food resources and to the extent that these food resources are available at a time and location that is accessible to splittail, the proposed restoration may offer some food benefits during a limited time window.

Certainty = 3 - Medium

Whether the proposed restored rearing habitats will result in increased splittail population abundance is not certain. Although the restored habitat will increase the opportunity for rearing juveniles to feed during their downstream migration, tidal marsh does not appear to be a limiting factor in splittail abundance compared to floodplain inundation (Kratville 2008). .The bulk of the adult splittail population resides in the brackish areas of Suisun Marsh (Kratville 2008). It is anticipated that most of the restored marsh in this ROA will be freshwater and so will only provide habitat for juvenile fish migrating into Suisun Marsh. This restoration may not provide a new population center or increase the numbers making it to Suisun Marsh. The restoration site is not located directly downstream of a floodplain and so its use by out-migrating fish may be limited.

P1d. Green Sturgeon

General Observations: The basic relationship between drivers and outcomes is described in Israel and Klimley, 2008, pages P1i Pg 4, 8, and 9.

Magnitude = 2 - Low
Information on green sturgeon diets and physical habitat needs as juveniles in the Delta is limited. Other species of juvenile sturgeon located in other systems do feed on drifting insects (Radtke 1967 and McCabe, G et al. 1993). This area of the Delta will not provide extensive mud bottoms as found in lower portions of the estuary. Soft bottom benthos are a food resource for the sturgeon. Most habitat limitations for green sturgeon appear to occur outside of the restoration area (i.e. upstream and downstream), as described on pages 4, 8, 9 in Israel and Klimley, 2008 and pages 19-21 of Israel et. al., 2009. It is unknown to what extent adult sturgeon used freshwater tidal marsh for foraging. The impact to individual sturgeon may be low but the extreme loss of freshwater tidal marsh in the Delta may have lowered the carrying capacity of the entire system for sturgeon. See pages 4, 8, 9 in Israel and Klimley, 2008 and pages 19-21 Israel et. al., 2009 for more detail.

Certainty = 2 - Low
There is minimal certainty about whether this proposed restoration will benefit sturgeon as described in this outcome. The minimal certainty is due to the lack of research on this aspect of sturgeon biology/ecology in the Delta. Most of the available information on sturgeon diets and predator/prey relationships is based upon other species of sturgeon, located outside of this system.

P1e. White Sturgeon

General Observations: The basic relationship linking drivers to outcomes is described in pages 1j, 19, 20, and 21 in the DRERIP White sturgeon model (Israel et. al., 2009).

Magnitude = 2 - Low
Information on white sturgeon diets and physical habitat needs as juveniles in the Delta is limited. Other species of juvenile sturgeon (located in other systems) do feed on drifting insects. . This area of the Delta will not provide extensive mud bottoms as found in lower portions of the estuary so benthic food items are expected to be limited in this restoration (Siegel, personal communication, Feb. 2009). Habitat limitations for white sturgeon appear to occur upstream and downstream of the restoration area (i.e. outside the ROA).

Certainty = 1 -Minimal
There is minimal certainty about whether this proposed restoration will benefit sturgeon as described in this outcome. The minimal certainty is due to the lack of research on this aspect of sturgeon biology/ecology in the Delta. Most of the available information on sturgeon diets and predator/prey relationships is based upon other species of sturgeon, located outside of this system.

Outcome P2: Food resources (i.e. organic material from the marsh plain and organic carbon, phytoplankton, zooplankton, and other organisms from intertidal channels) produced on the restored marsh will be exported, via tidal flow, and contribute to food availability downstream in the Delta and Suisun Marsh.

P2a: All Covered Fish species

General Observations: The Tidal Marsh and Foodweb models [Kneib et. al., 2008, page 9 and Durand, 2008, section 2.16)] provide a general indication that there may be a linkage between tidal marsh habitat as a driver and increases in availability and production of food resources as an outcome, but that the mechanism for this linkage may be movement by fish. The tidal marsh conceptual model also states that freshwater tidal marshes are net exporters of high-quality organic production (page 2 in Kneib et. al., 2008). See also Dame et al. 1986, Kimmerer and McKinnon 1989, Kneib 1997, Lucas et al. 2009.

Under this Conservation Measure, restoration would include vegetated marsh plain, tidal channel networks with depths that are shallow to medium subtidal, and shallow subtidal open water in the deeper portions of the restoration sites. Production and export of food resources from these distinct geomorphic features is a multi-step process that begins with primary production. The nature of the primary production will be different between these three geomorphic features, with the marsh plain being dominated by vascular plants with some epiphytic algae and the marsh channels and shallow subtidal open water being dominated by phytoplankton with contributions from FAV, SAV, and perhaps some epibenthic algae. This primary production is consumed by a range of secondary producers the nature of which again will vary across the three geomorphic elements, with the marsh plain supporting mainly detrital-based microbial communities and epiphytic, epibenthic, and aerial invertebrate grazers and the marsh channels and shallow open water supporting a mix of zooplankton and benthic and epibenthic invertebrates. Fish of varying size will also forage throughout the marsh channels and shallow open water and during higher tide stages on the marsh plain when it is inundated.

Please see the evaluation worksheet for action # HRCM4-Cache/Yolo, Outcome P3, for more details about **Tidal Marsh Contributions to Exported Production.**

There was disagreement within the evaluation team regarding the magnitude and certainty of expected benefits of tidal reintroductions with regard to the export of food (phytoplankton, zooplankton, insects, and small fish) to areas downstream of Rio Vista and the likely benefits to covered fish species. In the spirit of presenting the scientific discourse, both points of view are captured below.

Two key questions discussed were: (1) can we predict the sign of the flux of productivity (i.e. will the restoration area be a source or a sink for primary and secondary productivity); and (2) will there be adequate advection to move material out of the restoration area and downstream to Rio Vista (assuming the restoration area is a source of productivity, as opposed to a sink). Additional information and analyses is needed to better answer these key questions. To develop this additional information, the team recommends future development of a Tropho-dynamic model as described in the section on page 41 entitled “Research Needs”.

Viewpoint #1

Please see the text of Outcome P3 in worksheet HRCM4 – Cache Slough for additional background information about Viewpoint #1.

Magnitude = 3-4 – Moderate to High
Without advective connection, restoration will still have significant productivity benefits to covered fish species and to many other species due to providing areas of highly functional habitat in conjunction with restoration elsewhere that collectively provide fish species a range of options that spread risk through exploiting available resources when they are present. Refer to Ted Sommers, IEP Estuarine Ecology Team or CAERS poster. In addition, these areas would export that productivity through the “trophic relay” concept described in the tidal marsh conceptual model (fish export the productivity).

Certainty = 3 – Moderate
Certainty is reduced by the potential for establishment of invasive clams that could consume substantial portions of phytoplankton and hinder zooplankton productivity.

Viewpoint #2

Please see the text of Outcome P3 in worksheet HRCM4 – Cache Slough for additional background information about Viewpoint #2.

Magnitude = 1-2 - Minimal to Low
The implied relationship is that restored tidal marsh will export nonliving and living organic matter including plankton and fish, thereby supporting foodwebs of the upper estuary. An implicit assumption is that any increase in the area of shallow habitat would result in enhanced plant productivity some of which would be exported.

Certainty = = 1 -Minimal
The sign of the signal is difficult to determine, except for total organic carbon, most of which is dissolved. Although dissolved organic carbon (DOC) will likely flow out of the marsh, fluxes of other components may be in or out (Kneib et. al., 2008, page 9). Colonization by invasive clam species can wipe out the food web production effect entirely. We have no certainty at all that they will not colonize. In addition, colonization of the site by vertebrate consumers (e.g, inland silverside) can also significantly reduce the amount of food available for export beyond the site boundaries (Moyle 2002). There is evidence from within this system (Dean et al. 2005) that restored marshes can act as sinks for certain zooplankters; in this case, the sign of the signal would be negative.

Outcome P3: Provide local areas of cool water refugia (Feb-Jun) for Delta smelt and salmon.

The cause and effect relationship associated with this outcome is described in Stacey and Monismith 2008, Malamud-Roam 2000, and Enright 2008. Considering the local scale (small) of the action, the relationship between tides, physiography, and water temperature could be moderate. The relationship between drivers (wind, insolation, fetch, tides, currents) and linkages (long-wave, short wave, latent, and sensible heat flux) is complex and may produce both warmer and cooler water on a variety of time and space scales. Larger spatial gradients of water temperature will likely occur. The frequency of threshold temperatures for various species is uncertain. See Stacey and Monismith (2008), Malamud-Roam (2000), Enright (2008). Please see the detailed discussion of temperature in the Cache Slough HRCM4 worksheet, under Outcome P4.

P3a: Delta smelt

Magnitude: 2 - Low

Please refer to text in outcome P4 of HCM4 – Cache/Yolo Restoration Action. Delta smelt do experience thermal stress during late spring and summer. The spatial and temporal extent of the cool water refugia may be relatively limited. However, in some cases a large effect could be felt across relatively large area across the range. Drivers and outcomes are described in Stacey and Monismith 2008, Malamud-Roam 2000, and Enright 2008. Please refer to the discussion located in HCRM4 – Cache Slough Restoration Action, Outcome P4, page 25 for more details.

Certainty: 1 - Minimal
The basis for our understanding is a single unpublished study in Suisun Marsh. The extent to which this effect may transfer to the restoration site, and to which Delta smelt and salmon will take advantage of it, cannot be predicted. Please refer to text in outcome P4 of HCM4 – Cache/Yolo Restoration Action Outcome P4, page 26 for more details.

P3b. Chinook Salmon

P3b1: Fall run salmon

Magnitude = 2- Low.
Beneficial effect occurs for only a portion of the salmonid population passing through this region during a particular and narrow window of time. This outcome modifies Outcome P1 (creation of habitat). In evaluating that outcome, benefits of this action were interpreted in the light of unfavorable temperature conditions that occur in the area during late-spring and summer. To the extent that the tidal flooding/cooling phenomenon occurs on this restoration site (a function of geography and restoration design and site elevations) during the period of potential thermal stress (May through end of summer), it may provide some relief from the effects of thermal stress *for those*

salmon runs that migrate through this region at this time (fall and spring run and steelhead). That benefit impacts only the proportion of the population that migrates at this time and only the proportion of the population that migrates through this area (i.e. not all fall run or all steelhead). Although the team suggests a magnitude score of 2, for this outcome there is some debate within team as to whether this action's cool water refugia will offer any benefit at all. Chinook salmon using this area during late spring are probably on their way out of the estuary, and if it is too warm they will probably move on. The existence of thermal refugia (if it occurs in the area) may not make much difference to the salmon, and should not be considered a positive outcome pending further information.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

P3b2: Steelhead

Magnitude = 2- Low.
Beneficial effect occurs for only a portion of the salmonid population passing through this region during a particular and narrow window of time. This outcome modifies Outcome P1 (creation of habitat). In evaluating that outcome, benefits of this action were interpreted in the light of unfavorable temperature conditions that occur in the area during late-spring and summer. To the extent that the tidal flooding/cooling phenomenon occurs on this restoration site (a function of geography and restoration design and site elevations) during the period of potential thermal stress (May through end of summer), it may provide some relief from the effects of thermal stress *for those salmon runs that migrate through this region at this time (fall and spring run and steelhead).* That benefit impacts only the proportion of the population that migrates at this time and only the proportion of the population that migrates through this area (i.e. not all fall run or all steelhead).

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

**Note: Winter run, late-fall run, and spring do not occur in this area, will not derive benefits from this action, and are further discussed in Appendix B.

Potential Negative Ecological Outcome(s)

Outcome N1: Establishment of harmful invasive species.

Harmful invasive species have the potential to cause two types of adverse effects. First is to worsen conditions relative to the existing baseline; i.e., creating an attractive nuisance. Second is to detract from achieving the positive benefits the action could provide. The magnitude and certainty scores below are based upon an assessment relative to baseline conditions. The scores below for N1a to N1d do not represent the potential to distract detract from the positive benefits of the action because these deductions were considered by reducing the certainty scores for positive outcome # P1. Where appropriate, the impacts associated with the establishment of harmful invasive species on the restored marsh are discussed below.

N1a: Submerged Aquatic Vegetation (SAV)

General Observations: As described in the conceptual model, the establishment of SAV is controlled by local flow conditions and substrates (Anderson, In Preparation). Many aspects of SAV physiology are influenced by local flow conditions including turbidity and to some extent flow velocity which if too high can scour suitable substrate precluding SAV establishment. The initial establishment of SAV is an intermediate outcome and the development of a large sustainable SAV population is the final outcome.

Please note that establishment of SAV reduces the certainty that the positive outcome, P1 will occur. This has been noted in the scoring for P1.

Magnitude = 3 - Medium
The establishment of SAV in general is controlled by local flow conditions and substrates. Local flow conditions control many aspects of SAV physiology, most importantly in this area turbidity. In nearby Liberty Island where turbidities are generally higher due to wind wave action SAV is restricted to shallow near shore areas (UC Davis Egeria Report). . If turbidities are high in the restoration area then SAV establishment and growth may be reduced to levels similar to Liberty Island. If not there is the potential for SAV amounts similar to Franks Tract. The substrates in this area would be expected to support establishment of SAV (Anderson, In Preparation).

For this outcome, the baseline condition is that much of the existing 21,600 acres of Delta tidal marsh is infested with submerged aquatic vegetation (Ustin, 2008). . The restoration of a tidal marsh that eventually becomes infested with SAV is significant. Large, sustainable populations of SAV will produce significant changes in water quality (turbidity, pH, DO and temperature), or water flow characteristics (velocity and direction), which in turn can affect the quantity and quality of sediments (Anderson, In Preparation). Eventually, the clarity of water entering the site from upstream will increase by lowering velocities and allowing particulates to settle out of the water column. This increased water clarity could increase predation of fish entering the site from outside areas (i.e. predators now have greater visual range). One type of predator, Centrarchid fish, is strongly associated with SAV and increased Centrachid populations may create a population sink for native fish at this location, as discussed in N1b, below. In summary, this action will worsen conditions beyond that of baseline conditions and small to moderate fractions of all the covered fish species may experience highly significant but localized effects due to SAV. Given the rarity of Delta smelt, the impact of SAV establishment could be particularly significant on this species.

Certainty = 2 - Low
The initial colonization and ultimate patch distribution of SAV on the substrate is uncertain. As the substrate softens over time, it may be more conducive to SAV establishment and growth (i.e. bed characteristics are described as a driver in the conceptual model). It is well documented that the physical structure of SAV facilities slower water velocities which allows sediment particles to settle, thereby reducing turbidity, locally and creating a positive feedback loop for more SAV establishment (Anderson, In Preparation). The effect of specific restoration site substrate, how those substrates may change over time after restoration, and the role of flow velocity at these locations is not well understood (Anderson, In Preparation).

N1b: Non-native Centrarchids

General Observations: Drivers and outcomes are described in Brown and Michnuik, 2007; Grimaldo et al 2004; Nobriga and Feyrer 2007; and Nobriga et al. 2005. Centrarchid fish, as an assemblage, cover a range of ecological niches in the Delta. They are competitors for resources as well as predators on native fish. The magnitude of this effect is dependent on the assemblage of centrarchids that invade and the size of the populations. This is in turn partially dependent on the amount of SAV invasion into suitable habitat areas of the restored system.

Please note that establishment of Centrachids reduces the certainty that the positive outcome, P1 will occur. This has been noted in the scoring for P1.

Magnitude = 4 - High
For this outcome, the baseline condition is that much of the existing 21,600 acres of tidal marsh are excellent habitat for Centrarchid fish where they are associated with adjacent deeper water. This is illustrated by the large number of Bass Tournaments that occur in the Delta. The Delta is a stop on the national professional bass fishing circuit with $100,000 prizes. infested with centrarchids (citation needed). This action could worsen conditions beyond that of baseline. Centrachids are a concern because they prey upon and compete for food and other resources with native covered fish.

The establishment of Centrarchids in conjunction with SAV is well documented, especially in this portion of the Delta (Brown and Michniuk 2007; Grimaldo et al. 2004; Nobriga and Feyrer 2007; Nobriga et al. 2005). Centrarchid fish will become established in this area as they have in other South Delta locations where flows are more tidal than riverine (Brown and Michniuk 2007). The magnitude score given reflects the possible impact that these fish could have given evidence from the southern Delta. An increase in populations of this assemblage of centrarchids could have impacts on nearly every life stage of Delta smelt and other native fishes. Given the rarity of Delta smelt, the impact of Centrachids could be particularly significant.

Certainty = 2 - Low
The uncertainty is not whether or not Centrarchid fish will become established at the restoration site, but the extent of their populations and impacts on local native fish use once established. In areas with low SAV patch size the numbers of Centrarchid fish and their presumed impact on native fish are lower then where the opposite is true (Brown and Michniuk 2007). If the south Delta becomes brackish to the extant that Suisun Marsh is today, this may change.

N1c: *Corbicula*

The relationship between drivers and outcomes is described in the DRERIP Corbicula Conceptual Model (Thompson et. al., In revision).

Consequences of *Corbicula* establishment. If established, *Corbicula* would likely have a significant effect on food web dynamics because it consumes phytoplankton in shallow areas (Lopez et al. 2007). *Corbicula*'s consumption of primary productivity represents a significant limiting factor throughout the Delta that could greatly reduce productivity benefits of restoration efforts (Thompson et. al., In revision). No local studies have been undertaken to indicate whether *Corbicula* feeding has reduced zooplankton populations either through competition or direct predation (Thompson et. al., In revision page 11). Establishment of *Corbicula* would consume much of the positive benefits that were previously discussed above under positive outcomes.

Potential Control Options. There are no stressors identified that can limit the success of Corbicula in a significant manner. However, salinity can limit the spatial distribution of this species and food limitation is a source of stress (Thompson et. al., In revision, pages 8 and 13). The *Corbicula* conceptual model indicates that the only meaningful method to control their presence/abundance is salinity. This control method would require salinity intrusions into the restoration area of sufficient duration and at the appropriate times of year to have a meaningful effect. The conceptual model does not specify the duration and timing which might be most effective during recruitment. Water temperatures may influence the effectiveness of both recruitment and control measures.

Please note that establishment of *Corbicula* reduces the certainty that the positive outcome, P1 will occur. Establishment of *Corbicula* would consume much of the positive benefits that were previously discussed above under positive outcomes. This has been noted in the scoring for P1.

Magnitude: 1- Minimal
Corbicula can control phytoplankton biomass development in shallow areas, or consume the productivity of shallow areas exported to channels (Thompson et. al., In revision). This is a significant limiting factor throughout the Delta. However, the effect of the restoration on the establishment of Corbicula, and whether that constitutes a net positive or negative effect, is unknown and would be difficult to predict. For this outcome, the baseline condition is that much of the Delta is infested with *Corbicula*. The restoration of tidal marsh that eventually becomes infested with *Corbicula* would not represent a significant change above baseline conditions.

Certainty: 2 - Low

Specifically for restoration sites, the timing and extent of colonization by Corbicula cannot be predicted because of a lack of data from such locations. *Corbicula* are prolific reproducers and colonizers of newly available habitats in salinities below 2 ppt. Source populations can come from elsewhere within the Delta or from upstream tributary populations. *Corbicula* can establish on soft and hard substrates and on vegetation and they can colonize intertidal zones as well as deeper water. (*Corbicula* model). Based upon the biology of the species and the physical setting of the restoration site, the probability of *Corbicula* establishment in the West Delta restoration areas appears to be high, but ultimately cannot be predicted, partially due high variability in environmental conditions. The low certainty score considers the probability and extent of potential establishment.

Corbicula monitoring data from previous restoration sites in the Delta, such as Liberty Island or Little Holland Tract, would provide greater information about the probability of colonization on these eastern Delta sites. More information would improve the certainty rating. However, such data and analysis was not made available to the evaluation team.

N1d: Inland Silversides Effects on Delta and Longfin Smelt

General Observations: Inland silversides (*Menidia beryllina*) are highly tolerant of warm water, and variable salinity variability and are trophic generalists compared to Delta smelt (Moyle 2002). Inland silversides are the most numerous fish in shallow Delta habitats (Nobriga et al. 2005, Brown and May 2006). Page 3 of Nobriga and Herbold 2008 includes intraguild competition with inland silversides as one of the top five in-Delta stressors to Delta smelt. Inland silversides are thought to be a major predator of Delta smelt eggs (Bennett and Moyle 1996 and Bennett 2005 in Nobriga and Herbold 2008 page 12). In the laboratory, inland silversides reduce Delta smelt size relative to controls when they are reared together (Bennett 2005).

Inland silversides are also treated in the longfin smelt model. Moyle (2002, in Rosenfield 2008) suggested that based on timing of arrival in the Estuary and subsequent longfin population response, inland silverside might have had a major impact on longfin population dynamics. However, the model states that inland silverside prefer shallow water habitats where juvenile and sub-adult longfin are rare, thus, their impact as predators of juvenile and sub-adult longfin is probably slight (Rosenfield 2008, pg. 17). Spawning locations for longfin are unknown, so it is not known whether competition from inland silverside for spawning territory is a factor in their decline.

However, Delta smelt evolved with other intraguild competitors, including longfin smelt, and have survived with striped bass (introduced in 1879). Interaction between silversides and Delta smelt in the wild may be limited because Delta smelt typically inhabit offshore environments, while inland silversides typically inhabit shoreline habitats. Increased shoreline habitat would presumably increase the carrying capacity for inland silversides. However, predator-prey interaction between Delta smelt and inland silversides in the wild is speculative. Silversides may eat Delta smelt eggs or larvae if the eggs and larvae occur on the shorelines. It has not been shown that inland silversides reduce calanoid copepods (Nobriga and Herbold 2008, page 32), so they may not effectively compete with Delta smelt for prey.

Magnitude = 2 – Low: Inland silversides are the most abundant fish in shallow-water habitats in many areas of the Delta and may currently contribute to local depletions of zooplankton otherwise available to native fishes within these areas. Additionally, they may prey on embryos of species that lay eggs in these shallow areas (Moyle 2002). The crash of Delta smelt populations coincided with invasions of inland silversides into the estuary (Bennett and Moyle 1996). This action may change conditions relative to baseline by attracting (via restored marsh) a nuisance (inland silversides). This conservation measure will increase the local inland silverside population by providing additional shoreline breeding habitat. Because of the high existing abundance of inland silversides, the incremental increase in breeding habitat and thus population size above current conditions is considered small and the magnitude of this effect is considered to be low relative to baseline. Further, differential habitat selection (offshore environments for inland silverside) is expected to reduce the interspecific competition effects.

Certainty = 2 - Low: Understanding of interaction between Inland silversides and Delta smelt in the wild is low, particularly in regards to egg predation by inland silversides. Spatial interactions with longfin smelt are also uncertain.

Outcome N2: Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A – Covered fish species, N2-B, Non-covered wildlife species, N2-C, Human health.

General Observations, methyl mercury: Although current methylmercury levels on Liberty Island (analogue for future state of areas to be restored) are relatively low (Slotton et al. 2002, Alpers et. al., 2008, figure 5), there is potential for enhanced production of methylmercury in areas of high marsh that will be inundated infrequently (only during highest tides). The process of drying out between wetting events tends to oxidize species of sulfur, iron, carbon, and mercury, leading to higher potential to form methylmercury upon rewetting. Once formed, methylmercury biomagnifies in the aquatic food web, and ecological effects may occur in some sensitive species. Thus, the specific geomorphology of restoration sites and in particular the degree to which shallow depressions and poorly drained areas of high marsh are part of the restoration projects directly influences the degree of mercury methylization.

General Observations, other contaminants: Past land use determines risk of other contaminants: lead risk in areas with significant hunting, e.g., pheasant farms or duck clubs. Risk of residual pesticides (e.g., pyrethroids) in areas used for agriculture in past 2 years, which suggests that if these pesticides were used, allowing for a 2 year lag period between application and tidal restoration would be a prudent mitigation measure. Selenium contamination from the San Joaquin Valley is a concern.

N2a: Covered fish species

General Observations: Alpers et. al., 2008 (Table 2 and associated text) describes the relevant issues.

Magnitude: 1 – Minimal: No toxicological studies have been conducted with any of the target species regarding acute toxicity. Mercury concentrations in target fish are compared here against concentrations producing mortality in other fish species. Mercury concentrations in covered fish species are compared here against concentrations producing mortality in other fish species. Mercury concentrations in ppm-wet weight for white sturgeon, Chinook salmon and Steelhead collected during 2006 were 0.165-0.279, 0.094-0.396 and 0.06-0.13, respectively (Melwani et al. 2007). No tissue data for either longfin or Delta smelt was found. It is assumed that both species will have tissue concentrations similar to other fish taxa living one year and feeding primarily on zooplankton. Mercury concentrations in juvenile threadfin shad and juvenile largemouth bass in delta are 0.012-0.076 and 0.035-0.230, respectively (Slotton et al., 2006). In comparison death in rainbow trout in laboratory studies occurred at 4-ppm wet weight and the NOAEC for death in Brook trout at 2.7 ppm (in Wiener and Spry, 1996). In conclusion, there exists about a 10X safety factor between fish tissue concentrations in Delta and values reported to cause mortality in lab studies.

Regarding chronic toxicity, again no toxicological studies with any of target species. Therefore, have compared reported tissue concentration for individual species against known laboratory effects in other taxa. Decreased feeding efficiency and some hormones response changes observed at 0.25-0.27 ppm wet weight (page 30 of Alpers et al, 2008) have been noted. Decreases in growth occurred in fathead minnows at 0.6-0.7 ppm Hammerschmidt et al., 2002) and in juvenile walleye at 2.4 ppm (Friedmann et al., 1996). In conclusion, some up/down regulation of genes and alterations in feeding behavior are possible in the most contaminated individuals.

Certainty: 2 - Low
Scientists have a low certainty that the magnitude of this outcome is minimal (i.e. magnitude may be higher). Limited tissue data available for most covered species but large safety factor regarding acute toxicity, which makes it impossible to determine the proportion of population potentially at risk. Additionally, only limited toxicological data available for most of the important sub-lethal processes and none of this has been collected on species of interest.

N2b: Methyl mercury, non covered species

Magnitude: 3 - Medium
Fifty-eight percent of Forster's terns in San Francisco Bay are at risk of reproductive impairment from consuming fish with elevated mercury levels (Ackerman *et al*., 2008). No Forster's Terns nest in Delta. However, mercury levels in small fish consumed by terns are higher in parts of the Delta such as the Yolo Bypass than in San Francisco Bay suggesting that other bird species filling the Forster's tern niche in the delta may be at risk. Mercury may result in a possible sustained, minor population effect on large area.

In laboratory studies, mink have reproductive failure and die when fed fish diets of 0.5 and 1-ppm mercury, respectively (Dansereau *et al*., 1999). For comparison, mercury concentrations in 64% of largemouth bass, 23% of white catfish, and 35% of channel catfish caught in the Bay-Delta watershed have between 0.23 and 0.93 ppm mercury (Davis et al., 2006). Expected sustained minor population effect or effect on large area.

Additional studies on rails and other species are described in the evaluation worksheet for Cache Slough #HRCM 4,. Outcome N2a2, page 36 for additional details.

Certainty: 2-3 Low-Medium
Scientific understanding of methylmercury effects on some bird and mammal species is high, based on peer-reviewed studies conducted in the San Francisco Bay and elsewhere. However, methylmercury effects on other bird, reptile, and mammal species are unknown. The nature of this outcome is also greatly dependent on highly variable ecosystem processes.

N2c: Methyl Mercury, Human Health

General Observations: See also results from water quality team.

Magnitude: 2 – Low: Fish consumption advisories for the Delta recommend that children under the age of 17 and women of child bearing age consume no largemouth bass or smallmouth bass, spotted bass or Sacramento pikeminnow, and others should limit their consumption of these species to one meal a month (OEHHA, 2006, 2008a,b). Between 10,000 and 20,000 fishermen in the Delta are presently eating fish with more than 10X the recommended methylmercury RfD and could experience some sublethal mercury poisoning (personal communication, Dr Fraser Shilling). Action could increase mercury content of sport fish.

The probability of increased methyl mercury production and export into the food web is the same as that described above for covered and non-covered species.

Certainty: 3 - Medium
Uncertain magnitude and direction of change in mercury content of sport fish, although levels are more likely to increase than decrease. For a given increase in mercury content of sport fish, risk to human health is quantified based on peer-reviewed studies (OEHHA, 2008a,b). Unknown how many anglers would access the project area and what fish they would catch and consume.

The role of restoration projects under this Conservation Measure in contributing to mercury levels in fish species consumed by humans needs to be explored in relation to other mercury sources for those fish species.

Outcome N3: Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids.

N3a: Covered fish species

General Observations: Possible presence of legacy pesticides from 1960s (e.g. DDT) is unknown. More recent (illicit) use of DDT is possible. Pyrethroids are 20x more toxic compared to some other pesticides (organochlorides). They persist in the sediment and degrade in one or two years (DPR, 2008). The relationship between drivers and outcomes is described by the DRERIP Pyrethroids conceptual model (Werner and Oram, 2008, Figure 1).

Magnitude: 1-2 – Minimal - Low
To the extent that pyrethroids or pyrethrins were used in the area to be flooded, significant toxicity could occur within 1-2 years of application. After ~2 years, near-total degradation should occur. DDT and metabolites could cause reduction of insect populations and bioaccumulation in target fish species (and some non-target bird species). Possible presence of legacy pesticides from 1960s (e.g. DDT) is unknown.

Certainty: 1 - Minimal
The toxicity of various pesticides is not completely understood. Although some peer-reviewed studies for selected life stages of certain fish exist, there is not much data for covered fish species. The nature of outcome greatly dependent on highly variable ecosystem processes affecting fate (degradation) and transport of pesticides.

N3b: Non Covered Wildlife Species

General Observations: The relationship between drivers and outcomes is described in Werner and Oram, 2008, (Figure 1).

Magnitude: 1-2 Minimal - Low
To the extent that pyrethroids or pyrethrins were used in the area to be flooded, significant toxicity could occur within 1-2 years of application. After ~2 years, near-total degradation should occur. DDT and metabolites could cause reduction of insect populations and bioaccumulation in target fish species (and some non-target bird species).

Certainty:1 - Minimal
The toxicity of various pesticides is not well understood. A limited number of peer-reviewed studies for certain life stages of selected fish species exist. However, there is not much data for covered fish species available (Werner et. al., 2008). The effect that tidal marsh restoration will have on the availability of residual pesticides is greatly dependent on highly variable ecosystem processes affecting fate (degradation) and transport of pesticides. Additionally, legacy pesticides from 1960s (e.g. DDT) may be present on the restoration site and more recent (illicit) use is unknown.

Outcome N4: Resuspension and export of contaminants to downstream areas (A) mercury and methylmercury, (B) pesticides and herbicides (e.g. pyrethroids.

N4a: Covered fish species

Analysis of resuspension affects considers two separate physical settings: the restoration marsh sites and the adjacent tidal sloughs. The restored marsh sites are not likely experience much scour, since the adjacent tidal channels would be excavated as part of construction and the hard farm fields are not expected to scour easily. Adjacent tidal sloughs, which are typically comprised of more erodible substrate, may experience more scour both the bed and banks. The relationship between drivers and outcomes is described in Alpers et. al., 2008 (Figures 4, 7, and 8 and associated text) and Werner and Oram, 2008, Figure 1.

Magnitude: 1 - Minimal
The degree of scouring of pre-project soils depends on hydrodynamics. Scour could be a short-term phenomenon as channels reach geomorphic equilibrium. There is potential for increasing methylmercury concentrations in high-elevation marsh (infrequently wetted zone) and possible export of this to downstream environments.

Certainty: 2 - Low
Nature of this outcome is greatly dependent on highly variable ecosystem processes affecting fate (e.g.photodegradation of methylmercury) and transport.

Outcome N5: Creation of a population sink due to longer residence times with associated increased exposure to predators and entrainment.

N5a. All covered fish species

The logical argument is the possibility of large amounts of SAV and non-native fish species inhabiting this location and consequent high rates of predation on Delta smelt. In China Camp Marsh there is a net sink for mysid shrimp presumably due to large amounts of predation (Dean et al. 2005). Longer residence times mean more exposure to predators.

Magnitude = 2-Low
Rearing and migration rate are somewhat (not completely) at odds. Implicit in tidal restoration proposals is that fish will find "habitat" with food and stay to rear to a larger size. This implies that they are not migrating as fast as they might otherwise. Longer residence time means greater exposure to sources of mortality that come with the new "habitat" (Williams and Rosenfield, In preparation 2009). If a large percentage of the Delta smelt population spawned here and this outcome occurred here the magnitude could be higher. If not the magnitude could be lower.

Certainty = 4 - High
Lack of published studies in this system contributes to high uncertainty.

Outcome N6: Production of organic matter that will contribute to low dissolved oxygen (DO) conditions.

N6a. All covered fish species

General Observations: The relevant drivers and outcomes are described in Nobriga and Herbold 2008 (p. 25). Low dissolved oxygen concentrations occur during late spring through autumn in the San Joaquin River near Stockton (Jassby and Van Nieuwenhuyse 2006). It is also supported by the Stockton DW ship channel low DO conceptual model, at: http://www.sjrdotmdl.org/concept_model/about.htm
This restoration will produce organic matter that will contribute to low DO conditions. Organic carbon could be transported out of this restored marsh and the flow patterns would take this to problematic locations. (Note other problems may be caused by water treatment plants). (See the water quality group discussion).

Magnitude = 3 - Medium
Importing BOD to the Stockton DWSC will likely exacerbate low dissolved oxygen conditions in this area. This outcome may include increases in the frequency and magnitude of low DO incidents. LOW DO incidents reduce habitat available to fish species in the lower San Joaquin River; low DO conditions also inhibit use of the lower San Joaquin River as a migration corridor for anadromous fish species including Chinook salmon, steelhead, splittail, and (potentially) sturgeon (Stockton DWSC conceptual model: http://www.sjrdotmdl.org/concept_model/bio-effects_model/adverse.htm)

"The available information suggests that BOD concentrations contributed from [immediately upstream of the DWSC] are the primary factor affecting DO concentrations in [the ship channel] (Lehman 2003 and Stockton DWSC conceptual model: http://www.sjrdotmdl.org/concept_model/bio-effects_model/adverse.htm).

"Direct sources of BOD to [the DWSC] include the San Joaquin River and local sources from Smith Canal, the Calaveras River, Fourteen Mile Slough, and the Turning Basin. The San Joaquin River where it enters the DWSC at Channel Point is the greatest source of BOD to the DWSC (Lehman and Ralston 2001). One author found that at least 60% of the NBOD and CBOD in the DWSC at Light 43 (near Rough and Ready Island) were derived from the San Joaquin River (Lehman and Ralston 2001). The San Joaquin River also contributed 65% of the organic carbon, at least 70% of the ammonia load, and 40–60% of the VSS at Light 43 (Lehman and Ralston 2001).

Nitrogenous (ammonia and organic nitrogen) inputs from the Stockton Waste Treatment Plant are a major factor affecting BOD variations in the DWSC (Lehman 2003) and DO concentrations in the DWSC. Carbenaceous sources may account for 30% of BOD and "the phytoplankton biomass load from upstream primarily produced the carbonaceous oxygen demand" Lehman et al. 2004: 405).

Certainty = 2 - Low
The magnitude and timing of BOD exports from restored marshes into the Stockton DWSC are uncertain. Modeling exercises would be needed to understand this effect.

Important Gaps in Information and/or Understanding

Data needed to more fully evaluate tidal marsh restoration actions

- Residence times (average and spatial variance in that value) are necessary to determine how much and what kind of food would be produced on site and exported from the site. Residence time projections also affect temperature and dissolved oxygen conditions and these are important attributes of physical habitat. Finally, residence times for particles of water could inform assessment of "residence" times for fish. There is a non-linear relationship between fish "residence time" and the benefit of the rearing habitat as, at high "residence times" new habitat may serve to delay important migratory activities whereas at very low residence times, the new habitat will have reduced benefit because fish (or at least those that behave like particles) will experience the habitat for only a short period.
- A study of predator-prey-habitat interactions for Centrarchid fish.
- Striped bass model is needed to compile and synthesize life history information. This should also include a research study of predator-prey-habitat interactions.
- Expected retention time on restored tidal areas to understand likely productivity and food export potential to local sloughs.
- More spatially comprehensive hydrodynamics to understand whether changed flow patterns will reduce or simply redistribute predator pressure.
- Hydrologic and sediment information about turbidity levels, duration, and consequences on species as related to the following: Increased ability for Delta smelt to locate food due to increased turbidity from increased velocities in larger channels.
- *Corbicula* monitoring data from previous restoration sites in the Delta, such as Liberty Island or Little Holland Tract, would provide greater information about the probability of colonization on this Cache Slough site.
- Better data on where and when Delta smelt lay their eggs would better allow us to assess the potential impact of inland silverside predation.
- Data collection and analysis of whether relevant predatory species would be displaced by the expected changes in hydrodynamics in these sloughs.
- Modeling of a situation in which predators are displaced from the sloughs, and analysis of whether this would result in a reduced predator population in this region, or whether predators would simply relocate to another part of the migration corridor where hydrodynamics are more suitable (i.e. what is the new distribution of low velocity/tidally influenced habitat that could be suitable to predators?).
- Data collection and analysis of whether other predatory species (i.e. pikeminnow and striped bass, which prefer riverine habitats) benefit from the altered hydrodynamics.
- Liberty Island is often referred to as a model of a successful restoration project. Monitoring data and new bathymetric data should be fully analyzed to determine the features that makes Liberty Island successful and to consider how to apply those features to other restoration projects in the Delta. Specifically, the bathymetric data could be turned into a Digital Elevation Model (DEM) and combined with the habitat type mapping (i.e. vegetation and open water) to illustrate how the restoration provides habitat for covered and other species. This would include documenting the quality of existing LiDAR data for the vegetation mapping.

Research Needs

- Restoration techniques that will prevent colonization by invasive species.
- Management practices that can control invasive vegetation, clams, and predators (centrarchids and inland silversides) and limit colonization of these sites.
- Run (and life-history) specific studies of Central Valley Chinook salmon and studies of steelhead use of tidal marsh habitats would be extremely valuable to defining magnitude of impacts to these populations and increasing certainty. Various tools (including genetic markers and otolith signatures of population origin) could be used to asses both growth and survival of salmonids in tidal marsh habitats as well as changes in life history characteristics (survival and fecundity) over the course of the life cycle that arise from residence in tidal marsh habitats. Currently, all of the evidence for benefits of tidal marsh on salmonids comes from steelhead and fall run populations located well to the North (where high temperatures and invasive predators are not as problematic). Translating these results to all Central Valley salmonid populations is unwarranted and could lead to disastrous "restoration" projects.
- In addition, data on nutrient flow from the marsh plain to juvenile fish rearing in the adjacent channels is essential to determining the value of restored marshes as a food source for pelagic fish larvae (i.e. longfin and Delta smelt).
- Greater understanding and more research is needed about the availability and production of food in tidal marshes. Export of organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta has not been studied.
- Potential negative effects of methylmercury exposure on covered fish species remain largely unknown. Based on published studies involving other (non-targeted) fish species, there is reason for concern regarding possible chronic effects caused by methylmercury exposure, including: endocrine disruption, reduced reproductive success, reduced predator avoidance, and reduced feeding efficiency. (See Mercury Conceptual Model, Alpers et al. 2008, Table 4, page 30). Research is especially needed to determine possible effects caused by exposure during early life stages.
- A better understanding is needed regarding the relationship of mercury methylation to the duration of wetting and drying events in areas that are intermittently inundated (i.e. tidal marsh and floodplain). Laboratory and field studies of mercury cycling involving sediments in tidal marsh and floodplain environments should quantify the duration of drying time and the extent of dryness necessary to change the oxidation-reduction character of iron, sulfur, carbon, and mercury in sediments such that microbial activity associated with mercury methylation is enhanced.
- Tropho-dynamic model of ecological interactions linking primary production to the food web structure and production flows into, through, and out of the tidal marsh system.
- Landscape-level models that address the effects of variation in structural features of the tidal marsh environment (e.g., tidal channel complexity, channel width, channel length, edge: area ratios, etc.) on the population or production dynamics of specific plants and animals
- Future research could generate simulations of generic “applications” of the DRERIP Conceptual Models. For example, the temperature model could be “applied” to generic landscape characteristics, such as a restoration site with specific shapes (bowl or gradation), to consider how temperature dynamics are affected on various spatial and temporal scales. This exercise would help managers understand where further detail is needed by taking the conceptual models to the next level by conducting simulations to apply the concepts to a landscape.

Assess Reversibility and Opportunity for Learning

Reversibility

No/Hard. The following on-the-ground actions would be needed to reverse this action:

1) levees would need to be reconstructed
2) newly created tidal sloughs would have to be regarded
3) sites would have to be dewatered
4) wetland vegetation would have to be removed
5) newly installed levees would need to be removed as necessary
6) monitoring pre, during, and post construction

Although this reconstruction is technically possible, there would be significant financial and regulatory costs. Prior to action reversal, the following planning activities would be needed:

1) geotechnical evaluations for levee reconstruction
2) engineering design
3) evaluate land options for areas subject to subsidence reversal actions
4) environmental permitting and associated agency ESA consultation, Mitigation planning

Opportunity for Learning

High

Comments (refer to specific sources of information that support the above determination and identify high priority research questions and testable hypotheses).

High: Implementation of this project can be designed such that different engineering designs can be compared. Numerous physical and biological components can be monitored and ideally, the monitoring data would be used to assess and refine modeling simulations of the restoration as a part of a comprehensive adaptive management program. Please see text in the worksheet for Cache Slough, HRCM 4, for details.

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Appendix A Summary Tables Organized by Outcome

Table A1. Positive Outcomes

Outcome	Magnitude	Certainty
P1a: Increase rearing habitat area for Delta smelt.	1	2
P1b: Increase rearing habitat area for Fall-run Chinook salmon	2	2
P1c: Increase rearing habitat area for Splittail	2	3
P1d Increase rearing habitat area for Green sturgeon	2	2
P1e: Increase rearing habitat area for White sturgeon.	2	1
P2: Increase the availability and production of food in the Delta and Suisun Bay. All covered fish.	View #1: 3-4 View #2: 1-2	View #1: 3 View #2: 1
P3a: Locally provide areas of cool water refugia (Feb-Jun) for Delta smelt.	2	1
P3b1: Locally provide areas of cool water refugia (Feb-Jun) for spring-run salmon.	2	1
P3b2: Locally provide areas of cool water refugia (Feb-Jun) for fall run salmon	2	1
P3b3: Locally provide areas of cool water refugia (Feb-Jun) for steelhead.	2	1

Table A2. Negative Outcomes

Outcome	Magnitude	Certainty
N1a: Establishment of undesirable species such as SAV and Egeria	3	2
N1b: Establishment of undesirable species such as Non-native Centrarchids	4	2
N1c: Establishment of undesirable species …….. Corbicula	1	2
N1d: Establishment of undesirable species …….. Inland Silversides.	2	2
N2a: Potential for mercury methylation and local bioaccumulation … Covered fish species.	1	2
N2b: Potential for mercury methylation and local bioaccumulation Other species (not covered).	3	2 to 3
N2c: Potential for mercury methylation and local bioaccumulation … Human health.	2	3

N3a: Local effects of contaminants including toxicity from residual pesticides and herbicides …. Covered fish species.	1 to 2	1
N3b: Local effects of contaminants including toxicity from residual pesticides and herbicides ….. Other species (not covered).	1 to 2	1
N4a: Resuspension and export of contaminants to downstream areas … covered fish species.	1	2
N5a: Creation of a population sink due to longer residence times with associated increased exposure to predators and entrainment.	2	4
N6a: Production of organic matter that will contribute to low dissolved oxygen (DO) conditions.	3	2

Appendix B - Outcomes With Zero Magnitude

OP1a: Increase rearing habitat area (including physical and biotic attributes) for longfin smelt.

Longfin smelt do not occur frequently in this region. These fish do not appear to use tidal marsh habitats. The magnitude of this outcome is zero for this species.

OP1b: Increase rearing habitat area (including physical and biotic attributes) for steelhead.

Steelhead juveniles move through Delta from Jan-Jun, but mostly from late March-June. Salmonid model Fig 27. Steelhead conceptual model figure. The salmonid model indicates value of estuarine rearing varies across populations: (p15).

Magnitude = zero.
Outcome assumes that “rearing habitat area” (quantity) and/or food is limiting in this area. Model txt (p16)”Spring Chinook, or at least the Butte Creek population, pass quickly through the Delta, so habitat restoration there seems unlikely to do much for them. The same is probably true for late fall Chinook, and for steelhead.”

In other systems, steelhead use this kind of habitat but, the text notes, steelhead smolt in this system are large compared to other systems so research there is not likely to apply here. Steelhead will eat the types of food produced in this habitat. The DLO figure (Estuarine – growth) shows a low impact of this kind of habitat on competition – competition may have a moderate impact on growth.

Steelhead migrate through this area “mainly in April and May” (Salmonid model P 34.) High temperatures are common in this area during May (as indicated by an IEP gauge, rsan058, in the vicinity). Average daily temperatures exceed 20-21oC (beyond which sublethal effects accumulate; Reese and Harvey 2002 *and see* Richter and Kolmes 2005) during May in approximately 1/3 of years. In June, average daily temperatures exceed this critical threshold in almost every year. With warming that may occur under climate change projections, high temperatures may become more frequent and more extreme, even during April. Steelhead rearing in this proposed restoration site during May and June will probably be impacted by high temperatures and negative impacts could become more common with global warming.

Small benefits to some rearing steelhead may be largely offset by negative temperature effects to later rearing steelhead. This region has been highly altered by anthropogenic chemical inputs, channel modification, and invasive species (e.g., Brown and May 2006). Water quality in this area is notoriously poor: lethally low DO conditions occur throughout the year in the nearby Stockton Deepwater Ship Channel (including, occasionally, during the fall-run juvenile emigration period; http://www.sjrdotmdl.org/concept_model/bio-effects_model/lifestage.htm). In addition, the area is dominated by SAV and associated Centrarchid predators. Without action to correct water quality and flow problems in this area, construction of tidal marsh habitat is not likely to be successful in restoring native fish.

Certainty = 3 - Medium
No direct research on use of shallow estuarine habitat by steelhead in this system. Any effect will be limited to the San Joaquin population and to those times of year when temperatures are not too high in the target area.

In summary, estuarine habitat is not likely to be the limiting factor for steelhead from the San Joaquin River system.

OP2a: Locally provide areas of cool water refugia for winter-run salmon.

Magnitude = 0- Zero.
There will be no benefits of this restoration to winter-run salmon because this run passes through the region during a window of time when temperatures are not believed to be highly stressful to salmonids.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

OP2b: Locally provide areas of cool water refugia for late fall-run salmon.

Magnitude = 0- Zero.
There will be no benefits of this restoration to late fall-run salmon because this run passes through the region during a window of time when temperatures are not believed to be highly stressful to salmonids

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

OP2c: Locally provide areas of cool water refugia for spring-run salmon.

Magnitude = 0- Zero
Spring run do not occur in this south Delta area and so cannot receive the benefits of this restoration.

Appendix C: BDCP Info for South Delta ROA

BDCP Steering Committee
November 21, 2008

HANDOUT HABITAT #2

PRELIMINARY DRAFT—FOR DISCUSSION ONLY
Estimated Extent of Lands within Restoration Opportunity Areas that may be Suitable for Tidal Marsh Restoration Area by Elevation Class

Restoration Opportunity Area (ROA)	Area by Elevation Class (acres)										Total
	Upland (>+15 feet)[1]	Transitional Upland 2 (>+3-15 feet)[2]	Transitional Upland 1 (>+3-6 feet)[2]	Sea level Rise Accommoda-tion (>0-+3 feet)[2,3]	Tidal Marsh[4]	Subtidal 1 (<0-3 feet)[4]	Subtidal 2 (>-3-6 feet)[4]	Subtidal 3 (>-6-9 feet)[4]	Subtidal 4 (>9-12 feet)[4]	Subtidal 5 (>-12 feet)[4]	
South Delta ROA											
Fabian	N/A	46	425	1,166	2,303	1,397	368	12	0	0	5,717
Union Island	N/A	393	1,514	3,646	5,032	3,777	1,848	59	0	0	16,269
Upper Roberts Island	N/A	1,141	2,257	3,179	4,671	2,556	731	79	1	1	14,616
Subtotal	N/A	1,580	4,196	7,991	12,006	7,730	2,947	150	1	1	36,602

BDCP Steering Committee
November 21, 2008

HANDOUT HABITAT #3

PRELIMINARY DRAFT—FOR DISCUSSION ONLY

Potential Opportunities for Tidal Marsh Restoration by ROA based on Implementability, Suitability, and Cost (Does not include assessment of covered fish species benefits.)

Restoration Opportunity Area and Land Units	Potential Opportunities for Tidal Marsh Restoration (acres) [1]					
	Very High[2]	High[3]	Moderate[4]	Low[5]	Very Low[6]	Total Potential
South Delta ROA						
Fabian	0	0	0	4,900	370	5,270
Union Island	0	0	0	0	12,500	12,500
Upper Roberts Island	0	0	0	10,400	730	11,130
Subtotal	0	0	0	15,300	13,600	28,900

			Viewpoint 1		Viewpoint 2	
Outcome Code	**Covered Spp.**	**Description**	**Magnitude**	**Certainty**	**Magnitude**	**Certainty**
Positive Outcomes						
P2a	All	INCREASE THE AVAILABILITY AND PRODUCTION OF FOOD IN THE DELTA AND SUISUN BAY BY EXPORT FROM THE SOUTH DELTA OF ORGANIC MATERIAL VIA TIDAL FLOW FROM THE NEW MARSH PLAIN AND ORGANIC CARBON, PHYTOPLANKTON, ZOOPLANKTON, AND OTHER ORGANISMS PRODUCED IN NEW INTERTIDAL CHANNELS.	3-4	3	1-2	1
P3a	Delta smelt	Locally provide areas of cool water refugia for Delta smelt and Salmonids	2	1		
P1a	Delta smelt	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	1	2		
P1b	Fall-run Chinook Salmon	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	2		
P1d	Green sturgeon	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	2		
P1c	Splittail	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	3		
P1e	White sturgeon	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	1		

Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
Negative Outcomes						
N4a	All	Resuspension and export of mercury and methylmercury to downstream areas	1	2		
N3a	All	Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids	1-2	1		
N2a	All	POTENTIAL FOR MERCURY METHYLATION AND LOCAL BIOACCUMULATION TO AFFECT TARGET SPECIES	1	2		
N1b	All	Establishment of undesirable species (such as Centrachids,) that will prey or compete or alter habitat conditions for covered fish	4	2		
N1a	All	Establishment of undesirable species (such as egeria,) that will prey or compete or alter habitat conditions for covered fish	3	2		
N6a	All	Production of organic matter that will contribute to low dissolved oxygen (DO) conditions	3	2		
N5a	All	Creation of a population sink due to longer residence times with associated increased exposure to predators and entrainment.	2	4		
N1c	All	Establishment of undesirable species (such as Corbicula,) that will prey or compete or alter habitat conditions for covered fish	1	2		
N1d	Delta smelt	Establishment of undesirable species (such as Inland Silversides,) that will prey or compete or alter habitat conditions for covered fish	2	2		
N2c	Human health	POTENTIAL FOR MERCURY METHYLATION AND LOCAL BIOACCUMULATION TO AFFECT WILDLIFE: N2-A - TARGET SPECIES, N2-B, NON-TARGET WILDLIFE SPECIES, N2-C, HUMAN HEALTH.	2	3		
N3b	Others	Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids	1-2	1		
N2b	Wildlife	Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A - Target species, N2-B, Non-target wildlife species, N2-C, Human health.	3	2-3		

Viewpoint 1 Advective-driven transport of Cache Slough productivity will provide important and very substantial productivity contributions to larger regions of the northwestern Delta.

Viewpoint 2 Export from the restored marsh will be non-existent when Yolo Bypass is not flowing therby limiting productivity contributions beyond the restoration area.

HRCM 8:
East Delta ROA Tidal Marsh & Shallow Subtidal Restoration

Incomplete Working Draft
Scientific Evaluation Worksheet

Note about this "Incomplete Working Draft": this document is not completed. The Tidal Restoration Evaluation Team had limited time for this evaluation. Much information has been replicated from the Cache HRCM 4evaluation and has not been revised throughout to reflect the specific restoration sites and geographies of this ROA.

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Action:

HRCM8: East Delta ROA Tidal Marsh & Shallow Subtidal Restoration

Restore 1,300 acres to tidal action and vegetated tidal marsh and 300 acres of shallow subtidal habitats on portions of Canal Tract, Terminus Tract, and Bract Tract in the East Delta ROA (see Figure 1, below).

Evaluation Team: Tidal Marsh Workgroup

Dave Harlow (chair); Stuart Siegel (coach); Dan Kratville; Jon Rosenfield; Chris Enright; Armin Munevar; Wim Kimmerer; Amy Richey; Charlie Alpers; Kateri Harrison (note taker).

Date of Last Revision: May 21, 2009

Approach

1. Construct levees to isolate deeply subsided lands and protect property.
2. Plant tules or place fill material to raise elevations of shallowly subsided lands.
3. Create channels and/or berms to encourage the development of dendritic tidal channels.
4. Breach levees to reintroduce tidal exchange to leveed lands.
5. The canal levees of the eastern alignment of an around-Delta conveyance facility may be incorporated into the design of intertidal emergent wetland restoration. For example, in locations where the conveyance canal is located at elevations at or below elevations suitable for restoration of intertidal marsh, marsh may be restored to the east of canal levee, with the canal levee forming the western boundary of the restored marsh.

Intended Outcomes as Stated in Conservation Measure

1. Increase rearing habitat area for Sacramento splittail and San Joaquin Chinook salmon and possibly steelhead.
2. Increase the production of food for rearing salmonids, splittail, and other covered species.
3. Increase the availability and production of food in the east and central Delta by exporting organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta.
4. Locally provide areas of cool water refugia for Delta smelt.

Conceptual Model Information Regarding Intended Outcomes

The drivers and outcomes discussed in this worksheet are described in the following DRERIP conceptual models: Temperature, Delta smelt, Foodweb, Tidal marsh, Corbicula, Sediment, and Mercury. The references listed at the end of this document provide additional information.

Assumptions

Provided in BDCP Conservation Measure

1. Restoration would occur on Terminus Tract, Bract Tract, and Canal Tract.

Added by Evaluation Team

1. Restoring tidal marsh habitat on the different tracts of the East Delta ROA will have varying levels of both positive and negative effects. For example, some of tracts may be more efficient at the methylization of mercury and so may have a higher magnitude score for an associated negative outcome. Differences in hydrology, topography, soils, and land-use history will also manifest as distinctions in success of this action among the tracts. BDCP's estimated extent of restoration types based upon elevation for each sub-area is presented in Appendices C and D.

2. The time frame for realizing restoration benefits depends upon the approaches used. Reversal of subsidence on restored areas can take several years to a decade or more depending on starting elevations. The accretion rate depends on sediment supply and biomass accretion which depends on site-specific conditions. Sediment supply in the Delta is generally very low (Schoellhamer et. al., 2007).

3. Efforts to reverse subsidence before active restoration would be focused on the more deeply subsided portions of these landscapes, i.e., lands more than 6 feet below low tide. There is a hypothesis that shallow open water regions located contiguous to emergent tidal marsh provide enhanced ecosystem complexity and functions compared to those tidal marsh habitats located directly adjacent to deeper sloughs. Although this hypothesis has not been tested, preliminary information on current conditions at Liberty Island and Little Holland Tract suggest support. However, the details of these sites are not readily available to the broad research community at this time and so the information is anecdotal. This assumption also includes a time limit to allow for subsidence reversal so that restoration of an entire parcel is not delayed indefinitely. To speed up the subsidence reversal process, an alternative method would be to separate low-lying areas with new levees and reconnect those areas after subsidence reversal is accomplished.

4. Source of fill material will be identified and use of all material, including dredge spoils, will be approved by the RWQCB.

5. Tidal water would travel through Sycamore Slough.

6. Water output from the site, post-restoration, will meet water quality standards.

7. Prior to implementation, a Phase I Environmental Assessment with on-site sampling to assess legacy and other soil contaminants (i.e. mercury and pesticides) would be completed.

Problem(s) with Action as Written:

1. Since rearing habitat for juvenile fish by necessity includes local availability of food, the evaluation team merged the Intended Outcomes 1 and 2 (tidal marsh, rearing habitat, and local food) into one outcome.
2. Existing sloughs in the East Delta ROA are currently infested with aquatic weeds and function as a "biological desert". Remediation of this existing situation is not described in this action.
3. Fish will need to traverse the lower reaches of barren Hog and Sycamore sloughs.
4. This area's very poor exchange rates with the broader Delta will likely offer little benefit for exported production.
5. Loading of fill material on top of a shallow island may compress the underlying soils. This approach may not yield the intended result. A close study of existing soil conditions including analysis of the local soil map is needed to further evaluate this issue.
6. The conservation measure would benefit from an explicit recognition that restoration of tidal marsh functions on subsided landscapes, especially those subsided below emergent vegetation elevations, will take many years to many decades. In the interim, restoration sites below vegetation elevations will function as shallow subtidal habitat.
7. It is unlikely that intertidal mudflats will develop in the Delta because dominant intertidal emergent vegetation species in the Delta can grow throughout the tidal range and just into shallow sub tidal elevations (Brown 2003, Simenstad et. al., 2000 as cited in Schoellhamer et. al., 2007, p.26).

Scale of Action:

Small

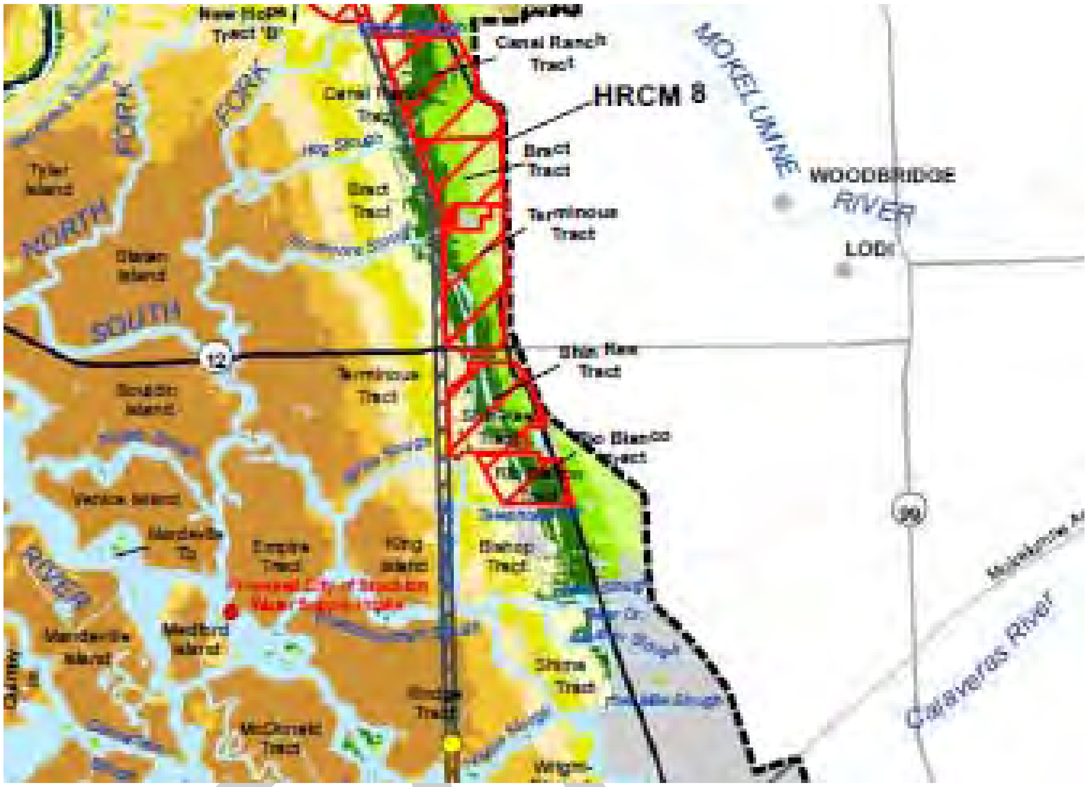
Rationale:

This is a small scale restoration action due to its limited spatial extent. As listed in Table1 below, the Delta currently has approximately 21,600 acres of tidal marsh habitat (baseline). Additionally, 67,000 acres of diked and other lands have been identified as potentially restorable to tidal marsh (neglecting effects of restoration on reducing tidal range). The proposed 1,300 of tidal marsh plus 300 acres of shallow sub-tidal restoration options would increase marsh acreage 6% above current conditions. Significant amounts of the 67,000 acres of identified restorable lands are highly constrained such that they could not be restored in the near term (South Delta and Netherlands alone account for 31,000 acres of the 67,000 acres). Therefore, this action also represents an important part of the potentially restorable tidal marsh lands.

Table 1. Summary of Tidal Marsh Acreages

Area	**Acreage**	**Source**
Delta (entire Delta proper)	738,000	DWR, 2009
Historic tidal marsh/wetlands in Delta	525,000	TBI, 2002
Current extent of tidal marsh/wetlands in Delta.	21,600	TBI, 2002
Restorable intertidal lands within Delta.	67,000	CA DVSP, 2008, Table 1, p.77.
Proposed East Delta tidal restoration (this action)	1,300 tidal marsh 300 sub-tidal	BDCP, 2009

Figure 1. East Delta Restoration Opportunity Areas



Evaluation Summary

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Note: Negative outcomes are scored relative to baseline conditions. These negative mechanisms may also decrease the certainty that positive effects of site restoration will be realized. Appendix "A" contains the above information in summary tables that are organized by the numerical order of the outcomes, rather than species.

Outcomes with Zero Magnitude

During the Evaluation process, several of the outcomes identified by BDCP early in the process, were found to have a zero magnitude. These outcomes are listed below and their evaluation is provided in Appendix B.

- OP1. Increase rearing habitat area (including physical and biotic attributes) for longfin smelt
- OP2. Increase rearing habitat area (including physical and biotic attributes) for Delta smelt
- OP3. Increase rearing habitat area (including physical and biotic attributes) for steelhead.
- OP4a: Locally provide areas of cool water refugia for winter-run salmon.
- OP4b: Locally provide areas of cool water refugia for late fall-run salmon.

Other Potential Negative Outcomes Identified, Not Evaluated

During the course of this evaluation, the tidal marsh team identified one potential negative outcome that it did not evaluate due to lack of time. It is recommended that this potential outcome be evaluated at some point in the future when additional time is available.

- ON1. Pesticides for mosquito control.
- ON2: Increase in the availability of selenium
- ON3: Resuspension and export of contaminants to downstream areas effects on non-covered wildlife species

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

No

Nature of Change:

This small scale action to restore 1,300 acres of tidal marsh and 300 acres of shallow subtidal habitat may change the environment on a local scale but not to such an extent that our current understanding of boundary conditions (Harrell et al 2008), hydrodynamics, and ecological processes in the Delta would change.

Overview of Productivity Import-Export

The Cache Slough evaluation worksheet (HRCM4) provides a complete discussion of productivity levels, import and export. Here we describe how conditions may differ from Cache Slough in order to provide the Conservation Measure evaluation appropriate specificity.

- East Delta has less tidal exchange (compared to Cache) due to geographic location (farther away from a river channel etc).
- The small area to be restored in East Delta ROA may result in less primary production (compared to Cache).
- May experience increased primary production compared to other restoration sites because its easterly location offers warmer spring and summer temperatures. However, the scale of the action is small in size and it is highly uncertain whether any of this production will be exported or will benefit covered fish species.

Potential Positive Ecological Outcome(s)

Outcome P1: Increase rearing habitat area (including physical and biotic attributes) for covered fish species.

As indicated at the beginning of this worksheet under the section entitled "Problems with Action", the team decided to merge two Intended Outcomes (rearing habitat and local food) into one outcome, P1, as shown below because rearing habitat for juvenile fish by necessity includes local availability of food. This outcome includes food (both primary and secondary production) produced within the vegetated marsh, within marsh channels, and within the subtidal areas adjacent to the vegetated marsh. General information that applies to salmon runs is provided in the worksheet for HRCM 4 – Cache Slough, Outcome P1c on page 15. Please note that green and white sturgeon are not known to utilize the Cosumnes and Molkemne River systems and so these species are not listed in the analysis below.

P1a. San Joaquin River/eastside Fall-run Chinook salmon & steelhead

General Observations: Fall-run juveniles move through the Delta from in the winter and spring (Williams and Rosenfield, In preparation, figure 3 and see also page 15 that shows the value of estuarine rearing varies across runs). Tidal exchange in some of these marshes will be hard to accomplish and residence times in the channels leading to the Marsh will be high. This will expose emigrating salmon and steelhead to poor habitat conditions for extended periods and delay successful emigration.

Magnitude = 2 - Low
Outcome assumes that "rearing habitat area" (quantity) and/or food is limiting. Page 16 of Williams and Rosenfield, In preparation, states that "Fall Chinook […] could benefit strongly from tidal marsh restoration". Fall Chinook generally enter estuarine habitats at a small size and the text anticipates benefits from additional rearing/growth opportunities. Fall run will eat the types of food produced in this habitat.

San Joaquin River and eastside fall-run migrate through this area from January and into June, with a pulse in May ((Williams and Rosenfield, In preparation) Figure 3). High temperatures are probably common in this area during May (as indicated by IEP gauges in the lower San Joaquin River, rsan 007 and rsan058). Average daily temperatures exceed 20-21^{o}C (beyond which sublethal effects accumulate; Reese and Harvey 2002 and see Richter and Kolmes 2005) during May in many years. In June, average daily temperatures probably exceed this critical threshold in almost every year. With warming that may occur under climate change projections, high temperatures may become more frequent and more extreme, even during April. Steelhead rearing in this proposed restoration site during May and June will probably be impacted by high temperatures and negative impacts could become more common with global warming.

The limited scale of this restoration proposal, the small number of fall-run likely to rear in this area, and the relative isolation of the proposed restoration sites from migratory corridors make the likely magnitude of this outcome undetectable. Benefits to some rearing Chinook salmon may be largely offset by negative temperature effects to later rearing steelhead.

Certainty = 2-Low
Because of the small scale of this project, its relative isolation from salmon migratory corridors, the high temperatures that are likely to persist through a large portion of the rearing season and the many other factors limiting fall run production in the San Joaquin River, it is moderately certain that the positive magnitude of this action will be minimal at best.

Establishment of *Corbicula*, could limit, if not eliminate the productivity benefits of the restoration to Chinook salmon. See Negative Outcome N1b. Similarly, colonization by invasive predators could result in added mortality that would counteract any benefits of restoration (especially if SAV invasion facilitates predation success).

P1b. Splittail

General Observations: The relationship between the drivers and outcomes is described in Kratville, 2008 on pages P1h Pg 12, 13, 14, 15.

Magnitude = 2 Low
While more tidal marsh will help rearing of juvenile splittail, the expected benefit to the overall population is medium. Sacramento splittail population abundance is limited by the lack of floodplain inundation to provide spawning habitat. When large scale inundation occurs, splittail population abundance is high for several years following the inundation event. Long periods without floodplain inundation results in reduced splittail population abundance. Splittail do not appear to be habitat limited at other life history stages.

Certainty = 3 - Medium
Whether the proposed restored rearing habitats will result in increased splittail population abundance is not certain. Although the restored habitat will increase the opportunity for rearing juveniles to feed during their downstream migration, tidal marsh does not appear to be a limiting factor in splittail abundance compared to floodplain inundation. The bulk of the adult splittail population resides in the brackish areas of Suisun Marsh. It is anticipated that most of the restored marsh in this ROA will be freshwater and so will only provide habitat for juvenile fish migrating into Suisun Marsh. This restoration may not provide a new population center or increase the numbers making it to Suisun Marsh. The restoration site is not located directly downstream of a floodplain and so its use by out-migrating fish may be limited.

Establishment of *Corbicula*, could limit, if not eliminate the productivity benefits of the restoration to splittail. See Negative Outcome N1b. Similarly, colonization by invasive predators could result in added mortality that would counteract any benefits of restoration (especially if SAV invasion facilitates predation success).

P1c. Green Sturgeon

General Observations: The basic relationship between drivers and outcomes is described in Israel and Klimley, 2008, pages P1i Pg 4, 8, and 9.

Magnitude = 2 - Low
Information on green sturgeon diets and physical habitat needs as juveniles in the Delta is limited. Other species of juvenile sturgeon located in other systems do feed on drifting insects (Radtke 1967 and McCabe, G et al. 1993). This area of the Delta will not provide extensive mud bottoms as found in lower portions of the estuary. Soft bottom benthos are a food resource for the sturgeon. Most habitat limitations for green sturgeon appear to occur outside of the restoration area (i.e. upstream and downstream), as described on pages 4, 8, 9 in Israel and Klimley, 2008 and pages 19-21 of Israel et. al., 2009. It is unknown to what extent adult sturgeon used freshwater tidal marsh for foraging. The impact to individual sturgeon may be low but the extreme loss of freshwater tidal marsh in the Delta may have lowered the carrying capacity of the entire system for sturgeon. See pages 4, 8, 9 in Israel and Klimley, 2008 and pages 19-21 Israel et. al., 2009 for more detail.

Certainty = 2- Low
There is minimal certainty about whether this proposed restoration will benefit sturgeon as described in this outcome. The minimal certainty is due to the lack of research on this aspect of sturgeon biology/ecology in the Delta. Most of the available information on sturgeon diets and predator/prey relationships is based upon other species of sturgeon, located outside of this system.

P1d. White Sturgeon

General Observations: The basic relationship linking drivers to outcomes is described in pages 1j, 19, 20, and 21 in the DRERIP White sturgeon model (Israel et. al., 2009).

Magnitude = 2 -Low
Information on white sturgeon diets and physical habitat needs as juveniles in the Delta is limited. Other species of juvenile sturgeon (located in other systems) do feed on drifting insects. . This area of the Delta will not provide extensive mud bottoms as found in lower portions of the estuary so benthic food items are expected to be limited in this restoration (Siegel, personal communication, Feb. 2009). Habitat limitations for white sturgeon appear to occur upstream and downstream of the restoration area (i.e. outside the ROA).

Certainty = 1 - Minimal
There is minimal certainty about whether this proposed restoration will benefit sturgeon as described in this outcome. The minimal certainty is due to the lack of research on this aspect of sturgeon biology/ecology in the Delta. Most of the available information on sturgeon diets and predator/prey relationships is based upon other species of sturgeon, located outside of this system.

Outcome P2: Food resources (i.e. organic material from the marsh plain and organic carbon, phytoplankton, zooplankton, and other organisms from intertidal channels) produced on the restored marsh will be exported, via tidal flow, and contribute to food availability downstream in the eastern and central Delta.

P2a. All covered fish species

General Observations: The Tidal Marsh and Foodweb models [Kneib et. al., 2008, page 9 and Durand, 2008, section 2.16)] provide a general indication that there may be a linkage between tidal marsh habitat as a driver and increases in availability and production of food resources as an outcome, but that the mechanism for this linkage may be movement by fish. The tidal marsh conceptual model also states that freshwater tidal marshes are net exporters of high-quality organic production (page 2 in Kneib et. al., 2008). See also Dame et al. 1986, Kimmerer and McKinnon 1989, Kneib 1997, Lucas et al. 2009. Please see the evaluation worksheet for action # HRCM4-Cache/Yolo, Outcome P3, for more details about **Tidal Marsh Contributions to Exported Production.**

There was disagreement within the evaluation team regarding the magnitude and certainty of expected benefits of tidal reintroductions with regard to the export of food (phytoplankton, zooplankton, insects, and small fish) to areas downstream of Rio Vista and the likely benefits to covered fish species. In the spirit of presenting the scientific discourse, both points of view are captured below.

Two key questions discussed were: (1) can we predict the sign of the flux of productivity (i.e. will the restoration area be a source or a sink for primary and secondary productivity); and (2) will there be adequate advection to move material out of the restoration area and downstream to Rio Vista (assuming the restoration area is a source of productivity, as opposed to a sink). Additional information and analyses is needed to better answer these key questions. To develop this additional information, the team recommends future development of a Tropho-dynamic model as described in the section on page 41 entitled "Research Needs".

Viewpoint #1

Please see the text of Outcome P3 in worksheet HRCM4 – Cache Slough for additional background information about Viewpoint #1.

Magnitude = 3-4 – Moderate to High
Without advective connection, restoration will still have significant productivity benefits to covered fish species and to many other species due to providing areas of highly functional habitat in conjunction with restoration elsewhere that collectively provide fish species a range of options that spread risk through exploiting available resources when they are present. Refer to Ted Sommers, IEP Estuarine Ecology

Team or CAERS poster. In addition, these areas would export that productivity through the "trophic relay" concept described in the tidal marsh conceptual model (fish export the productivity).

Certainty = 3 – Moderate
Certainty is reduced by the potential for establishment of invasive clams that could consume substantial portions of phytoplankton and hinder zooplankton productivity.

Viewpoint #2

Please see the text of Outcome P3 in worksheet HRCM4 – Cache Slough for additional background information about Viewpoint #2.

Magnitude = 1-2 Minimal to Low
The implied relationship is that restored tidal marsh will export nonliving and living organic matter including plankton and fish, thereby supporting foodwebs of the upper estuary. An implicit assumption is that any increase in the area of shallow habitat would result in enhanced plant productivity some of which would be exported.

Certainty = 1 - Minimal
The sign of the signal is difficult to determine, except for total organic carbon, most of which is dissolved. Although dissolved organic carbon (DOC) will likely flow out of the marsh, fluxes of other components may be in or out (Kneib et. al., 2008, page 9). Colonization by invasive clam species can wipe out the food web

production effect entirely. We have no certainty at all that they will not colonize. In addition, colonization of the site by vertebrate consumers (e.g, inland silverside) can also significantly reduce the amount of food available for export beyond the site boundaries (Moyle 2002). There is evidence from within this system (Dean et al. 2005) that restored marshes can act as sinks for certain zooplankters; in this case, the sign of the signal would be negative.

Outcome P3: Provide local areas of cool water refugia for Delta smelt and salmonids

The cause and effect relationship associated with this outcome is described in Stacey and Monismith 2008, Malamud-Roam 2000, and Enright 2008. Considering the landscape scale (medium) of the action, the relationship between tides, physiography, and water temperature could be moderate. The relationship between drivers (wind, insolation, fetch, tides, currents) and linkages (long-wave, short wave, latent, and sensible heat flux) is complex and may produce both warmer and cooler water on a variety of time and space scales. Larger spatial gradients of water temperature will likely occur. The frequency of threshold temperatures for various species is uncertain. See Stacey and Monismith (2008), Malamud-Roam (2000), Enright (2008).

For more details, please see the introductory text in the HRCM 4- Cache Slough action worksheet and the Suisun Marsh Tidal Marsh Restoration Worksheet, specifically, Outcome P4.

P3a: Delta smelt

Magnitude: 2 - Low
The spatial extent of cool water refugia could be relatively limited. However, in some cases a large effect could be felt across relatively large area across the range. Please refer to the discussion located in HCRM4 – Cache Slough Restoration Action, Outcome P4, page 25 for more details.

Certainty: 1 - Minimal
The basis for our understanding is a single unpublished study in Suisun Marsh. The extent to which this effect may transfer to the restoration site, and to which Delta smelt and salmon will take advantage of it, cannot be predicted.. Please refer to text in outcome P4 of HCM4 – Cache/Yolo Restoration Action Outcome P4, page 27 for more details.

P3b. Salmonids

High temperatures are currently rare during May (as indicated by IEP gauges rsac075 and rsac054; Enright *pers. comm.*). Temperatures exceeding 20-21°C (beyond which sublethal effects accumulate; Reese and Harvey 2002 *and see* Richter and Kolmes 2005) are more common and widespread in June, July, and August (as indicated by IEP gauges rsac075 and rsac054; Enright pers. comm.). With warming that may occur under climate change projections, high temperatures may become more frequent and extreme. Thus, Chinook salmon (spring-run and fall-run) and steelhead rearing in this proposed restoration site during June and July will probably be impacted by high temperatures. Forces that reduce those temperatures may improve survival, growth and smoltification success.

Benefits are limited to those emigrants rearing in this habitat after May, when temperatures in this region increase above optimal rearing threshold of 12-16°C (Marine and Cech 2004). These benefits are expected to be transient (on annual and decadal time scales) and will never effect more than a small fraction of populations for any of the covered species (unless there is a cumulative impact from numerous restoration that produce the same cooling effect. Also, as mentioned in the description, this phenomenon is transient over time as the timing of tidal cycle shifts. Complexity of thermodynamics in conjunction with local geomorphology and long-term climate change and sea level rise introduce considerable uncertainty.

In addition to the runs listed below, please see Appendix B for winter-run etc.

P3b1: Spring run salmon

Magnitude = 2- Low.
This outcome modifies Outcome P1 (creation of habitat). In evaluating that outcome, benefits of this action were interpreted in the light of unfavorable temperature conditions that occur in the area during late-spring and summer. To the extent that the tidal flooding/cooling phenomenon occurs on this restoration site (a function of geography and restoration design and site elevations) during the period of potential thermal stress (May through end of summer), it may provide some relief from the effects of thermal stress *for those salmon runs that migrate through this region at this time (fall and spring run and steelhead).* That benefit impacts only the proportion of the population that migrates at this time and only the proportion of the population that migrates through this area.

Certainty = 1-Minimal

Certainty is minimal for reasons similar to that described in P3a, above. This outcome is highly dependent upon highly variable ecosystem processes. Although scientists have a reasonable understanding at the general level, the range of data needed to evaluate at the action scale is lacking.

P3b2: Fall run salmon

Magnitude = 2- Low
Beneficial effect occurs for only a portion of the salmonid population passing through this region during a particular and narrow window of time.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

P3b3: Steelhead

Magnitude = 2- Low.
Beneficial effect occurs for only a portion of the salmonid population passing through this region during a particular and narrow window of time.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

Potential Negative Ecological Outcome(s)

Outcome N1: Establishment of undesirable species (such as Egeria) that will prey or compete or alter habitat conditions for covered fish.

Harmful invasive species have the potential to cause two types of adverse effects. First is to worsen conditions relative to the existing baseline; i.e., creating an attractive nuisance. Second is to detract from achieving the positive benefits the action could provide. The magnitude and certainty scores below are based upon an assessment relative to baseline conditions. The scores below for N1a to N1d do not represent the potential to distract detract from the positive benefits of the action because these deductions were considered i by reducing the certainty scores for positive outcome # P1. Where appropriate, the impacts associated with the establishment of harmful invasive species on the restored marsh are discussed below.

N1a: Submerged Aquatic Vegetation (SAV) (including *Egeria*)

General Observations: As described in the conceptual model, the establishment of SAV is controlled by local flow conditions and substrates (Anderson, In Preparation). Many aspects of SAV physiology are influenced by local flow conditions including turbidity and to some extent flow velocity which if too high can scour suitable substrate precluding SAV establishment. The initial establishment of SAV is an intermediate outcome and the development of a large sustainable SAV population is the final outcome.

The basic relationship between drivers and outcomes is described in the DRERIP aquatic vegetation conceptual model on pages 8, 9 10 and Figure 2 (Anderson, In preparation). Please note that establishment of SAV reduces the certainty that the positive outcome, P1 will occur. This has been noted in the scoring for P1.

Magnitude = 3 - Medium
The establishment of SAV in general is controlled by local flow conditions and substrates. Local flow conditions control many aspects of SAV physiology, most importantly in this area turbidity. In nearby Liberty Island where turbidities are generally higher due to wind wave action, SAV is restricted to shallow near shore areas (Ustin et al. 2008). If turbidities are high in the restoration area, then SAV establishment and growth may be reduced to levels similar to Liberty Island. If not, there is the potential for SAV amounts similar to Franks Tract. The substrates in this area would be expected to support establishment of SAV (Anderson, In preparation). Small to moderate fractions of all the covered fish species may experience highly significant but localized effects due to SAV and therefore the net effect is medium.

For this outcome, the baseline condition is that much of the existing 21,600 acres of Delta tidal marsh is infested with submerged aquatic vegetation (Ustin, 2008). The restoration of a tidal marsh that eventually becomes infested with SAV is significant. Large, sustainable populations of SAV will produce significant changes in water quality (turbidity, pH, DO and temperature), or water flow characteristics (velocity and direction), which in turn can affect the quantity and quality of sediments (Anderson, In Preparation).

Eventually, the clarity of water entering the site from upstream will increase by lowering velocities and allowing particulates to settle out of the water column. This increased water clarity could increase predation of fish entering the site from outside areas (i.e. predators now have greater visual range). One type of predator, Centrarchid fish, is strongly associated with SAV and increased Centrachid populations may create a population sink for native fish at this location, as discussed in N1b, below. In summary, this action will worsen conditions beyond that of baseline conditions and small to moderate fractions of all the covered fish species may experience highly significant but localized effects due to SAV. Given the rarity of Delta smelt, the impact of SAV establishment could be particularly significant on this species.

Certainty = 2 - Low
There is high uncertainty about the initial colonization and ultimate patch distribution of SAV on the substrate. As the substrate softens over time, it may be more conducive to SAV establishment and growth (i.e. bed characteristics are described as a driver in the conceptual model). It is well documented that the physical structure of SAV facilities slower water velocities which allows sediment particles to settle, thereby reducing turbidity, locally and creating a positive feedback loop for more SAV establishment (Anderson, In Preparation). The effect of specific restoration site substrate, how those substrates may change over time after restoration, and the role of flow velocity at these locations is not well understood (Anderson, In Preparation).. The uncertainty of this outcome is largely dependent on how the final marsh system functions (Anderson 2007). Future changes to water salinity in the eastern Delta may affect the certainty score related to this outcome.

N1b: Non-native Centrarchids

General Observations: Centrarchid fish, as an assemblage, cover a range of ecological niches in the Delta. They are competitors for resources as well as predators on native fish. The magnitude of this effect is dependent on the assemblage of centrarchids that invade and the size of the populations. This is in turn partially dependent on the amount of SAV invasion into the restored system.

Please note that establishment of centrachids reduces the certainty that the positive outcome, P1 will occur. This has been noted in the scoring for P1. The relationship among drivers and outcomes is described in Brown and Michniuk 2007; Grimaldo et al. 2004; Nobriga and Feyrer 2007; Nobriga et al. 2005).

Magnitude = 4 - High
For this outcome, the baseline condition is that much of the existing 21,600 acres of tidal marsh are excellent habitat for Centrarchid fish where they are associated with adjacent deeper water. This is illustrated by the large number of Bass Tournaments that occur in the Delta. The Delta is a stop on the national professional bass fishing circuit with $100,000 prizes. This action could worsen conditions beyond that of baseline. Centrachids are a concern because they prey upon and compete for food and other resources with native covered fish.

The establishment of Centrarchids in conjunction with SAV is well documented, especially in this portion of the Delta (Brown and Michniuk 2007; Grimaldo et al. 2004; Nobriga and Feyrer 2007; Nobriga et al. 2005). Centrarchid fish, as an assemblage, cover a range of ecological niches in the Delta. They are competitors for resources as well as predators on native fish. The magnitude of this effect is dependent on the assemblage of Centrarchids that invade and the size of the populations. This is in turn partially dependent on the amount of SAV invasion into suitable habitat areas of the restored system. The extent of their impact on the native ecology of the restored marsh is partially dependent on the extent of SAV establishment and patch size. It is highly probable that Centrarchid fish will become established in this area as they have everywhere else in the Delta.

Certainty = 3 - Medium
It is highly probable that Centrarchid fish will become established on this restoration site. However, once established, the ultimate size of the centrachid population and their impacts to local native fish are less certain. In areas with low SAV patch size, the numbers of Centrarchid fish and their presumed impact on native fish are lower then where the opposite is true (Brown and Michniuk 2007).

N1c: *Corbicula*

The relationship between drivers and outcomes is described in the DRERIP Corbicula Conceptual Model (Thompson et. al., In revision).

Consequences of *Corbicula* establishment. If established, *Corbicula* would likely have a significant effect on food web dynamics because it consumes phytoplankton in shallow areas and/or consumes the productivity of shallow areas exported to channels to such a high extent that it exhibits top-down trophic control. *Corbicula*'s consumption of primary productivity represents a significant limiting factor throughout the Delta that could greatly reduce productivity benefits of restoration efforts (Thompson et. al., In revision). According to the *Corbicula* model (Thompson et. al., In revision page 11), no local studies have been undertaken to indicate whether *Corbicula* feeding has reduced zooplankton populations either through competition or direct predation. In this case, the baseline condition is that much of the Delta is infested with *Corbicula*. The restoration of tidal marsh which may also become infested with *Corbicula* at some future time would not represent a significant change above baseline conditions. Establishment of *Corbicula* would however, consume much of the positive benefits that were previously discussed above under positive outcomes.

Potential Control Options. There are no stressors identified that can limit the success of Corbicula in a significant manner. However, salinity can limit the spatial distribution of this species and food limitation is a source of stress (Thompson et. al., In revision, pages 8 and 13). The *Corbicula* conceptual model indicates that the only meaningful method to control their presence/abundance is salinity. This control method would require salinity intrusions into the restoration area of sufficient duration and at the appropriate times of year to have a meaningful effect. The conceptual model does not specify the duration and timing which might be most effective during recruitment. Water temperatures may influence the effectiveness of both recruitment and control measures.

Magnitude: 1- Minimal
Corbicula can control phytoplankton biomass development in shallow areas, or consume the productivity of shallow areas exported to channels. Corbicula is a significant limiting factor throughout Delta (Thompson et. al., In revision). For this outcome, the baseline condition is that much of the Delta is infested with *Corbicula*. The restoration of tidal marsh that eventually becomes infested with *Corbicula* would not represent a significant change above baseline conditions.

Certainty: 2 - Low

The timing and extent of colonization by *Corbicula* cannot be predicted for specific restoration sites due to lack of data.

Corbicula are prolific reproducers and colonizers of newly available habitats in salinities below 2 ppt. Source populations can come from elsewhere within the Delta or from upstream tributary populations. *Corbicula* can establish on soft and hard substrates and on vegetation and they can colonize intertidal zones as well as deeper water. (*Corbicula* model). Based upon the biology of the species and the physical setting of the restoration site, the probability of *Corbicula* establishment in the east Delta restoration areas appears to be high, but ultimately cannot be predicted, partially due high variability in environmental conditions. The low certainty score considers the probability and extent of potential establishment.

Corbicula monitoring data from previous restoration sites in the Delta, such as Liberty Island or Little Holland Tract, would provide greater information about the probability of colonization on these east Delta sites. More information would improve the certainty rating. However, such data and analysis was not made available to the evaluation team.

N1d: Inland Silversides Effects on Delta and Longfin Smelt

General Observations

Inland silversides (*Menidia beryllina*) are highly tolerant of warm water, salinity variability and are trophic generalists compared to Delta smelt (Moyle 2002). Inland silversides are the most numerous fish in Suisun Marsh shoreline habitats (Matern et al. 2002), and the most numerous fish in shallow Delta habitats (Nobriga et al. 2005, Brown and May 2006). The Delta smelt model (page 3) includes intraguild competition with inland silversides as one of the top five in-Delta stressors to Delta smelt. Inland silversides are thought to be a major predator of Delta smelt eggs (Bennett and Moyle 1996 and Bennett 2005 in the Delta smelt conceptual model pg 12). In the laboratory, inland silversides reduce Delta smelt size relative to controls when they are reared together (Bennett 2005).

Inland silversides are also treated in the longfin smelt model. Moyle (2002, in Rosenfield, 2008) suggested that based on timing of arrival in the Estuary and subsequent longfin population response, inland silverside might have had a major impact on longfin population dynamics. However, the model states that inland silverside prefer shallow water habitats where juvenile and sub-adult longfin are rare, thus, their impact as predators of juvenile and sub-adult longfin is probably slight (Rosenfield, 2008, pg. 17). Spawning locations for longfin are unknown, so it is not known whether competition from inland silverside for spawning territory is a factor in their decline.

However, Delta smelt evolved with other intraguild competitors, including longfin smelt, and have survived with Striped bass (introduced in 1879). Interaction between silversides and Delta smelt in the wild may be limited because Delta smelt typically inhabit offshore environments, while inland silversides typically inhabit shoreline habitats. Increased shoreline habitat would presumably increase the carrying capacity for Inland silversides. However, predator-prey interaction between Delta smelt and Inland silversides in the wild is speculative. Silversides may eat Delta smelt eggs or larvae if the eggs and larvae occur on the shorelines. It has not been shown that Inland silversides reduce calanoid copepods (Norbriga and Herbold, 2008, page 32), so they may not effectively compete with Delta smelt for prey.

Williams and Rosenfield, In preparation; Israel and Klimley, 2008; Kratville**,** 2008); and Israel et. al., 2009 do not mention inland silversides so this evaluation assumes no adverse effects and focuses its evaluation on Delta smelt and longfin smelt.

Magnitude = 2 (low)
Inland silversides are the most abundant fish in shallow-water habitats in many areas of the Delta and may currently contribute to local depletions of zooplankton otherwise available to native fishes within these areas. Additionally, they may prey on embryos of species who lay eggs in these shallow areas (Moyle 2002). The crash of Delta smelt populations coincided with invasions of inland silversides into the estuary (Bennett and Moyle 1996). This action may change conditions relative to baseline by attracting (via restored marsh) a nuisance (inland silversides). This conservation measure will increase the local inland silverside population by providing additional shoreline breeding

habitat. Because of the high existing abundance of inland silversides, the incremental increase in breeding habitat and thus population size above current conditions is considered small and the magnitude of this effect is considered to be low relative to baseline. Further, differential habitat selection (offshore environments for inland silverside) is expected to reduce the interspecific competition effects.

Certainty = 2 - Low
Understanding of interaction between inland silversides and Delta smelt in the wild is low, particularly in regards to egg predation by Inland silversides. Better data on where and when Delta smelt lay their eggs would better allow us to assess the potential impact of Inland silverside predation. Spatial interactions with longfin smelt are also uncertain.

Outcome N2: Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A – covered fish species, N2-B, Non-covered wildlife species, N2-C, Human health.

N2a: Covered fish species

General Observations: methyl mercury: The relationship between drivers and outcomes is supported by (Alpers et. al., 2008, Table 2 and associated text). Although current methylmercury levels on Liberty Island (analogue for future state of areas to be restored) are relatively low (Slotton et al. 2002, (Alpers et. al., 2008, figure 5), there is potential for enhanced production of methylmercury in areas of high marsh that will be inundated infrequently (only during highest tides). The process of drying out between wetting events tends to oxidize species of sulfur, iron, carbon, and mercury, leading to higher potential to form methylmercury upon rewetting. Once formed, methylmercury biomagnifies in the aquatic food web and ecological effects may occur in some sensitive species. Thus, the specific geomorphology of restoration sites and in particular, the degree to which shallow depressions and poorly drained areas of high marsh are part of the restoration projects directly influences the degree of mercury methylization.

General Observations, other contaminants
Past land use determines risk of other contaminants: lead risk in areas with significant hunting (e.g., pheasant farms or duck clubs). Risk of residual pesticides (e.g., pyrethroids) in areas used for agriculture in past two years, which suggests that if these pesticides were used, allowing for a two year lag period between application and tidal restoration would be a prudent mitigation measure. Selenium contamination from the San Joaquin Valley and other sources is also a concern, however it was not evaluated in this worksheet..

Magnitude: 1 - Minimal
No toxicological studies have been conducted with any of the covered species regarding acute toxicity. Mercury concentrations in covered fish are compared against concentrations producing mortality in other fish species. Mercury concentrations in covered fish species are compared here against concentrations producing mortality in other fish species. Mercury concentrations in ppm-wet weight for white sturgeon, Chinook salmon and Steelhead collected during 2006 were 0.165-0.279, 0.094-0.396 and 0.06-0.13, respectively (Melwani et al. 2007). Tissue data for longfin and Delta smelt was not found. This analysis assumes that both species will have tissue concentrations similar to that of other fish taxa living one year and feeding primarily on zooplankton. Mercury concentrations in juvenile threadfin shad and juvenile largemouth bass in the Delta are 0.012-0.076 and 0.035-0.230, respectively (Slotton et al., 2006). In comparison death in rainbow trout in laboratory studies occurred at 4-ppm wet weight and the NOAEC for death in Brook trout at 2.7 ppm (in Wiener and Spry, 1996). From these facts, one can conclude that, about a 10X safety factor between fish tissue concentrations in the Delta and the values reported to cause mortality in lab studies.

Regarding chronic toxicity, again there are no toxicological studies with any of covered species. Therefore, this analysis compares the reported tissue concentration for individual species against known laboratory effects in other taxa. Decreased feeding efficiency and some hormone response changes are observed at 0.25-0.27 ppm wet weight (Alpers et. al., 2008, page 30). Decreases in growth occurred in fathead minnows at 0.6-0.7 ppm (Hammerschmidt et al., 2002) and in juvenile walleye at 2.4 ppm (Friedmann et al., 1996). In conclusion, some up/down regulation of genes and alterations in feeding behavior are possible in the most contaminated individuals.

Certainty: 2 - Low
Limited tissue data is available for most covered species and there is a large safety factor regarding acute toxicity.

Limited toxicological data is available for most of the important sub-lethal processes and none of this data has been collected for the species of interest. A very limited tissue data set is available for most of the covered species and this makes it impossible to determine the proportion of population potentially at risk.

N2b: Methyl mercury, non covered species

General Observations: The relationship between drivers and outcomes is described in the DRERIP Mercury Conceptual model (Alpers et. al., 2008, Table 2 and associated text).

Magnitude: 3 - Medium
Fifty-eight percent of Forster's terns in San Francisco Bay are at risk of reproductive impairment from consuming fish with elevated mercury levels (Ackerman *et al*., 2008). No Forster's Terns nest in Delta. However, mercury levels in small fish consumed by terns are higher in parts of the Delta, such as the Yolo Bypass, than in San Francisco Bay. This suggests that other bird species filling the Forster's tern niche in the Delta may be at risk. Mercury contamination may result in possible sustained, minor population effect on large area.

In laboratory studies, mink have reproductive failure and die when fed fish diets of 0.5 and 1-ppm mercury, respectively (Dansereau *et al*., 1999). For comparison, mercury concentrations in 64% of largemouth bass, 23% of white catfish, and 35% of channel catfish caught in the Bay-Delta watershed have between 0.23 and 0.93 ppm mercury (Davis et al., 2006). Expected sustained minor population effect or effect on large area.

Certainty: 2-3 Low-Med
Scientific understanding of methylmercury effects on some bird and mammal species is high and this is based on peer-reviewed studies from the San Francisco Bay Area and elsewhere outside of the system. However, methylmercury effects on other bird, reptile, and mammal species is unknown. The nature of this outcome is greatly dependent on highly variable ecosystem processes.

N2c: Methyl mercury, Human Health

General Observations: See also results from water quality team.

Magnitude: 2 - Low
Fish consumption advisories for the Delta recommend that children under the age of 17 and women of child bearing age consume no largemouth bass or smallmouth bass, spotted bass or Sacramento pikeminnow, and others should limit their consumption of these species to one meal a month (OEHHA, 2006, 2008a,b). Between 10,000 and 20,000 fishermen in the Delta are presently eating fish with more than 10X the recommended methylmercury RfD and could experience some sublethal mercury poisoning (personal communication, Dr Fraser Shilling). The proposed restoration action could increase mercury content of sport fish.

The probability of increased methyl mercury production and export into the food web is the same as that described above for covered and non-covered species.

Certainty: 3 - Medium
Uncertain magnitude and direction of change in mercury content of sport fish; although levels are more likely to increase than decrease. For a given increase in mercury content of sport fish, risk to human health is quantified based on peer-reviewed studies (OEHHA, 2008a,b). It is not known how many anglers would access the project area and what fish they would catch and consume.

Outcome N3: Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids.

N3a: Covered fish species

General Observations: Possible presence of legacy pesticides from 1960s (e.g. DDT) is unknown. More recent (illicit) use of DDT is possible. Pyrethroids are 20x more toxic compared to some other pesticides (organochlorides). They persist in the sediment and degrade in one or two years (DPR, 2008). The relationship between drivers and outcomes is described by the DRERIP Pyrethroids conceptual model (Werner and Oram, 2008, Figure 1).

Magnitude: 1-2 – Minimal - Low
To the extent that pyrethroids or pyrethrins were used in the area to be flooded, significant toxicity could occur within 1-2 years of application. After ~2 years, near-total degradation should occur. DDT and metabolites could cause reduction of insect populations and bioaccumulation in target fish species (and some non-target bird species). Possible presence of legacy pesticides from 1960s (e.g. DDT) is unknown.

Certainty: 1 - Minimal
The toxicity of various pesticides is not completely understood. Although some peer-reviewed studies for selected life stages of certain fish exist, there is not much data for covered fish species. The nature of outcome greatly dependent on highly variable ecosystem processes affecting fate (degradation) and transport of pesticides.

N3b: Non covered wildlife species

General Observations: The relationship between drivers and outcomes is described in Werner and Oram, 2008, (Figure 1).

Magnitude: 1-2 Minimal - Low
To the extent that pyrethroids or pyrethrins were used in the area to be flooded, significant toxicity could occur within 1-2 years of application. After ~2 years, near-total degradation should occur. DDT and metabolites could cause reduction of insect populations and bioaccumulation in target fish species (and some non-target bird species).

Certainty: 1 - Minimal
The toxicity of various pesticides is not well understood. A limited number of peer-reviewed studies for certain life stages of selected fish species exist. However, there is not much data for covered fish species available (Werner et. al., 2008). The effect that tidal marsh restoration will have on the availability of residual pesticides is greatly dependent on highly variable ecosystem processes affecting fate (degradation) and transport of pesticides. Additionally, legacy pesticides from 1960s (e.g. DDT) may be present on the restoration site and more recent (illicit) use is unknown.

Outcome N4: Resuspension and export of contaminants to downstream areas (A) mercury and methylmercury, (B) pesticides and herbicides (e.g. pyrethroids).

N4a: Covered fish species

Analysis of resuspension affects considers two separate physical settings: the restoration marsh sites and the adjacent tidal sloughs. The restored marsh sites are not likely experience much scour, since the adjacent tidal channels would be excavated as part of construction and the hard farm fields are not expected to scour easily. Adjacent tidal sloughs, which are typically comprised of more erodible substrate, may experience more scour both the bed and banks.

General Observations: The relationship between drivers and outcomes is described in Alpers et. al., 2008 (Figures 4, 7, and 8 and associated text) and Werner and Oram, 2008, Figure 1.

Magnitude: 1 - Minimal
The degree of scouring of pre-project soils depends on hydrodynamics. Scour could be a short-term phenomenon as channels reach geomorphic equilibrium.. Potential for increasing methylmercury concentrations in high-elevation marsh (infrequently wetted zone) and possible export of this to downstream environments.

Certainty: 2 - Low
The nature of this outcome is greatly dependent on highly variable ecosystem processes affecting fate (e.g. photodegradation of methylmercury) and transport.

Outcome N5: Restoration site creates a population sink for covered fish species (Provides rearing habitat that becomes a one-way trip.)

N5a. San Joaquin Chinook:

General Observations:
The relationship linking drivers and outcomes discussed in this analysis is described by Brown 2003 (and sources cited therein). Rearing and migration are two activities that

juvenile salmonids (and other migratory species) must accomplish to complete their life cycle. These two activities are in a dynamic tension as migration rate and rearing time are somewhat inversely proportional (when juveniles are "rearing" in a habitat, they are not migrating). If migrating salmonid juveniles begin to rear in a habitat that then becomes inhospitable (due to changing temperatures, the appearance of predators, or radically altered hydrodynamics cause by export pumping), the "rearing habitat" may instead become an area of high mortality. Similarly, if migrating juveniles have difficulty exiting habitat to continue their migrations, rearing habitat may delay important transitions from one habitat to the next.

Magnitude = 1 - Minimal.
The geographic location of the proposed restoration site is disconnected from probable migration corridors for San Joaquin River salmon. Salmon may migrate upstream into waterways other than their natal stream (Williams 2006) and so it is possible that emigrating Chinook will move into these "restored" areas. However, temperatures will likely become stressful in these areas towards the end of the migratory period. As a result, in the days and weeks after Chinook salmon migrate into the sloughs and restored wetlands, it is possible that the habitat will degrade (due to rising temperature and declining dissolved oxygen) and that Chinook salmon in these backwater wetlands will find them hard to escape.

Certainty = 3 - Medium
The number of Chinook salmon entering these restoration sites (and the frequency with which this occurs) is difficult to project but is likely to be low (making the certainty of a minimal magnitude moderately certain).

N5b. Steelhead:

General Observations:
The relationship linking the drivers to outcomes discussed in this worksheet are described by Brown 2003 (and sources cited therein).

Magnitude = 1 - Minimal
The geographic location of the restoration site is disconnected from probable migration corridors for steelhead. Steelhead may migrate upstream into waterways other than their natal stream (Williams 2006) and so it is possible that emigrating steelhead will move into these "restored" areas. However, temperatures will likely become stressful in these areas towards the end of the migratory period. As a result, in the days and weeks after steelhead migrate into the sloughs and restored wetlands, it is possible that the habitat will degrade (due to rising temperature and declining DO) and that steelhead juveniles in these backwater wetlands will find them hard to escape.

Certainty = 3 - Medium
The number of steelhead entering these restoration sites (and the frequency with which this occurs) is difficult to project but is likely to be low.

N5c. Delta smelt:

General Observations:
The relationship linking drivers to the outcomes discussed in this worksheet are described by Brown 2003 (and sources cited therein).

Magnitude = 2 - Low
The geographic location of the restoration sites occur on the edge of the Delta smelt's historic range. Still, larval Delta smelt may be dispersed into these marshes and the sloughs that surround them. Temperature and other water quality conditions (see above) are likely to deteriorate towards the end of the spring. Delta smelt may be trapped in these areas – unable to escape deteriorating conditions. Because Delta smelt are expected to occur here only in low numbers and with low frequencies, the ultimate impact of this effect is expected to be small.
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Certainty = 3 - Medium
The low number and frequency of Delta smelt occurrence in this area make it moderately likely that the magnitude of this impact will be low. Under current conditions in the southeast Delta, Delta smelt larvae that enter restored marsh habitats in this area will suffer high mortality rates. This action does not represent a significant change from that baseline condition.

Important Gaps in Information and/or Understanding

Data needed to more fully evaluate tidal marsh restoration actions

- Residence times (average and spatial variance in that value) are necessary to determine how much and what kind of food would be produced on site and exported from the site. Residence time projections also affect temperature and dissolved oxygen conditions and these are important attributes of physical habitat. Finally, residence times for particles of water could inform assessment of “residence” times for fish. There is a non-linear relationship between fish “residence time” and the benefit of the rearing habitat as, at high “residence times” new habitat may serve to delay important migratory activities whereas at very low residence times, the new habitat will have reduced benefit because fish (or at least those that behave like particles) will experience the habitat for only a short period.
- Centrarchid models are needed to understand predator-prey-habitat interactions.
- Striped bass model is needed to understand predator-prey-habitat interactions.
- Expected retention time on restored tidal areas to understand likely productivity and food export potential to local sloughs.
- Baseline predation pressure in this region should be better understood.
- More spatially comprehensive hydrodynamics to understand whether changed flow patterns will reduce or simply redistribute predator pressure.
- Hydrologic and sediment information about turbidity levels, duration, and consequences on species as related to the following: Increased ability for Delta smelt to locate food due to increased turbidity from increased velocities in larger channels.
- Prior to implementation, conduct a complete Phase I Environmental Assessment with on-site sampling to assess legacy and other soil contaminants (i.e. mercury and pesticides).
- *Corbicula* monitoring data from previous restoration sites in the Delta, such as Liberty Island or Little Holland Tract, would provide greater information about the probability of colonization on this site.
- Better data on where and when Delta smelt lay their eggs would better allow assessment of the potential impact of inland silverside predation.
- Analysis of factors contributing the success or failure of other past tidal marsh restoration actions in the Delta.
- Liberty Island is often referred to as a model of a successful restoration project. Monitoring data and new bathymetric data from Liberty Island should be fully analyzed to determine the features that makes it successful and to consider how to apply those features to other restoration projects in the Delta. Specifically, the bathymetric data could be turned into a Digital Elevation Model (DEM) and combined with the habitat type mapping (i.e. vegetation and open water) to illustrate how the restoration provides habitat for covered and other species. This would include documenting the quality of existing LiDAR data for the vegetation mapping.

Research Needs

- Restoration techniques that will prevent colonization by invasive species.
- Management practices that can control invasive vegetation, clams, and predators (centrarchids and inland silversides) and limit colonization of these sites.
- Run (and life-history) specific studies of Central Valley Chinook salmon and studies of steelhead use of tidal marsh habitats would be extremely valuable to defining magnitude of impacts to these populations and increasing certainty. Various tools (including genetic markers and otolith signatures of population origin) could be used to asses both growth and survival of salmonids in these habitats as well as <u>changes in life history characteristics (survival and fecundity) over the course of the life cycle</u> that arise from residence in tidal marsh habitats. Currently, all of the evidence for benefits of tidal marsh on salmonids comes from steelhead and fall run populations well to the North (where high temperatures and invasive predators are not as problematic). Translating these results to all Central Valley salmonid populations is unwarranted and could lead to disastrous "restoration" projects. In addition, data on nutrient flow from the marsh plain to juvenile fish rearing in the adjacent channels is essential to determining the value of restored marshes as a food source for larvae of pelagic fish (like longfin and Delta smelt).
- Future research should generate simulations of generic “applications” of the DRERIP Conceptual Models. For example, the temperature model could be “applied” to generic landscape characteristics, such as a restoration site with specific shapes (bowl or gradation), to consider how temperature dynamics are affected on various spatial and temporal scales. This exercise would help managers understand where further detail is needed by taking the conceptual models to the next level by conducting simulations to apply the concepts to a landscape.
- Data on nutrient flow from the marsh plain to juvenile fish rearing in the adjacent channels is essential to determining the value of restored marshes as a food source for pelagic fish larvae (i.e. longfin and Delta smelt).
- It would be helpful if future research could generate simulations of generic “applications” of the DRERIP Conceptual Models. For example, the temperature model could be “applied” to generic landscape characteristics, such as a restoration site with specific shapes (bowl or gradation), to consider how temperature dynamics are affected on various spatial and temporal scales. This exercise would help managers understand where further detail is needed by taking the conceptual models to the next level by conducting simulations to apply the concepts to a landscape.
- Greater understanding and more research is needed about the availability and production of food in tidal marshes. Export of organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta has not been studied.
- Evaluate the effectiveness of water management strategies on managed wetlands to reduce the production of low dissolved oxygen events associated with managed wetlands operations and transfer what is learned into best management practices for the broader managed wetlands community in this region. In addition, it is likely the reduction of low DO events will result in

- conditions less favorable for MeHg production and thus reduce MeHg loading to the surrounding aquatic environment. This hypothesis needs testing.
- Potential negative effects of methylmercury exposure on covered fish species remain largely unknown. Based on published studies involving other (non-targeted) fish species, there is reason for concern regarding possible chronic effects caused by methylmercury exposure, including: endocrine disruption, reduced reproductive success, reduced predator avoidance, and reduced feeding efficiency. (See Mercury Conceptual Model, Alpers et al. 2008, Table 4, page 30). Research is especially needed to determine possible effects caused by exposure during early life stages.
- A better understanding is needed regarding the relationship of mercury methylation to the duration of wetting and drying events in areas that are intermittently inundated (i.e. tidal marsh and floodplain). Laboratory and field studies of mercury cycling involving sediments in tidal marsh and floodplain environments should quantify the duration of drying time and the extent of dryness necessary to change the oxidation-reduction character of iron, sulfur, carbon, and mercury in sediments such that microbial activity associated with mercury methylation is enhanced.
- Tropho-dynamic model of ecological interactions linking primary production to the food web structure and production flows into, through, and out of the tidal marsh system.
- Landscape-level models that address the effects of variation in structural features of the tidal marsh environment (e.g., tidal channel complexity, channel width, channel length, edge: area ratios, etc.) on the population or production dynamics of specific plants and animals.

Assess Reversibility and Opportunity for Learning

Reversibility

No/Hard. The following on-the-ground actions would be needed to reverse this action:

1) levees would need to be reconstructed
2) newly created tidal sloughs would have to be regarded
3) sites would have to be dewatered
4) wetland vegetation would have to be removed
5) newly installed levees would need to be removed as necessary
6) monitoring pre, during, and post construction

Although this reconstruction is technically possible, there would be significant financial and regulatory costs. Prior to action reversal, the following planning activities would be needed:

1) geotechnical evaluations for levee reconstruction
2) engineering design
3) evaluate land options for areas subject to subsidence reversal actions
4) environmental permitting and associated agency ESA consultation,
5) Mitigation planning

Opportunity for Learning

High: Implementation of this project can be designed such that different engineering designs can be compared. Numerous physical and biological components can be monitored and ideally, the monitoring data would be used to assess and refine modeling simulations of the restoration as a part of a comprehensive adaptive management program. See text in the Cache Slough (HRCM 4) worksheet for details.

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Appendices

Appendix A: Summary Tables Organized by Outcome

Table 3. Positive Outcomes

Outcome	Magnitude	Certainty
P1: Increase rearing habitat area (including physical and biotic attributes) for covered fish species.		
a: San Joaquin River/eastside Fall-run Chinook salmon and steelhead.	2	2
b. Splittail	2	3
c. Green Sturgeon	2	2
d. White sturgeon	2	1
P2: Food resources (i.e. organic material from the marsh plain and organic carbon, phytoplankton, zooplankton, and other organisms from intertidal channels) produced on the restored marsh will be exported, via tidal flow, and contribute to food availability downstream in the eastern and central Delta. (all covered fish species)		
a. Viewpoint #1	3-4	3
b. Viewpoint #2	1-2	1
P3. Locally provide areas of cool water refugia for Delta smelt and salmonids.		
a: Delta smelt.	2	1
b1. Spring-run.	2	1
b2: Fall-run.	2	1
b3: steelhead.	2	1

Table 4. Negative Outcomes

Outcome	Magnitude	Certainty
N1: Establishment of undesirable species (such as Egeria) that will prey or compete or alter habitat conditions for covered fish.		
a. SAV.	3	2
b. Non-native Centrarchids	4	3
c. Corbicula.	4	3
d. Inland silversides.	2	2
N2: Potential for mercury methylation and local bioaccumulation to affect wildlife.		
a. Covered fish species	1	2
b. Other species (not covered).	3	2 to 3
c. Human health.	2	3
N3: Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids		
a. Covered fish species.	1 to 2	1
b. Other species (not covered).	1 to 2	1
N4: Resuspension and export of contaminants to downstream areas (A) mercury and methylmercury, (B) pesticides and herbicides (e.g. pyrethroids).		
a. covered fish species.	1	2
N5: Restoration site creates a population sink for covered fish species (Provides rearing habitat that becomes a one-way trip.)		
a: San Joaquin Chinook	1	3
b. Steelhead.	1	3
c. Delta smelt	2	3

Appendix B - Outcomes With Zero Magnitude

OP1. Increase rearing habitat area (including physical and biotic attributes) for longfin smelt.

General Observations: Longfin smelt do not occur in this area with any frequency. These fish do not use tidal marsh habitats. The magnitude of this outcome is zero for this species with a certainty of "4".

Longfin smelt do not occur with any regularity or abundance in this region. Longfin smelt model text indicates: LFS are rarely detected above Rio Vista on the Sacramento River (Wang 1991; and R. Baxter, CDFG, unpublished data). Furthermore, model indicates that, soon after they become free-swimming fish, longfin smelt concentrate in deepwater environments – marsh is not considered "rearing habitat" for longfin smelt.

OP2. Increase rearing habitat area (including physical and biotic attributes) for Delta smelt.

General Observations: Drivers, linkages, and outcomes are described by the DRERIP Delta smelt conceptual model (Norbriga and Herbold, 2008) which states that the food web supporting Delta smelt production is a primary component of habitat suitability that affects Delta smelt growth rates, health, fecundity, and mortality. The food web supporting Delta smelt is based on the production of pelagic zooplankton (see page 21 of model). Delta smelt historically spawned in the east Delta in some years (Norbriga and Herbold, 2008, page. 11).

Magnitude: The magnitude is scored as a **zero** because Delta smelt were periodically found in the east Delta historically (Bennett 2005, Figure 1) but they are infrequent or absent from this area in recent years (Norbriga and Herbold, 2008, Figure 3). Delta smelt eat food produced on tidal marshes; but, Delta smelt do not forage in shallow environments (Norbriga and Herbold, 2008, page. 27 and elsewhere, and pers. comm. with B. Herbold, US EPA). Delta smelt will not benefit from the physical habitat structure to be created on shallow parts of this restored landscape. Food consumed *in the shallow tidal areas* is likely to be nil. This outcome assumes that Delta smelt are limited by food production in this area. The food consumed in directly adjacent pelagic habitats depends entirely on how much of the zooplankton produced in the shallow areas is consumed by fish that actually forage in shallow environments where the food is produced. Delta smelt rearing in open water habitats may have, in the past, relied on export of food from a vast network of tidal marshes (Norbriga and Herbold, 2008, page 12). The limited scale of this restoration proposal, the infrequent occurrence of Delta smelt in this area, and the relative isolation of the proposed restoration sites from pelagic habitats and migratory corridors used by later life history stages of Delta smelt make the likely magnitude of this outcome undetectable.

Certainty: Certainty is moderate and is scored as a **3.** The magnitude of outcome is dependent on highly variable ecosystem processes or other external factors. The impact of food produced on site is related to how much of that food makes it into the adjacent channels and bays and to the nature and extent of food limitation in this region currently. These factors are somewhat uncertain. The magnitude of food production depends on physical aspects of the restoration (e.g. those that contribute to retention time) and biological outcomes (e.g. the amount of food consumed in shallow areas that is then not exported to adjacent deep habitats).

OP3. Increase rearing habitat area (including physical and biotic attributes) for Steelhead.

General Observations: Drivers, linkages, and outcomes are described by the DRERIP Salmonid model which indicates that steelhead juveniles move through Delta from Jan-Jun, but mostly from late March-June (Williams and Rosenfield, In preparation, Fig 27 and DLO figure. See also the value of estuarine rearing varies across populations on page 15). Tidal exchange in some of these marshes will be hard to accomplish and residence times in the channels leading to the Marsh will be high. This will expose emigrating salmon and steelhead to poor habitat conditions for extended periods and delay successful emigration.

Magnitude: The magnitude of this action will not be detectable and is scored as a zero. This outcome assumes that "rearing habitat area" (quantity) and/or food is limiting in this area. Page 16 of Williams and Rosenfield, In preparation states "Spring Chinook, or at least the Butte Creek population, pass quickly through the Delta, so habitat restoration there seems unlikely to do much for them. The same is probably true for late fall Chinook, <u>and for steelhead</u>." This conceptual model (Estuarine – growth) shows a low impact of this kind of habitat on competition – competition may have a moderate impact on growth. In other systems, steelhead use tidal marsh habitat but, the text notes, steelhead smolt in this system are large compared to other systems so research there is not likely to apply here. Steelhead will eat the types of food produced in this habitat. Steelhead migrate past this area "mainly in April and May" (Salmonid model P 34.) High temperatures are probably common in this area during May (as indicated by IEP gauges in the lower San Joaquin River, rsan 007 and rsan058). Average daily temperatures exceed 20-21oC (beyond which sublethal effects accumulate; Reese and Harvey 2002 and see Richter and Kolmes 2005) during May in many years. In June, average daily temperatures probably exceed this critical threshold in almost every year. With warming that may occur under climate change projections, high temperatures may become more frequent and more extreme, even during April. Steelhead rearing in this proposed restoration site during May and June will probably be impacted by high temperatures and negative impacts could become more common with global warming.

The limited scale of this restoration proposal, the infrequent occurrence of steelhead in this area, and the relative isolation of the proposed restoration sites from migratory corridors make the likely magnitude of this outcome undetectable. Benefits to some rearing steelhead may be largely offset by negative temperature effects to later rearing steelhead.

Certainty: Certainty is moderate and scored as a 3. There is no direct research on use of shallow estuarine habitat by steelhead in this system. Any effect will be limited to the San Joaquin population and to those times of year when temperatures are not too high in the target area.

OP4a: Locally provide areas of cool water refugia for winter-run salmon.

Magnitude = 0- Zero.
There will be no benefits of this restoration to winter-run salmon because this run passes through the region during a window of time when temperatures are not believed to be highly stressful to salmonids.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

OP4b: Locally provide areas of cool water refugia for late fall-run salmon.

Magnitude = 0- Zero.
There will be no benefits of this restoration to late fall-run salmon because this run passes through the region during a window of time when temperatures are not believed to be highly stressful to salmonids

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

Appendix C: Excerpt From BDCP Steering Committee November 21, 2008, Handouts #2 and #3

BDCP Steering Committee
November 21, 2008

HANDOUT HABITAT #2

PRELIMINARY DRAFT—FOR DISCUSSION ONLY
Estimated Extent of Lands within Restoration Opportunity Areas that may be Suitable for Tidal Marsh Restoration Area by Elevation Class

Note: The acreage values presented in this table that may be suitable for tidal marsh restoration are likely somewhat less than shown because the footprint of roads and other features that might not be removed to accommodate tidal marsh restoration are included in the table. Acreage values shown for the South Delta ROA do not include lands that may also be suitable for floodplain restoration.

Restoration Opportunity Area (ROA)	Area by Elevation Class (acres)										Total
	Upland (>+15 feet)[1]	Transitional Upland 2 (>+3-15 feet)[2]	Transitional Upland 1 (>+3-6 feet)[2]	Sea level Rise Accommoda-tion (>0-+3 feet)[2,3]	Tidal Marsh[4]	Subtidal 1 (<0-3 feet)[4]	Subtidal 2 (>-3-6 feet)[4]	Subtidal 3 (>-6-9 feet)[4]	Subtidal 4 (>9-12 feet)[4]	Subtidal 5 (>-12 feet)[4]	
East Delta ROA											
Canal Ranch Tract	N/A	133	521	568	714	113	1	0	0	0	2,050
Bract Tract	N/A	212	329	254	273	8	0	0	0	0	1,076
Terminous Tract	N/A	105	216	412	847	131	2	0	0	0	1,713
Shin Kee Tract	N/A	7	60	422	625	344	134	14	1	1	1,608
Rio Blanco Tract	N/A	1	3	69	399	200	151	20	0	0	843
Subtotal	N/A	458	1,129	1,725	2,858	796	288	34	1	1	7,290

BDCP Steering Committee
November 21, 2008

HANDOUT HABITAT #3

PRELIMINARY DRAFT—FOR DISCUSSION ONLY
Potential Opportunities for Tidal Marsh Restoration
by ROA based on Implementability, Suitability, and Cost
(Does not include assessment of covered fish species benefits.)

Restoration Opportunity Area and Land Units	Potential Opportunities for Tidal Marsh Restoration (acres)[1]					
	Very High[2]	High[3]	Moderate[4]	Low[5]	Very Low[6]	Total Potential
East Delta ROA						
Canal Ranch Tract	0	0	0	1,400	0	1,400
Bract Tract	0	0	0	540	0	540
Terminous Tract	0	0	0	1,400	0	1,400
Shin Kee Tract	0	0	0	1,400	130	1,530
Rio Blanco Tract	0	0	0	0	670	670
Subtotal	0	0	0	4,740	800	5,540

Notes:

[1]Cell values above 1,000 acres are rounded to the nearest 100 acres. Cell values below 1,000 acres are rounded to the nearest 10 acres.

[2]Very high = the extent of sea level rise accommodation, tidal marsh, and subtidal 1acreage elevation classes from Handout #2 that achieve >80% of the highest possible Step 2 criteria score from Handout #1.

[3]High = the extent of the subtidal 2 acreage elevation class from Handout #2 that achieves >80% of the highest possible Step 2 criteria score from Handout #1and the extent of sea level rise accommodation, tidal marsh, and subtidal 1 acreage elevation classes from Handout #1 that achieve >70-80% of the highest possible Step 2 criteria score from Handout #1.

[4]Moderate = the extent of the subtidal 2 acreage elevation class from Handout #2 that achieves >70-80% of the highest possible Step 2 criteria score from Handout #1and the extent of sea level rise accommodation, tidal marsh, and subtidal 1 acreage elevation classes from Handout #1 that achieve >60-70% of the highest possible Step 2 criteria score from Handout #1.

[5]Low = the extent of the subtidal 2 acreage elevation class from Handout #2 (Table 1) that achieves >60-70% of the highest possible Step 2 criteria score from Handout #1 and the extent of sea level rise accommodation, tidal marsh, and subtidal 1 acreage elevation classes from Handout #1 that achieve >50-60% of the highest possible Step 2 criteria score from Handout #1.

[6]Very Low = the extent of the subtidal 2 acreage elevation class from Handout #2 (Table 1) that achieves >50-60% of the highest Step 2 criteria score from Handout #1 and the extent of sea level rise accommodation, tidal marsh, and subtidal 1 acreage elevation classes from Handout #1 that achieve ≤50% of the highest possible Step 2 criteria score from Handout #1.

[7]Includes upland elevation class acreage shown in Handout #2 for this location that would be excavated to elevations that would support tidal marsh.

			Viewpoint 1		Viewpoint 2	
Outcome Code	**Covered Spp.**	**Description**	**Magnitude**	**Certainty**	**Magnitude**	**Certainty**
Positive Outcomes						
P2a	All	Increase the availability and production of food in the east and central Delta by exporting organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta.	3-4	3	1-2	1
P3a	Delta Smelt	Locally provide areas of cool water refugia for delta smelt	2	1		
P1a	Fall-run Chinook salmon- San Joaquin River or eastside	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	2		
P1c	Green Sturgeon	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	2		
P1b	Splittail	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	3		
P1d	White Sturgeon	Increase rearing habitat area (including physical and biotic attributes) for covered fish species	2	1		

Outcome Code	Covered Spp.	Description	Magnitude	Certainty	Magnitude	Certainty
Negative Outcomes						
N4a	All	Resuspension and export of mercury and methylmercury to downstream areas	1	2		
N3a	All	Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids	1-2	1		
N2a	All	Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A - Target species, N2-B, Non-target wildlife species, N2-C, Human health.	1	2		
N1b	All	Establishment of undesirable species (such as Centrachids) that will prey or compete or alter habitat conditions for covered fish.	4	3		
N1a	All	Establishment of undesirable species (such as egeria,) that will prey or compete or alter habitat conditions for covered fish.	3	2		
N7a	Chinook salmon- San Joaquin	Restoration site creates a population sink for covered fish species (Provides rearing habitat that becomes a one-way trip	1	3		
N1c	All	Establishment of undesirable species (such as Corbicula) that will prey or compete or alter habitat conditions for covered fish.	4	2		
N7c	Delta smelt	Restoration site creates a population sink for covered fish species (Provides rearing habitat that becomes a one-way trip	2	3		
N1d	Delta smelt	Establishment of undesirable species (such as Inland Silversides) that will prey or compete or alter habitat conditions for covered fish.	2	2		
N2c	Human health	Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A - Target species, N2-B, Non-target wildlife species, N2-C, Human health.	2	3		
N3b	Others	Local effects of contaminants including toxicity from residual pesticides and herbicides: e.g. pyrethroids	1-2	1		
N7b	Steelhead	Restoration site creates a population sink for covered fish species (Provides rearing habitat that becomes a one-way trip	1	3		
N2b	Wildlife	Potential for mercury methylation and local bioaccumulation to affect wildlife: N2-A - Target species, N2-B, Non-target wildlife species, N2-C, Human health.	3	2-3		

Viewpoint 1 Advective-driven transport of Cache Slough productivity will provide important and very substantial productivity contributions to larger regions of the northwestern Delta.

Viewpoint 2 Export from the restored marsh will be non-existent when Yolo Bypass is not flowing therby limiting productivity contributions beyond the restoration area.

HRCM 9:
Suisun Marsh ROA Tidal Marsh & Shallow Subtidal Restoration

Scientific Evaluation Worksheet

Note about this "Incomplete Working Draft": this document is not completed. The Tidal Restoration Evaluation Team had limited time for this evaluation. Much information has been replicated from the Cache HRCM 4 evaluation and has not been revised throughout to reflect the specific restoration sites and geographies of this ROA. Information relative to Outcome P4 was updated in August 2009 to reflect individual species evaluations.

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EVALUATION TEAM 1

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Action

HRCM9: Suisun Marsh ROA Tidal Marsh & Shallow Subtidal Restoration

Evaluation Team

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Date of Last Revision: September 17, 2009

Action Description and Clarifying Assumptions

Re-establish 9,000 acres of brackish intertidal marsh and shallow subtidal aquatic within the Suisun Marsh.

Approach

1. Reconnect 10 miles of disconnected remnant sloughs to Suisun Bay and remove remnant slough dikes to reintroduce tidal connectivity to slough watersheds to restore tidal marsh.
2. Breach dikes to reintroduce tidal exchange to diked lands at locations west of Suisun Slough. Including 500 to 2,250 acres in Region 1 (west), and 460 to 2070 acres in Region 2 (central), 180 to 810 acres in Region 3 (north), and 860 to 3,870 acres on Region 4 (south). (See Figure 1 below)
3. Protect transitional grassland contiguous with restored intertidal marsh habitat within the Suisun Marsh.
4. Plant tules or other techniques to raise elevations of shallowly subsided lands.

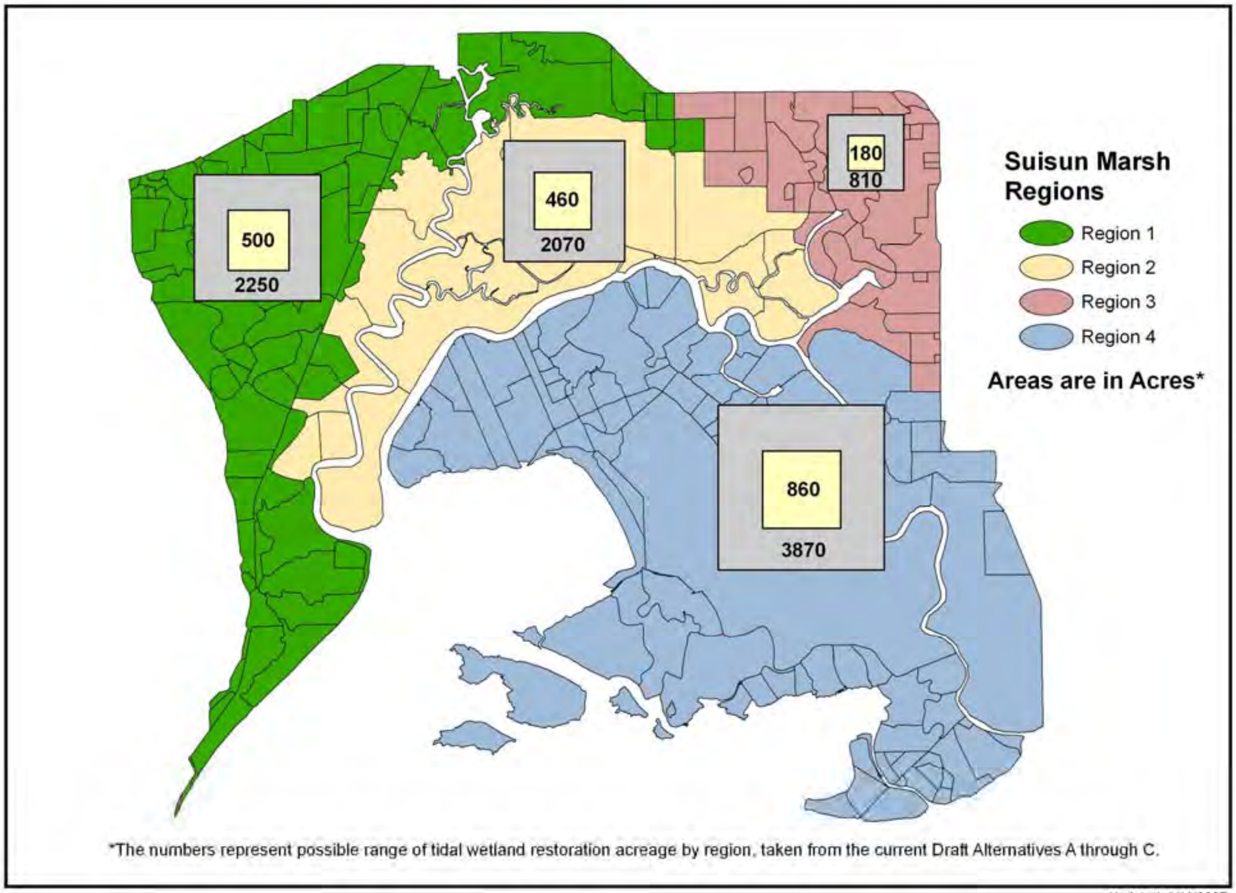

Figure 1. Suisun Marsh Plan Tidal Marsh Restoration Target Ranges by Subregions.
Ranges reflect different alternatives in SMP. *Source: CDFG et. al., In Preparation*

Intended Outcomes as Stated in Conservation Measure

1. Increase rearing habitat area for Chinook salmon, Sacramento splittail, and possibly steelhead.
2. Increase the production of food for rearing salmonids, splittail, and other covered species.
3. Increase the availability and production of food in Suisun Bay by exporting organic material via tidal flow from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Bay; locally providing areas of cool water refugia for Delta smelt.
4. Reduce periodic low dissolved oxygen events associated with the discharge of waters from lands managed as seasonal freshwater wetlands that would be restored as brackish intertidal marsh.

Conceptual Model Information Regarding Intended Outcomes

Relationships among drivers, linkages, and outcome is described in the following DRERIP conceptual models: salmonid, Delta smelt, and longfin smelt; and by the following studies as listed "References Cited" located at the end of this document:

- Hobbs, Bennett, and Burton.
- Williams, 2006.
- Enright (Temperature data via pers. comm.).
- IEP Temperature data (as processed by Kimmerer, pers. Comm.)

Assumptions

Provided in BDCP Conservation Measure:

1. Restoration would equally in north and south Suisun Marsh. (See re-write below)

Added by Evaluation Team:

1. The Evaluation Team re-wrote the assumption provided by BDCP to now read as follows: Restoration would <u>occur</u> equally in north and south Suisun Marsh <u>following the regional targets set by the Suisun Marsh Plan (see Figure 1 above) (</u>CDFG et. al., In Preparation).
2. Levee breaches will not mute tides and will be large enough to avoid steep velocity gradients (eddies) that promote fish predation.
3. Subtidal dendritic channel networks will be excavated where necessary, recognizing that downcutting through managed wetland substrate could be slow. It is expected that managed wetland pond bottoms will be less consolidated than Delta agricultural fields.
4. The time frame for providing restoration benefits derives directly from the restoration design and specific approaches utilized. Pre-breach subsidence reversal can take several years to a decade or more depending on starting elevations. The sediment accretion rate, once land is open to the tides, depends on sediment supply and biomass accretion which may be faster or slower depending on site-specific conditions. The southern portion of Suisun Marsh which faces the shallow open bays has higher sediment loads compared to the northern Suisun Marsh. Northern Suisun Marsh has higher baseline land surface elevations compared to southern Suisun, requiring less subsidence reversal. In many cases northern sites are at elevations

5. where emergent vegetation can colonize upon restoring tidal action (see Figure 2 below).
6. The extent of active pre-restoration subsidence reversal efforts would be focused on the more deeply subsided portions of this landscapes in higher energy settings such as where wind fetch large and where sediment supplies low. See existing marsh elevations in Figure 2, below.
7. Water output from the site, post-restoration, will meet water quality standards.
8. Prior to implementation, a Phase I Environmental Assessment with on-site sampling to assess legacy and other soil contaminants (i.e. mercury and pesticides) would be completed.

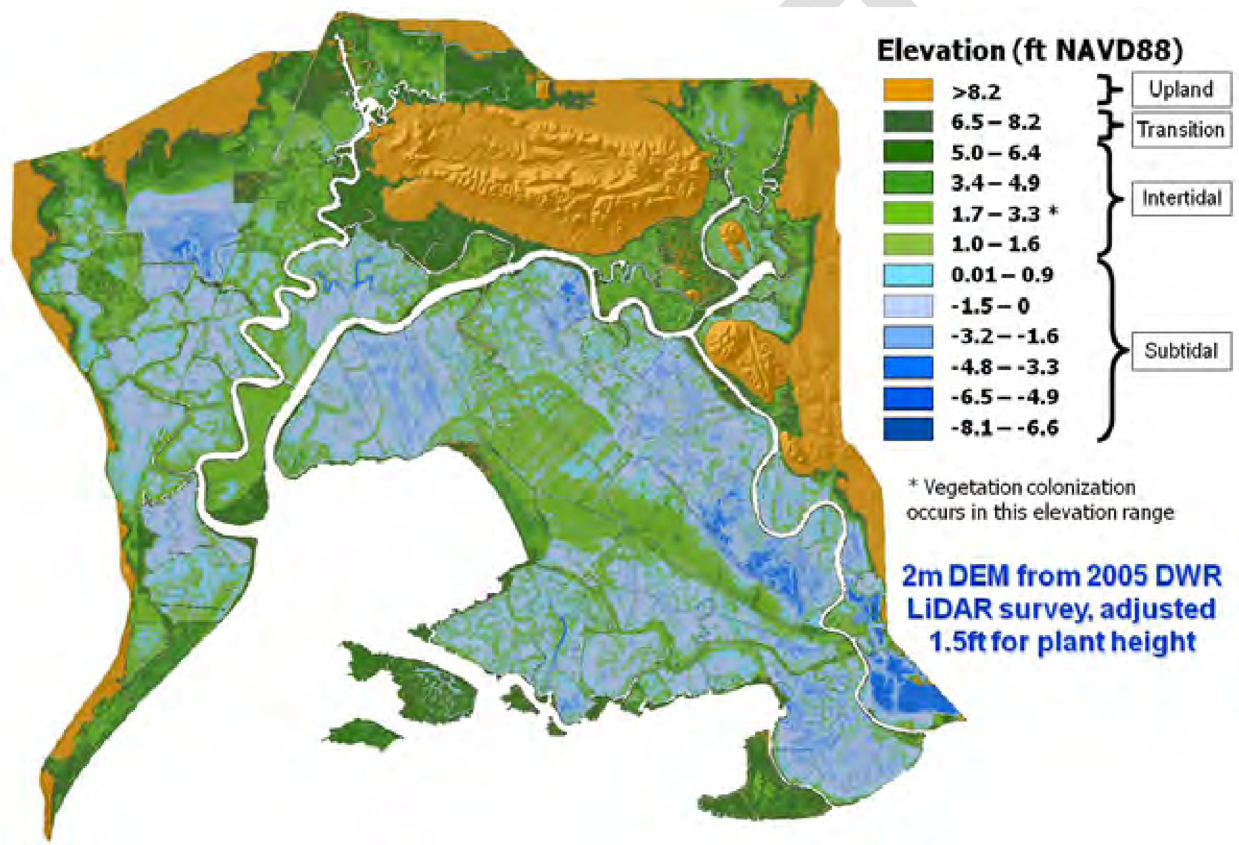

Figure 2. Suisun Marsh approximate existing elevations.
Emergent vegetation interferes with LiDAR detection of actual ground surface; this figure reflects DWR's uniform 1.5-foot uniform lowering of LiDAR elevations within wetland interiors to account for this interference, recognizing the over-simplification of this adjustment. Very little field data exist to calibrate this adjustment. *Source: DWR*

Problem(s) with Action as Written:

1. The conservation measure would benefit from an explicit recognition that restoration of tidal marsh functions on subsided landscapes will take many years to many decades. In the interim, the region will function as a shallow intertidal habitat.

2. The evaluation needs to consider alternate approaches for shallowly subsided lands. Approach #4 indicates one approach – pre-breach tule planting on the subsided areas. Another approach would be to leave some subsided lands as shallow subtidal habitat, since the Action itself is to restore "tidal marsh and shallow subtidal habitat". Each approach leads to a different outcome on different time scales.

3. Because rearing habitat by necessity includes local availability of food, the evaluation team merged the first two Intended Outcomes (rearing habitat and local food) into one outcome.

4. There is generally no functional difference between Approach #1 (reconnecting 10 miles of disconnected remnant sloughs) and Approach #2 (breach dikes to restore tidal exchange) and thus for the purposes of this evaluation, we are considering the approach to be only as stated in #2. Approach #2 provides for restoration acreage targets within the four subregions established in the Suisun Marsh Plan (CDFG et. al., In Preparation). Aiming to restore large clusters will lead to large channels conveying the necessary tidal prism. If the intent is to create large sloughs, then the action should be rewritten to specify large sloughs. The approach should be to either restore large clusters or to restore wetlands that include the few remnant diked large sloughs.

5. The action should articulate whether the intent is restoration of many separate sites or fewer, larger clusters of sites. The pattern of property ownership in Suisun Marsh is hundreds of individually-owned duck clubs and ownership size is typically a few hundred acres (polygons within Figure 1 depict land ownership boundaries). To the extent that the action has a specific goal to restore large tidal sloughs (approach #1 but not reflected distinctly in intended outcomes), restoration should be focused on multiple clubs that border the extant large sloughs currently functioning as water supply distributary canals.

Scale of Action

Large.

Rationale:

This is a large scale restoration action due to its large spatial extent. As listed in Table1 below, the Delta currently has approximately 21,600 acres of tidal marsh habitat (baseline). Additionally, 67,000 acres of diked and other lands have been identified as potentially restorable to tidal marsh (neglecting effects of restoration on reducing tidal range). The proposed 9,000 acres of tidal marsh and shallow sub-tidal restoration options would significantly increase marsh acreage above current conditions. Significant amounts of the 67,000 acres of identified restorable lands are highly constrained such that they could not be restored in the near term (South Delta and Netherlands alone account for 31,000 acres of the 67,000 acres). Therefore, this action also represents an important part of the potentially restorable tidal marsh lands.

Table 1. Summary of Tidal Marsh Acreages

Area	Acreage	Source
Delta (entire Delta proper)	738,000	DWR, 2009
Historic tidal marsh/wetlands in Delta	525,000	TBI, 2002
Current extent of tidal marsh/wetlands in Delta.	21,600	TBI, 2002
Restorable intertidal lands within Delta.	67,000	CA DVSP, 2008, Table 1, p.77.
Proposed Cosumnes/Moklemne tidal restoration (this action)	9,000 tidal marsh and sub-tidal	BDCP, 2009

Evaluation Summary

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

> *Note: Asterisk (*) indicates that this negative outcome is measured relative to baseline conditions. These negative mechanisms also decrease the certainty that positive effects of site restoration will be realized*. Appendix "A" contains the above information in summary tables that are organized by the numerical order of the outcomes, rather than species. This alternative format may be helpful to some readers. Please refer to Appendix A for details.

Other Negative Outcomes Identified, Not Evaluated

During the course of this evaluation, the team identified two potential negative outcome that it did not evaluate due to lack of time. It is recommended that this potential outcome be evaluated at some point in the future when additional time is available.

- ON1. Pesticide use for mosquito control
- ON2: Increase in the availability of selenium

Positive Outcomes Identified, Not Evaluated

During the course of this evaluation, the team identified one potential positive outcome that it did not evaluate due to lack of time.

- Reduce methyl mercury by changing land use.

Outcomes with Zero Magnitude

During the Evaluation process, several of the outcomes identified by BDCP early in the process, were found to have a zero magnitude. These outcomes are listed below and their evaluation is provided in Appendix B.

- OP1: Locally provide areas of cool water refugia for winter-run salmonids.
- OP2: Locally provide areas of cool water refugia for late fall-run salmonids.

Relation to Existing Conditions

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

Yes

Nature of Change:

This action would result in three large changes to baseline conditions:

1. **Conversion of diked managed wetlands to tidal perennial wetlands.** Most of the Suisun Marsh diked wetlands are managed as seasonal wetlands to promote waterfowl utilization during the winter migratory period, in support of hunting activities. Some of the diked wetlands are managed as perennial wetlands, and others are managed to provide habitats for the endangered salt marsh harvest mouse. The most significant change of this conservation measure is conversion of these "duck clubs" from diked seasonal wetlands to perennial tidal marsh which would have corresponding effects on habitat suitability for waterfowl. Although tidal marsh restoration sites provide some waterfowl support functions, especially in early stages of evolution, the final restoration condition/stage will reduce waterfowl habitats relative to existing conditions.

2. **Reduce tidal range in portions of Suisun Marsh.** The Suisun Marsh Plan (SMP) conducted two-dimensional numerical modeling (RMA model) to examine restoration effects on tide range within Suisun Marsh (CDFG et. al., In Preparation). The modeling compared restoration scenarios of differing configurations within the spatial distribution of restoration activities shown in Figure 1. One scenario focused on mostly northern marsh restoration and another scenario focused mainly on southern marsh restoration. In general, the modeling found significant reductions in tidal range, ranging from elimination of tides at the upper reaches of the smaller tidal sloughs to well under one foot in Grizzly Bay in the south. The model predicts effects would be strongly localized to the amount of restoration along any particular reach of tidal slough, to the size of the restoration site, and to the baseline elevation of the restoration site. The lower the starting elevation of the restoration site, the greater the tidal dampening effect.

3. **Altered tidal flows in major sloughs.** The SMP RMA modeling also showed altered tidal flows in the major sloughs with restoration, concurrent with reductions in tidal range (CDFG et. al., In Preparation). Model results for the west end of Montezuma Slough showed flow increases ranging from 6,000 to 12,000 cfs over baseline values

of 17,000-32,000 cfs depending on time of year and spring-neap tide conditions. Suisun Slough tidal flow changes were highly dependent on the scenario modeled. Focusing restoration in the north increased flows 2,000-3,000 cfs over a baseline of 4,000-7,000 cfs (again, varies with time of year and spring-neap tide conditions). In contrast, focusing restoration in the south reduced flows 2,000-4,000 cfs and in particular reduced the variability in flows between spring and neap tide conditions considerably.

4. **Altered west Delta salinity conditions.** The hydrodynamic connectivity between Suisun Marsh and the Delta and the resulting effects on salinity levels exhibits sensitivity to location of restoration in Suisun Marsh and to Delta outflow conditions. Focusing restoration in northern Suisun Marsh tends to reduce salinities in the west Delta under low Delta outflow conditions by up to 10-20%. In contrast, focusing restoration in southern Suisun Marsh tends to increase salinities in the west Delta under low Delta outflow conditions by up to 5-15%. It is important to note that the baseline salinity values being altered are in the range of 0.5-1.5 mS/cm. These percent changes are relatively small in absolute salinity values.

Salinity Management in Suisun Marsh

Water management in Suisun Marsh has focused on salinity control since the 1970's. The State and federal water projects built several salinity control structures in the Marsh between 1970 and 1990, including the Roaring River Distribution System, Morrow Island Distribution System, Goodyear Slough Outfall, Lower Joice Island Unit, Cygnus Unit, and the Suisun Marsh Salinity Control Gate (SMSCG). The SMSCG is the largest and most effective salinity control structure within Suisun Marsh. It is located at the east end of Montezuma Slough near its confluence with the Sacramento River. When operational (October-January), the salinity gate is opened on ebb tide to allow low salinity Sacramento River water into the Marsh and closed on flood tide to prevent ocean water incursion into the western end of Montezuma Slough. When the gate is operating, net flow in Montezuma Slough is more than 70 cubic meters per second (cms) (2,500 cubic feet per second [cfs]) (east to west) compared to nearly zero when not operating. By comparison, the discharge in the Sacramento River measured at Freeport (near Sacramento) during the typical period of gate operation is on the order of 200-500 cms (7,000-18,000 cfs). When not operational, the gate is left in the fully open position, allowing full tidal exchange between Montezuma Slough and the lower Sacramento River. (Enright 2009, in preparation).

Gate operations are effective at controlling salinity levels at most locations in the Marsh. The magnitude, timing, and duration of salinity reduction in response to the SMSCG operation vary with proximity, with greater salinity reductions observed in the eastern part of Suisun Marsh, less reductions in the western Marsh, and no reductions observed in the northwestern part of the Marsh. Water quality stations are located throughout Suisun Marsh. A drop in salinity due to gate operations is seen immediately at monitoring station S-64 (National Steel) and about one day or so later at S-49 (Montezuma Slough at Beldon's Landing) because both are located close to the gates. However, it takes about two to three days before a salinity drop can be observed at S-42 (Suisun Slough and Volanti) and S-21 (Chadborne Slough at Sunrise Club), because both are located in the north-central part of the marsh. Salinity levels at C-2 (Sacramento River at Collinsville) tend to increase slightly from gate operations because the interactions between tidal exchange, outflow, and gate operations result in a more erratic salinity pattern. At S-35 (Goodyear Slough) in the far western Suisun Marsh, gate operations are effective in controlling salinity, but to a lesser magnitude and with a longer time lag due to the distance of the station from the gates. At S-97 (Ibis), gate operations are not effective in controlling salinity because of its location in the far northwest portion of the marsh (Enright 2009, in preparation).

Existing Topography of Suisun Marsh Managed Wetlands

Although DWR LiDAR data from 2005 and 2007 is utilized for planning and analytical purposes, this data has uncertainty in its measurement of existing topography of managed wetlands in the range of 1-3 feet depending on location. The extensive vegetative cover of the managed wetlands combined with the large height variability across plant species present in the marsh and LiDAR's inability to penetrate dense vegetation effectively causes these large uncertainties. Only three wetland-scale ground-based topographic surveys exist for validating LiDAR data (Blacklock surveyed by DWR and clubs 112 and 123 surveyed by the Low DO/MeHg BMP project) and they show difference from 2005 LiDAR ranging from about 0.5 ft with short, lower density vegetation to more than 2 feet with tall, dense vegetation. These three sites are not adequate to evaluate the full LiDAR data but provide some sense of the range of measurement uncertainty. LiDAR cannot penetrate water and therefore ponded areas do not yield accurate LiDAR measurements of elevations. Levees, which are mostly unvegetated, present fairly reliable LiDAR-derived elevations. Figure 2 above shows the 2005 LiDAR topographic data set, with an applied 1.5-foot uniform lowering within managed wetland interiors to account for vegetation interference.

Overview of Productivity Import-Export

The worksheet for HRCM4-Cache Slough contains a detailed discussion of the general concepts around productivity in restored tidal marshes and shallow open water habitat, including the availability of primary productivity to the aquatic food web within and outside of restoration sites. Related discussion items include:

- role of restoration stage, sedimentation, and biomass accumulation, and sea level rise
- role of hydrology and hydrologic connectivity
- role of *Corbicula* in affecting exported production
- role of residence time in affecting productivity levels.

Please see the Cache Slough worksheet for details about this topic.

Potential Positive Ecological Outcome(s)

Outcome P1: Increase rearing habitat area (including physical and biotic attributes) for covered fish species.

As indicated at the beginning of this worksheet under the section entitled "Problems with Action", the team decided to merge two Intended Outcomes (rearing habitat and local food) into one outcome, P1, as shown below because rearing habitat for juvenile fish by necessity includes local availability of food. This outcome includes food (both primary and secondary production) produced within the vegetated marsh, within marsh channels, and within the subtidal areas adjacent to the vegetated marsh. General information that applies to salmon runs is provided in the worksheet for HRCM 4 – Cache Slough, Outcome P1c on page 15. Please note that green and white sturgeon are not known to utilize the Cosumnes and Molkemne River systems and so these species are not listed in the analysis below.

P1a. Delta smelt

The food web supporting Delta smelt production is a primary component of habitat suitability that affects Delta smelt growth rates, health, fecundity, and mortality (Norbriga and Herbold, 2008, page 21). The food web supporting Delta smelt is based on the production of pelagic zooplankton. Delta smelt are believed to be food limited for at least some life stages. Delta smelt are found in the large sloughs of Suisun Marsh (Norbriga and Herbold, 2008, p. 11).

Magnitude = 3 - Medium.
Delta smelt sub-adults rear in Suisun Bay (Norbriga and Herbold, 2008, p 11). Although they consume food produced on tidal marshes, the DRERIP Delta smelt conceptual model (p. 27 and elsewhere, and pers. comm. with B. Herbold, US EPA) indicates that Delta smelt do not forage in shallow environments. Delta smelt will not benefit from the physical habitat structure to be created on shallow parts of this restored landscape. Food consumed *in the shallow tidal areas* is likely to be nil.

The food consumed in directly adjacent pelagic habitats depends entirely on how much of the zooplankton produced in the shallow areas is consumed by fish that actually forage in shallow environments where the food is produced. Historically, a significant component of the Delta smelt population would have access to food produced in the direct vicinity of this project (i.e. they have been found rearing in this area to an extent that depended on hydrologic conditions. (See Norbriga and Herbold, 2008). This outcome assumes that Delta smelt are limited by food production. The Conceptual Model indicates that Delta smelt rearing in open water habitats may have, in the past, relied on export of food from a vast network of tidal marshes (Norbriga and Herbold, 2008, p12).

Certainty = 1-Minimal
The magnitude of outcome is dependent on highly variable ecosystem processes or other external factors. The impact of food produced on site is related to how much of that food makes it into the adjacent channels and bays and to the nature and extent of food limitation in this region currently. These factors are somewhat uncertain. The magnitude of food production depends on physical aspects of the restoration (e.g. those that contribute to retention time) and biological outcomes (e.g. the amount of food

consumed in shallow areas that is then not exported to adjacent deep habitats). This is a significant amount of restored habitat in the center of the Delta smelt geographic range. *Corbicula* establishment could limit, if not eliminate, the productivity benefits of the restoration to Delta smelt. See Negative Outcome N1b. Similarly, establishment of SAV and centrarchid (or other) predators could lead to predation rates on the site that eliminate any net benefits at a population level.

Comments and/or Assumptions used in scoring: Residence times in the restored sections are such that they optimize production and transport of zooplankton species consumed by this fish. This analysis assumes salinities in Suisun Bay are maintained at levels that provide habitat for rearing Delta smelt. If water management in the restored areas includes managed tidal marshes, these are assumed to be managed so as to prevent releases of water with high biological oxygen demand (BOD) into Delta smelt habitat. The team also assumed the area would be managed so as not to entrain Delta smelt.

P1b. Longfin smelt:

Longfin smelt larvae, juveniles, and sub-adults rear in Suisun Bay and other pelagic parts of the estuary, (Rosenfield, 2008). Larvae are commonly found in large sloughs of Suisun Marsh (Suisun Marsh Survey, Moyle pers. comm.), probably because they are forced there by hydrodynamic dispersion. Sub-adults and adults are much less common in Suisun Marsh.

Magnitude = 1 - Minimal
Longfin are widespread in the San Francisco Estuary and are detected each year in the western Delta, Suisun Bay, and Suisun Marsh (Baxter 1999; Fig 6 and Rosenfield 2008, page 5). Although larvae are frequently found in marsh environments, it is likely that they are simply dispersed there by local hydrodynamics (Baxter 1999). It is not likely that they depend on these habitats for survival (Moyle pers. comm.) as larval longfin smelt are found throughout the Estuary (Rosenfield, 2008). Furthermore, the DRERIP Conceptual Model indicates that, soon after they become free-swimming fish, longfin smelt concentrate in deepwater environments (i.e. marsh is not considered “rearing habitat” for longfin smelt). Post-larval longfin are only rarely found in marsh environments.

This outcome assumes that longfin smelt are food-limited in this locality. Indeed, Hobbs et al. 2006 found that longfin in the northern part of Suisun Bay were in better condition than longfin in southern Suisun Bay. Thus, the water bodies influenced by this restoration action may not be food-limiting to longfin smelt.

Certainty = 1- Minimal
Sampling of longfin smelt detects larvae in Suisun Marsh and Suisun Bay. However, only a small fraction of larval longfin is detected in Marsh environments. The lifetime success rate of larval longfin smelt that occur in marsh environments is not known.

P1c. Chinook and Steelhead

A number of considerations apply to all the salmonids for this conservation measure and these are described here, followed by run-specific magnitude and certainty evaluations. The value of estuarine rearing varies across runs (see Williams and Rosenfield, In preparation page 15).

General Seasonality of Delta Use. Juveniles of most runs migrate during winter through spring.

Role of Outmigrant Size in Duration of Delta Use. Larger outmigrants generally rear for shorter periods in the lower estuary before moving to the ocean. Life histories that include rearing upstream (including in-rivers and on floodplains) produce large outmigrants that are believed to derive less benefit from restoration of rearing habitat in the Delta.

Temperature. Salmonids are sensitive to warm water. With warming that may occur under climate change, water temperatures are expected to occur in this area with some frequency during April and October as well. Steelhead, fall run Chinook salmon, and spring run Chinook salmon are typically present in the Delta during some of these months and value of tidal marsh restoration to these runs would be reduced because of the warmer water.

Role of Delta in Overall Life-History of Salmonids. Delta rearing is but one relatively short period in the overall life of salmonids and is not believed to be a key limiting factor for spring run, winter run, late-fall run or steelhead. Other limiting factors such as upstream spawning and rearing habitats and water operations (including Delta exports) are more important in the overall life history for these salmonids.

Food Productivity to Support Rearing. Factors affecting food productivity described in this worksheet indicate that salmonids would find food resources in the Cache Slough area. The benefits of this productivity would accrue more to smaller migrants and when water temperatures support growth and smoltification.

Predator Exposure. Estuarine habitats that support salmonid rearing potentially also support predator populations, including (in particular) introduced Centrarchids that prefer shallow slow-moving freshwater environments. Increasing the residence time of

salmonids in the Delta (by increasing rearing habitat) may also increase exposure to predator populations – the number of predator species in the Delta is much higher now than it was historically because of the introduction of Centrarchid and other non-native predators and maintenance of conditions that support those predators.

P1c1. Winter-run Chinook salmon

Winter-run juveniles move through the Delta from fall through winter.

Magnitude = 1 - Minimal

This outcome assumes that "rearing habitat area" (quantity) and/or food is limiting. The Conceptual Model, page 16, states, "Spring Chinook, or at least the Butte Creek population, pass quickly through the Delta, so habitat restoration there seems unlikely to do much for them. The same is probably true for late fall Chinook, and for steelhead. The case for winter Chinook seems equivocal." Winter-run will consume the types of zooplankton produced in this restoration (under the assumed condition). Most winter-run migrate through this area when temperatures are cool enough to support rearing (Williams and Rosenfield, In preparation, Figure 3).

The conceptual model (Williams and Rosenfield, In preparation) shows a moderate impact of this kind of habitat on competition – competition may have a moderate impact on growth – but both of these impacts are highly speculative. Food limitation is not considered a major limitation on survival in this part of the life stage. Winter-run have the smallest population of any Chinook salmon run in this system. They have access to the same estuarine habitats as the other runs (and probably more access than fall or spring run fry that migrate later in the year when temperatures are higher). Thus, competition and growth limitation due to habitat limitation in the Estuary is least likely for this run among all the Central Valley Chinook populations. In addition, this run rears upstream and probably enters the Estuary at a size where rearing in the Estuary is less important.

The relative impact of stressors across habitats and upstream impacts are more likely to be important. Stressors in the Estuary are related to stressors other than limitation of habitat (Williams and Rosenfield, In preparation). The major impacts to winter-run Chinook salmon occur well-upstream of Suisun Marsh (e.g. they have only one spawning location with limited access to cold water or quality spawning and incubation habitat). Juveniles appear to migrate during the winter when water temperatures and flows allow them access to the maximum amount of presently-available rearing habitat. Also, because they migrate at a different time of year than the more populous fall-run, competition for "habitat" in the Delta is probably not a big stressor to this population. Finally, these fish migrate at a size where estuarine habitat is not believed to be a big benefit to them. For these reasons, the magnitude of impact to this run is expected to be "minimal", at best.

Certainty = 1-Minimal
Winter run represent a unique life history strategy for the species as a whole. No direct studies of this run's habitat use in estuarine habitats have been published. However,

unless access to additional spawning/rearing habitats (with adequate cold water and spawning gravel) is created upstream, rearing habitats in the Delta will be of little value to this species.

P1c2.Spring-Run Chinook Salmon

Spring-run juveniles move through the Delta from winter through spring.

Magnitude = 3 - Medium.
This outcome assumes that "rearing habitat area" (quantity) and/or food is limiting. The conceptual model, page16, states,"Spring Chinook, or at least the Butte Creek population, pass quickly through the Delta, so habitat restoration there seems unlikely to do much for them. The same is probably true for late fall Chinook, and for steelhead". The model's evaluation seems focused on one spring run population (Butte Creek). In fact, many juveniles from other populations migrate at a smaller size than Butte Creek

juveniles (Williams 2006). They migrate at about the same time as fall-run and thus may experience competition with fall run. So, this restoration may alleviate competition for a segment of the population. The conceptual model indicates moderate benefits of increasing rearing habitat.

Spring-run salmon will consume the types of fish and zooplankton produced in this restoration (under the assumed condition). High temperatures are currently rare during May (as indicated by IEP gauges rsac075 and rsac054; Enright *pers. comm.*). Temperatures exceeding 20-21^{o}C (beyond which sub-lethal effects accumulate; Reese and Harvey 2002 *and see* Richter and Kolmes 2005) are more common and widespread in June, July, and August (as indicated by IEP gauges rsac075 and rsac054; Enright *pers. comm.*). With warming that may occur under climate change projections, high temperatures may become more frequent and extreme. Thus, spring-run rearing in this proposed restoration site during June, and July will probably be impacted by high temperatures. Only the component of the population that migrate as fry, early in the year, will experience much benefit from tidal marsh restoration.

Whereas upstream habitats are more likely to be important to productivity of this run, stressors in the Estuary may be related to competition with hatchery and wild production of fall run Chinook salmon (Williams and Rosenfield, In preparation).

In summary, whereas spring-run Chinook are commonly believed to migrate at a large size, juveniles from two of important watersheds (Deer and Mill Creek) appear to migrate at a small size and these fish may benefit from rearing habitat restoration at lower elevations. Spring-run that migrate at small body size must compete with more abundant fall run Chinook salmon migrants. Thus, creation of suitable rearing habitat may alleviate an important bottleneck for this species. However, it is important to note that only a fraction of the spring-run population will benefit from rearing habitat restoration; the fraction includes (a) those fish that migrate at a size where rearing in low elevation habitats is important, (b) those fish that migrate early enough in the year to capitalize on beneficial temperatures in restored habitats (e.g. before May), and (c) those fish that have not already benefited from growth on rearing habitat on floodplains. For all of these reasons, the “medium” magnitude score is probably a generous assessment of likely benefits.

Certainty = 1 - Minimal
There are no direct studies of spring-run Chinook salmon habitat use in this ecosystem. Variability (inter-population and inter-annual) in the relationship between habitat volume-density-competition-and growth contribute to uncertainties (Williams and Rosenfield, In preparation).

Given the temperature limitations and differences in life history among spring-run populations, the Evaluation Team can be moderately certain that the maximum positive magnitude of this impact from this action is medium; however, there is relatively low certainty that there will be any beneficial impact at all. Establishment of *Corbicula*, SAV, or predatory fish populations could limit if not eliminate the productivity benefits of the restoration to Chinook salmon. See Negative Outcome N1a, b, and c.

P1c3. Fall-run Chinook Salmon

Fall-run juveniles move through the Delta from winter through spring.

Magnitude = 3

This outcome assumes that "rearing habitat area" (quantity) and/or food is limiting. The conceptual model, page 16, states "Fall Chinook […] could benefit strongly from tidal marsh restoration". Fall Chinook enter estuarine habitats at a small size and the text anticipates benefits from additional rearing/growth opportunities.

Fall-run will consume the types of zooplankton produced in this restoration (under the assumed condition). High temperatures are currently rare during May (as indicated by IEP gauges rsac075 and rsac054; Enright *pers. comm.*). Temperatures exceeding 20-21^{o}C (beyond which sublethal effects accumulate; Reese and Harvey 2002 *and see* Richter and Kolmes 2005) are more common in June, July, and August (as indicated by IEP gauges rsac075 and rsac054; Enright *pers. comm.)*. With warming that may occur under climate change projections, high temperatures may become more frequent. Thus, fall run rearing in this proposed restoration site during June, and July will probably be impacted by high temperatures.

This outcome will likely benefit the Sacramento portion of the fall-run population as it tends to migrate earlier than the San Joaquin and East side fall run populations (salmonid model Figure 3). Later migrants from the Sacramento or San Joaquin are not likely to benefit from this restoration (and may actually be negatively impacted if they inhabit sloughs when high temperatures prevail).

Stressors in the Estuary are relatively important to fall run Chinook salmon (Williams and Rosenfield, In preparation).

In summary, most fall-run Chinook migrate as fry and these fish may benefit from rearing habitat restoration at lower elevations. Fall run Chinook salmon are the most abundant Chinook salmon in this Estuary. They are produced in hatcheries and they migrate at the same time as spring-run Chinook salmon. They also migrate at times when potential rearing habitats may be inaccessible due to high temperatures or reduced inundation of habitat. Thus, they are more likely to be exposed to competition for habitat than some other salmonid populations in this Estuary. Creation of suitable rearing habitat may alleviate an important bottleneck for this species. A relatively large fraction of the fall-run population may benefit from this habitat restoration; the fraction includes (a) those fish that migrate early enough in the year to capitalize on beneficial temperatures in restored habitats (e.g. before May), and (b) those fish that have not already benefited from growth on rearing habitat on floodplains.

Certainty = 1 - Minimal

Fall run Chinook use of fresh water tidal and sub-tidal environments is well-documented in other systems but is not well studied in this system (Williams and Rosenfield, In preparation p. 24) possibly because this kind of habitat is limited in this ecosystem (Williams and Rosenfield, In preparation p.10). The effect of global climate change on water temperatures in this area during fall run migration period also decreases the window of time during each year when restoration will produce benefits.

Other factors create uncertainty as to the benefits of this measure for this population. *Corbula* establishment could limit if not eliminate the productivity benefits of the restoration to Chinook salmon. Similarly, establishment of predators or SAV that supports predation could eliminate most or all of the benefits created by this measure. See Negative Outcome N1a, b, c, and d.

Assumptions/Comments: Benefits of this restoration for emigrating Chinook salmon from the Sacramento River will be reduced as accessibility to and use of floodplain habitats increases. Juveniles are not likely to spend significant time rearing in downstream habitats if they have already reared on floodplain habitats. Once they reach a threshold size/condition, they are likely to migrate to the ocean.

P1c4. Late Fall-run Chinook salmon

Late-fall run juveniles move through the Delta from fall through winter. The fisheries biology community is currently debating whether late fall run Chinook exhibit separate reproduction from fall run. As that debate has not yet been settled, this evaluation presents late fall run as a distinct run.

Magnitude = 1 - Minimal
This outcome assumes that "rearing habitat area" (quantity) and/or food is limiting. The conceptual model, page 16, states, "Spring Chinook, or at least the Butte Creek population, pass quickly through the Delta, so habitat restoration there seems unlikely to do much for them. The same is probably true for late fall Chinook, and for steelhead" (Williams and Rosenfield, In preparation).

Late fall-run will consume the types of zooplankton produced in this restoration (under the assumed condition). Most late-fall run migrate through this area when temperatures are cool enough to support rearing. Conceptual models suggest a low impact of this kind of habitat on competition and of competition on growth (Williams and Rosenfield, In preparation). Late-fall run are a relatively small population, they emigrate earlier than fall and spring runs (see Figures 3 and 4 of Williams and Rosenfield, In preparation) and therefore are not expected to experience competition for estuarine habitat with these more populous runs (i.e. they are less likely to be "habitat" limited in the estuary than the other runs).

Upstream impacts (e.g. access to spawning habitats) are more likely to be important and that stressors in the Estuary are uncertain (Williams and Rosenfield, In preparation). Tidal marsh has a low impact on competition and competition in this area has a low impact on growth (Williams and Rosenfield, In preparation).

In summary, the major impacts to late fall-run Chinook salmon occur well-upstream of Suisun Marsh (e.g. they have only one spawning location with limited access to cold water or quality spawning and incubation habitat). Juveniles appear to migrate during the winter when water temperatures and flows allow them access to the maximum amount of presently-available rearing habitat. Also, because they migrate at a different time of year than the more populous fall-run, competition for "habitat" in the Delta is probably not a big stressor to this population. Finally, these fish migrate at a size where estuarine habitat is not believed to be a big benefit to them. For these reasons, the magnitude of impact to this run is expected to be "minimal", at best.

Certainty = 1- Minimal
The importance of growth in estuarine environments is unstudied for this run and there is a low certainty of impact (Williams and Rosenfield, In preparation).

The Evaluation Team is moderately certain that this action will have no more than a minimal impact on late-fall run productivity. There is considerably less certainty that there will be any benefit to late-fall Chinook from this restoration. Establishment of *Corbicula*, SAV, or predatory fish populations could limit, if not eliminate the productivity benefits of the restoration to Chinook salmon. See Negative Outcome N1a, b, c, and d.

P1d. Splittail

The relationship of drivers, linkages and outcomes are described in pages 12, 13, 14, and 15 of the Splittail Conceptual model (Kratville, 2008).

Magnitude = 3 - Medium
Suisun Marsh is the dominant population center for Sacramento splittail. Restoring 9,000 acres of tidal marsh to this area may have significant population level effects. This newly restored area will only be used by increased numbers of splittail if adequate floodplain spawning is provided. Splittail populations are largely controlled by floodplain inundation that allows for large scale spawning events. Following a spawning event, if large accessible amounts of new habitat for juvenile and adult splittail become available, the population may increase.

Certainty = 2- Low
The uncertainty lies in whether this new rearing area will increase splittail populations. This restoration will increase the opportunity for rearing juveniles; however this does not appear to be a limiting factor in splittail abundance compared to floodplain inundation. This level of spawning only occurs in years with large scale floodplain inundation. This outcome is dependent on splittail being able to spawn in numbers great enough to need access to this new habitat.

Establishment of *Corbicula*, could limit, if not eliminate the productivity benefits of the restoration to splittail. See Negative Outcome N1b. Similarly, colonization by invasive predators could result in added mortality that would counteract any benefits of restoration (especially if SAV invasion facilitates predation success).

P1e. Green Sturgeon

The relationship of drivers, linkages, and outcomes is described in pages 4, 8, and 9 of the Green Sturgeon Conceptual model (Israel and Klimley, 2008).

Magnitude = 2 - Low
Information on green sturgeon diets and physical habitat needs as juveniles in the Delta is limited. Other species of sturgeon in other systems do feed on drifting insects as juveniles. Tidal marsh restoration in this area may be associated with large mud flats which sturgeon are known to access for food (Israel and Klimley, 2008, pages 10 and16). If this occurs, green sturgeon juveniles and adults may benefit from this increased habitat. This may not translate into improved population numbers.

Certainty = 2 - Low
The key limiting factors are thought to be upstream in spawning locations. There is low certainty about whether this proposed restoration will benefit sturgeon as described in this outcome. The low certainty is due to the lack of research on this aspect of sturgeon biology/ecology in the Delta.

P1f. White Sturgeon

The relationship of drivers, linkages, and outcomes is described in pages 19, 20, 21 of the white sturgeon model (Israel et. al., 2009).

Magnitude = 2 - Low
Information on white sturgeon diets and physical habitat needs as juveniles in the Delta is limited. Other species of sturgeon in other systems do feed on drifting insects as juveniles. Tidal marsh restoration in this area may be associated with large mud flats where sturgeon are known to access for food (Israel et. al., 2009, pages 9, 16, and 17).

If this occurs, white sturgeon juveniles and adults may benefit from this increased habitat. This may not translate into improved population numbers.

Certainty = 2 - Low
The key limiting factors are thought to be upstream in spawning locations. There is low certainty about whether this proposed restoration will benefit sturgeon as described in this outcome. The low certainty is due to the lack of research on this aspect of sturgeon biology/ecology in the Delta.

Outcome P2: Increase the availability and production of food in Suisun Bay by exporting organic material via tidal flow from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Bay.

P2a. All covered fish species

General Observations: The Tidal Marsh and Foodweb models [Kneib et. al., 2008, page 9 and Durand, 2008, section 2.16)] provide a general indication that there may be a linkage between tidal marsh habitat as a driver and increases in availability and production of food resources as an outcome, but that the mechanism for this linkage may be movement by fish. The tidal marsh conceptual model also states that freshwater tidal marshes are net exporters of high-quality organic production (page 2 in Kneib et. al., 2008). See also Dame et al. 1986, Kimmerer and McKinnon 1989, Kneib 1997, Lucas et al. 2009. Please see the evaluation worksheet for action # HRCM4-Cache/Yolo, Outcome P3, for more details about **Tidal Marsh Contributions to Exported Production.**

There was disagreement within the evaluation team regarding the magnitude and certainty of expected benefits of tidal reintroductions with regard to the export of food (phytoplankton, zooplankton, insects, and small fish) to areas downstream of Rio Vista and the likely benefits to covered fish species. In the spirit of presenting the scientific discourse, both points of view are captured below.

Two key questions discussed were: (1) can we predict the sign of the flux of productivity (i.e. will the restoration area be a source or a sink for primary and secondary productivity); and (2) will there be adequate advection to move material out of the restoration area and downstream to Rio Vista (assuming the restoration area is a source of productivity, as opposed to a sink). Additional information and analyses is needed to better answer these key questions. To develop this additional information, the team recommends future development of a Tropho-dynamic model as described in the section on page 41 entitled "Research Needs".

Viewpoint #1

Please see the text of Outcome P3 in worksheet HRCM4 – Cache Slough for additional background information about Viewpoint #1.

Magnitude = 3-4 – Moderate to High
Without advective connection, restoration will still have significant productivity benefits to covered fish species and to many other species due to providing areas of highly functional habitat in conjunction with restoration elsewhere that collectively provide fish species a range of options that spread risk through exploiting available resources when they are present. Refer to Ted Sommers, IEP Estuarine Ecology Team or CAERS poster. In addition, these areas would export that productivity through the "trophic relay" concept described in the tidal marsh conceptual model (fish export the productivity).

Certainty = 3 – Moderate
Certainty is reduced by the potential for establishment of invasive clams that could consume substantial portions of phytoplankton and hinder zooplankton productivity.

Viewpoint #2

Please see the text of Outcome P3 in worksheet HRCM4 – Cache Slough for additional background information about Viewpoint #2.

Magnitude = 1 (Minimal) to 2 (Low)
The implied relationship is that restoring 5,000 to 11,000 acres of tidal marsh will export nonliving and living organic matter including plankton and fish, thereby supporting foodwebs of the upper estuary. An implicit assumption is that any increase in the area of shallow habitat would result in enhanced plant productivity some of which would be exported.

Certainty = 1 -Minimal
.The sign of the signal is difficult to determine, except for total organic carbon, most of which is dissolved. Although dissolved organic carbon (DOC) will likely flow out of the marsh, fluxes of other components may be in or out (Kneib et. al., 2008, page 9). Colonization by invasive clam species can wipe out the food web production effect entirely. We have no certainty at all that they will not colonize. In addition, colonization of the site by vertebrate consumers (e.g, inland

silverside) can also significantly reduce the amount of food available for export beyond the site boundaries (Moyle 2002). There is evidence from within this system (Dean et al. 2005) that restored marshes can act as sinks for certain zooplankters; in this case, the sign of the signal would be negative.

Outcome P3: Provide local areas of cool water refugia for Delta smelt and salmonids.

The cause and effect relationship associated with this outcome is described in Stacey and Monismith 2008, Malamud-Roam 2000, and Enright 2008. Considering the landscape scale (Large) of the action, the relationship between tides, physiography, and water temperature could be very large. The relationship between drivers (wind, insolation, fetch, tides, currents) and linkages (long-wave, short wave, latent, and sensible heat flux) is complex and may produce both warmer and cooler water on a variety of time and space scales. Larger spatial gradients of water temperature will likely occur. The frequency of threshold temperatures for various species is uncertain. See Stacey and Monismith (2008), Malamud-Roam (2000), Enright (2008).

Geomorphic complexity in natural marshes filter physical drivers and generate water temperature variability at tidal, spring-neap, and seasonal timescales. These processes may create cool water refugia for Delta smelt as a positive outcome of the proposed conservation measure. Sea level rise and marsh evolution by sedimentation and bioaccumulation will change the nature of the land-water interface over time.

The quantitative dynamics of heat flux by various mechanisms or "linkages" are well understood (Temperature CM; Stacey and Monismith In revision). Heat flux dynamics can be written as advection-diffusion equations with the heat flux linkages explicitly accounted for. Predictability and cause and effect relationships between action-approach-outcome are uncertain because parameterization of each heat flux linkage is data intensive and location specific. Predictable outcomes depend on detailed local understanding of drivers including wind dynamics, wind fetch, shading, humidity, landscape physiography, and tides. These details can be worked out for a given site with sufficient monitoring and assessment. However, in the abstract, local temperature may exhibit net increases or decreases depending on the relationship between drivers and linkages.

Enright (2008) measured large temperature responses to particular combinations of tidal and seasonal tide phase and time of day on a natural marsh. A 335-year tidal precession currently brings the high-high spring tide to the Suisun Marsh region near midnight during the summer. Natural tidal marshes orient their marsh plain elevation to approximately mean higher-high water. Extreme tides overtop the low natural channel levees and inundate the marsh plane shallowly. Water is rapidly cooled by long-wave, latent and sensible heat flux (Stacey and Monismith In revision) before it is returned to the tidal channel on the ensuing ebb tide to low-low water. Measured station temperature decreases up to 5 degrees C have been observed within approximately 6 hours. This process is a direct product of the landscape morphology. There is reasonable certainty that this is a real phenomenon in mature tidal marshes and can generate significant cooling that may have regional effect. The magnitude of the effect depends on acreage within the elevation band, depth of inundation, air temperature, humidity, timing of tides, and the water exchange dynamics between tidal channels and marsh plain.

Where tidal action results in frequent shallow inundation, short-wave, long-wave, latent, and sensible heat transfer will significantly affect the heat content of water. At seasonal, spring-neap, and tidal timescales, episodes of both cool water refugia and warm water are likely to occur depending primarily on the superposition of tidal and diel phasing. Considering the shallow slope of the landscape (hopefully in the absence of ditches), there will be linear elevation bands that will differentially warm and cool water. The Delta smelt spawning months are Feb-May when cool water refugia would be helpful. Currently, high-high spring tides in April-May occur in the early morning hours (~3-5AM), which may facilitate regional cooling; high tides during these months are not at the annual maxima associated with the summer and winter solstices but instead are closer to the annual minima associated with spring and fall equinoxes. The timing of the high-high tide processes ~1.5 hours per decade. Therefore, in 50 years, the May high-high tide may occur in the late morning and general regional warming could occur. This process would be occurring Delta wide. Sea-level rise may deepen northern reach channels.

P3a: Delta smelt

Magnitude: 2 - Low
As noted above, the spatial extent of this outcome could be limited. However, in some cases the effect could occur across a relatively large area. Thermal stresses for Delta smelt in this location occur typically in May and June, so some potential for a benefit exists. Please refer to the discussion located in HCRM4 – Cache Slough Restoration Action, Outcome P4, page 25 for more details.

Certainty: 1 - Minimal
The basis for our understanding is a single unpublished study in Suisun Marsh. The extent to which this effect may transfer to the restoration site, and to which Delta smelt and salmon will take advantage of it, cannot be predicted. Please refer to the discussion located in HCRM4 – Cache Slough Restoration Action, Outcome P4, page 26 for more details.

P3b. Salmonids

High temperatures are currently rare during May (as indicated by IEP gauges rsac075 and rsac054; Enright *pers. comm.*). Temperatures exceeding 20-21^{o}C (beyond which sublethal effects accumulate; Reese and Harvey 2002 *and see* Richter and Kolmes 2005) are more common and widespread in June, July, and August (as indicated by IEP gauges rsac075 and rsac054; Enright pers. comm.). With warming that may occur under climate change projections, high temperatures may become more frequent and extreme. Thus, Chinook salmon (spring-run and fall-run) and steelhead rearing in this proposed restoration site during June and July will probably be impacted by high temperatures. Forces that reduce those temperatures may improve survival, growth and smoltification success.

Benefits are limited to those emigrants rearing in this habitat after May, when temperatures in this region increase above optimal rearing threshold of 12-16^{o}C (Marine and Cech 2004). Benefits of this effect will be transient (temperatures will not be reduced below critical for all days during months when the effect occurs at all). Also, as mentioned in the description, this phenomenon is transient over time as the timing of tidal cycle shifts.

P3b1: Spring run salmon

Magnitude = 2- Low.
Beneficial effect occurs for only a portion of the salmonid population passing through this region during a particular and narrow window of time. This outcome modifies Outcome P1 (creation of habitat). In evaluating that outcome, benefits of this action were interpreted in the light of unfavorable temperature conditions that occur in the area during late-spring and summer. To the extent that the tidal flooding/cooling phenomenon occurs on this restoration site (a function of geography and restoration design and site elevations) during the period of potential thermal stress (May through end of summer), it may provide some relief from the effects of thermal stress *for those salmon runs that migrate through this region at this time (fall and spring run and steelhead).* That benefit impacts only the proportion of the population that migrates at this time and only the proportion of the population that migrates through this area (i.e. not all fall run or all steelhead).

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

P3b2: Fall run salmon

Magnitude = 2- Low.
Beneficial effect occurs for only a portion of the salmonid population passing through this region during a particular and narrow window of time. This outcome modifies Outcome

P1 (creation of habitat). In evaluating that outcome, benefits of this action were interpreted in the light of unfavorable temperature conditions that occur in the area during late-spring and summer. To the extent that the tidal flooding/cooling phenomenon occurs on this restoration site (a function of geography and restoration design and site elevations) during the period of potential thermal stress (May through end of summer), it may provide some relief from the effects of thermal stress *for those salmon runs that migrate through this region at this time (fall and spring run and steelhead).* That benefit impacts only the proportion of the population that migrates at this time and only the proportion of the population that migrates through this area (i.e. not all fall run or all steelhead).

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

P3b3: Steelhead

Magnitude = 2- Low.
Beneficial effect occurs for only a portion of the salmonid population passing through this region during a particular and narrow window of time. This outcome modifies Outcome P1 (creation of habitat). In evaluating that outcome, benefits of this action were interpreted in the light of unfavorable temperature conditions that occur in the area during late-spring and summer. To the extent that the tidal flooding/cooling phenomenon occurs on this restoration site (a function of geography and restoration design and site elevations) during the period of potential thermal stress (May through end of summer), it may provide some relief from the effects of thermal stress *for those salmon runs that migrate through this region at this time (fall and spring run and steelhead).* That benefit impacts only the proportion of the population that migrates at this time and only the proportion of the population that migrates through this area (i.e. not all fall run or all steelhead).

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

Outcome P4: Reduce periodic low dissolved oxygen events and associated mercury methylation events associated with the discharge of waters from lands managed as seasonal freshwater wetlands that would be restored as brackish intertidal marsh.

This outcome includes methylmercury and dissolved oxygen (DO) together because MeHg dynamics are interrelated with dissolved oxygen (DO) dynamics.

P4a. All covered fish species

Interactions between environmental conditions and wetland management practices in Suisun Marsh can lead to localized and periodic episodes of severely low dissolved oxygen (DO) events in adjoining water bodies. These low DO plumes impact the neighboring aquatic ecosystem, impairing primary and secondary production in this area (and its contribution to the larger food web of the Marsh and Estuary) and even causing acute mortality in at-risk fish species. Past research has observed that such DO sags coincide in both time and space with initial fall flood-up and discharge activities of adjacent managed wetlands (Schroeter and Moyle, *pers. comm*.). Low DO levels are also known to occur during June in Peytonia and Boynton sloughs (Schroeter *unpublished*) and these may also be related to management of tidal marshes for waterfowl production. The wetlands in question are dry-managed during the summer and early fall months. The wetlands are then prepared for waterfowl habitat and hunting with a series of flood-drain-flood cycles. Dissolved oxygen sags associated with these events most commonly occur in November (Schroeter *unpublished.*); they can be persistent, lasting from weeks to even months. During large events, the effects from a local discharge may be transported several kilometers through tidal action to sloughs with little or no pond drainage activities. Peytonia, Boynton, and Suisun Sloughs in the northwest Marsh have exhibited the most significant low DO problems. (Schroeter and Moyle, *pers. comm*.).

The indirect effects (e.g. impacts to the local substrate biota and regional food web) of this phenomenon are difficult to assess. Unlike low DO problems elsewhere (e.g. the Stockton Deepwater Ship Channel), low DO plumes in Suisun Marsh do not create a barrier to fish migration to mainstem river habitats; however, the potential for local creeks to support fall-run Chinook or steelhead spawning should be evaluated (Schroeter *pers. comm*.). Because these low DO events are localized and usually occur during a time of the year when many covered species are present in the Marsh only in low numbers, if at all, the impact of low DO events on total population size (or recovery potential) for any particular species is low.

Co-occurring with these low DO events are elevated methyl mercury (MeHg) conditions. MeHg is a neurotoxin endemic to the Delta that bioaccumulates in the food web, adversely affecting fish and wildlife species and posing a health risk to humans. MeHg is thought to be produced in association with bacterial sulfate reduction, a process favorable in low DO environments, in the presence of a labile form of inorganic mercury (Alpers 2008). The amount of MeHg released from managed ponds is currently unknown; preliminary data indicate pond releases have elevated MeHg concentrations that may range up to an order of magnitude over accepted limits (Stephenson pers comm.).

Magnitude of Physical Outcome
The processes that produce low DO and high MeHg events occur across all of Suisun Marsh. The problems may be amplified in some regions, especially the north and northwest Marsh, due to proximity to regional wastewater treatment plant outflows (and associated nutrients), and lower mixing and dilution rates with the larger estuary. If the bulk of the planned 9,000 acres of restoration was concentrated in this region, a significant reduction in seasonal low DO and mercury methylation events could be realized because the processes that create them would be eliminated. [Depending on hydroperiod, elevation, and soil circumstances, restored wetlands may exhibit organic matter decomposition processes, on a far less episodic basis. Organic matter decomposition on natural wetlands do not generally exceed the carrying capacity of adjacent tidal sloughs.]

Certainty of Physical Outcome
Certainty of wetland restoration for improving low DO/MeHg events has several components including variable soil conditions, allochthonous inputs (nutrient loading), and water residence time. Further, restoration of tidal actions on subsided landscape will produce different DO/MeHg characteristics compared to a projected mature tidal marsh of the future. However, the correlation between seasonal managed wetland water operations and spikes of biological oxygen demand (BOD) and methylmercury is well known (Seigel et al. 2008, Schroeter et al 2005, Stephenson et al. 2008). Restoration of tidal action eliminates episodic low DO events that overwhelm the regional aquatic environment's ability to process the organic matter (OM) without consuming the in situ oxygen.

Magnitudes of Biological Outcomes
Reducing periodic low dissolved oxygen events in Suisun Marsh will reduce the fish and invertebrate kills associated with this problem. Addressing this problem is expected to have somewhat beneficial effects on regional food web productivity and to reduce MeHg

contamination. The magnitude of impacts to individual covered species will be proportional to the proportion of the species' population that uses the relevant habitats when periodic low DO events occur. Populations of all covered species are naturally very low in the Marsh during June, when low DO events have been documented. Use of the Marsh in November, when low DO events occur due to managed tidal marsh operations, is described below.

<u>Fall run Chinook</u>
Magnitude = 1 - Minimal
Certainty = 2 – Low
When low DO events result from the management of tidal wetlands in Suisun Marsh, it is unlikely that Fall-run Chinook salmon juveniles are in the area. Fall run Chinook salmon kills have occurred in the marsh coincident with low DO events in Suisun Slough (R. Schroeter, *pers. comm.*). Impacts to adults that are migrating to maintstem rivers are unlikely to be substantial; however, the seasonal biological oxygen demand in the fall would prevent migration of fall run salmon into local creeks. This is not a significant impact to the overall population of the Central Valley, but may represent a local risk to any successful spawning in the small and vulnerable urban creeks (R. Schroeter, *pers. comm.*).

<u>Spring-run Chinook</u>
Magnitude = 0 -Zero
Certainty = 4 – High
When low DO events result from the management of tidal wetlands in Suisun Marsh, it is unlikely that spring-run Chinook salmon juveniles are in the area. Significant numbers of adult spring run are also not expected to be in the area when low DO events occur.

<u>Winter-run Chinook</u>
Magnitude = 1 -Minimal
Certainty = 2 – Low
When low DO events result from the management of tidal wetlands in Suisun Marsh, early migrating winter-run Chinook salmon juveniles could possibly be in the area. It is not certain that these fish are in the area and, if they are, they would represent a small fraction of the total population.

<u>Late-fall run Chinook</u>
Magnitude = 1 -Minimal
Certainty = 2 – Low
When low DO events result from the management of tidal wetlands in Suisun Marsh, late-fall run Chinook salmon juveniles may be in the area. It is not certain that these fish are in the area and, if they are, how many what fraction of the total population is affected by direct mortality from low DO events. Impacts to migrating adults are not likely to be substantial.

<u>Steelhead</u>
Magnitude = 2 -Low
Certainty = 2 – Low
When low DO events result from the management of tidal wetlands in Suisun Marsh, it is unlikely that steelhead juveniles are in the area. Impacts to adults migrating to mainstem rivers are unlikely to be substantial; however low DO plumes could block access to spawning adults migrating to local creeks to spawn (R. Schroeter *pers.*

comm.). The frequency and abundance of steelhead spawning in these local creeks is uncertain.

Longfin smelt
Magnitude = 2-Low
Certainty = 2-Low
In years when longfin smelt adults are in Suisun Marsh, they are most abundant during November (Rosenfield and Baxter 2007). However, the numbers of longfin smelt in Suisun Marsh are, at most in any year, a small fraction of the total adult population. Post-larval LFS may also be affected in June if biological oxygen demand is high in Goodyear Slough when post-larval LFS are present, but this is an infrequent occurrence (R. Schroeter *pers. comm.*) and would not impact a large fraction of the LFS population in any case.

Delta smelt
Magnitude = 1 – Minimal
Certainty = 2 - Low
It is unlikely that sizeable numbers of Delta smelt would be impacted by any but the largest low Dissolved Oxygen plumes from managed wetlands in Suisun Marsh – these events are quite rare (Moyle *pers. comm.*). The degree of impact (numbers of fish affected) is uncertain.

Sacramento splittail
Magnitude = 2 – Low
Certainty = 3 – Medium
Sacramento splittail are relatively abundant in Suisun Marsh and, in particular, in the small sloughs that are most commonly impacted by low DO releases from managed tidal wetlands. Still, these are localized events and the number of fish impacted in any given event is probably not a substantial fraction of the splittail population.

Green sturgeon
Magnitude = 2 – Low
Certainty = 1 – Minimal
Green sturgeon are probably highly susceptible to low DO mortality and sub-lethal effects (*for review, see* http://www.sjrdotmdl.org/concept_model/bio-effects_model/tolerate.htm#wsturgeon). Few sturgeon are ever detected in surveys of Suisun Marsh (B. Herbold, *pers. comm.*) but they are generally rare, so the impact to even a few fish might represent a measureable impact on the population at times.

White sturgeon
Magnitude = 3 – Medium
Certainty = 1 – Minimal
White sturgeon are probably highly susceptible to low DO mortality and sub-lethal effects (*for review, see* http://www.sjrdotmdl.org/concept_model/bio-effects_model/tolerate.htm#wsturgeon). White sturgeon are detected at low levels in surveys of Suisun Marsh (R. Schroeter *pers. comm*.); they are generally rare, so impact to even a few fish might produce a measureable impact on the population.

Potential Negative Ecological Outcome(s)

Outcome N1: Establishment of undesirable species (such as Egeria) that will prey or compete or alter habitat conditions for covered fish.

Harmful invasive species have the potential to cause two types of adverse effects. First is to worsen conditions relative to the existing baseline; i.e., creating an attractive nuisance. Second is to detract from achieving the positive benefits the action could provide. The magnitude and certainty scores below are based upon an assessment relative to baseline conditions. They do not represent the potential to distract from the positive benefits of the action. These deductions are factored into the certainty scores for positive outcome # P1. Where appropriate, the impacts are discussed below.

N1a: Submerged Aquatic Vegetation (SAV)

General Observations: The potential for undesirable species such as *Egeria* to alter habitat condition for covered fish is described in the Aquatic Vegetation Conceptual Model (see Anderson, In preparation pages 8, 9, 10 and Figure 2).

Magnitude = 1 - Low
Salinity conditions in Suisun Marsh are too high to allow for establishment of most species of SAV that occur in the Delta currently. citation needed

Certainty = 4 - High
Global warming is expected to increase salinities in this area of the Delta so future changes should reduce the likelihood of invasion by this group of fresh water SAV (citation needed).

N1b: Non-native Centrarchids

General Observations: The potential for non-native Centrarchids to establish in the Delta is described by Brown and Michniuk 2007; Grimaldo et al. 2004; Nobriga and Feyrer 2007; Nobriga et al. 2005.

Magnitude = 1 - Minimal
Establishment of centrarchids in conjunction with SAV is well documented in the Delta (Brown and Michniuk 2007; Grimaldo et al. 2004; Nobriga and Feyrer 2007; Nobriga et al. 2005). Since salinity levels in this area are currently too high to allow for establishment of submerged aquatic vegetation, the levels are also too high to allow establishment of Centrachids that occur in the Delta. Centrarchid invasion of newly restored Suisun Marsh habitats is very unlikely.

Certainty = 4 - High
Centrarchids do not currently exit in the Suisun Marsh and climate change is expected to increase salinities in this area in the future.

N1c: *Corbicula*

Consequences of *Corbicula* establishment. If established, *Corbicula* would likely have a significant effect on food web dynamics because it consumes phytoplankton in shallow areas and/or consumes the productivity of shallow areas exported to channels to such a high extent that it exhibits top-down trophic control. *Corbicula*'s consumption of primary productivity represents a significant limiting factor throughout the Delta that could greatly reduce productivity benefits of restoration efforts (Thompson et. al., In revision). According to the *Corbicula* model (Thompson et. al., In revision page 11), no local studies have been undertaken to indicate whether *Corbicula* feeding has reduced zooplankton populations either through competition or direct predation. In this case, the baseline condition is that much of the Delta is infested with *Corbicula*. The restoration of tidal marsh which may also become infested with *Corbicula* at some future time would not represent a significant change above baseline conditions. Establishment of *Corbicula* would however, consume much of the positive benefits that were previously discussed above under positive outcomes.

Potential Control Options. There are no stressors identified that can limit the success of Corbicula in a significant manner. However, salinity can limit the spatial distribution of this species and food limitation is a source of stress. (Thompson et. al., In revision, pages 8 and 13). The *Corbicula* conceptual model indicates that the only meaningful method to control their presence/abundance is salinity. This control method would require salinity intrusions into the Suisun Marsh of sufficient duration and at the appropriate times of year to have a meaningful effect. The conceptual model does not specify the duration and timing which might be most effective during recruitment. Water temperatures may influence the effectiveness of both recruitment and control measures.

Magnitude = 1-Minimal
Corbicula can control phytoplankton biomass development in shallow areas, or consume the productivity of shallow areas exported to channels. This is a significant limiting factor throughout Delta. For this outcome, the baseline condition is that much of the Delta is infested with *Corbicula*. The restoration of tidal marsh that eventually becomes infested with *Corbicula* would not represent a significant change above baseline conditions.

Certainty = 2 -Low

The timing and extent of colonization by *Corbicula* cannot be predicted for specific restoration sites due to lack of data.

> *Corbicula* are prolific reproducers and colonizers of newly available habitats in salinities below 2 ppt. Source populations can come from elsewhere within the Delta or from upstream tributary populations. *Corbicula* can establish on soft and hard substrates and on vegetation and they can colonize intertidal zones as well as deeper water. (*Corbicula* model). Based upon the biology of the species and the physical setting of the restoration site, the probability of *Corbicula* establishment in the Suisun Slough restoration areas appears to be high, but ultimately cannot be predicted, partially due high variability in environmental

conditions. The low certainty score considers the probability and extent of potential establishment.

Corbicula monitoring data from previous restoration sites in the Delta, such as Liberty Island or Little Holland Tract, would provide greater information about the probability of colonization on this Suisun site. More information would improve the certainty rating. However, such data and analysis was not made available to the evaluation team.

N1d: Inland Silversides

General Observations: Inland silversides (*Menidia beryllina*) are highly tolerant of warm water, salinity variability and are trophic generalists compared to Delta smelt (Moyle 2002). Inland silversides are the most numerous fish in Suisun Marsh shoreline habitats (Matern et al. 2002), and the most numerous fish in shallow Delta habitats (Nobriga et al. 2005, Brown and May 2006). The Delta smelt model (page 3) includes intraguild competition with inland silversides as one of the top five in-Delta stressors to Delta smelt. Inland silversides are thought to be a major predator of Delta smelt eggs (Bennett and Moyle 1996 and Bennett 2005 in the Delta smelt conceptual model pg 12). In the laboratory, inland silversides reduce Delta smelt size relative to controls when they are reared together (Bennett 2005).

Inland silversides are also treated in the longfin smelt model. Moyle (2002, in Rosenfield, 2008) suggested that based on timing of arrival in the Estuary and subsequent longfin population response, inland silverside might have had a major impact on longfin population dynamics. However, the model states that inland silverside prefer shallow water habitats where juvenile and sub-adult longfin are rare, thus, their impact as predators of juvenile and sub-adult longfin is probably slight (Rosenfield, 2008, pg. 17). Spawning locations for longfin are unknown, so it is not known whether competition from inland silverside for spawning territory is a factor in their decline.

However, Delta smelt evolved with other intraguild competitors, including longfin smelt, and have survived with Striped bass (introduced in 1879). Interaction between silversides and Delta smelt in the wild may be limited because Delta smelt typically inhabit offshore environments, while Inland silversides typically inhabit shoreline habitats. Increased shoreline habitat would presumably increase the carrying capacity for Inland silversides. However, predator-prey interaction between Delta smelt and Inland silversides in the wild is speculative. Silversides may eat Delta smelt eggs or larvae if the eggs and larvae occur on the shorelines. It has not been shown that inland silversides reduce calanoid copepods (Norbriga and Herbold, 2008, page 32), so they may not effectively compete with Delta smelt for prey.

Williams and Rosenfield, In preparation; Israel and Klimley, 2008; Kratville**,** 2008); and Israel et. al., 2009 do not mention inland silversides so this evaluation assumes no adverse effects and focuses its evaluation on Delta smelt and longfin smelt.

Magnitude: 2 - Low

Inland silversides are the most abundant fish in shallow-water habitats in many areas of the Delta and may currently contribute to local depletions of zooplankton otherwise available to native fishes within these areas. Additionally, they may prey on embryos of species that lay eggs in these shallow areas (Moyle 2002). The crash of Delta smelt populations coincided with invasions of inland silversides into the estuary (Bennett and Moyle 1996). This action may change conditions relative to baseline by attracting (via restored marsh) a nuisance (inland silversides). This conservation measure will increase the local inland silverside population by providing additional shoreline breeding habitat. Because of the high existing abundance of inland silversides, the incremental increase in breeding habitat and thus population size above current conditions is considered small and the magnitude of this effect is considered to be low relative to baseline. Further, differential habitat selection (offshore environments for inland silverside) is expected to reduce the interspecific competition effects.

Certainty: 2 - Low
Understanding of interaction between Inland silversides and Delta smelt in the wild is low, particularly in regards to egg predation by inland silversides. Better data on where and when Delta smelt lay their eggs would better allow us to assess the potential impact of inland silverside predation. Spatial interactions with longfin smelt are also uncertain.

Outcome N2: Potential for mercury methylation and local bioaccumulation: N2-A – Covered fish species, N2-B, Non-covered wildlife species, N2-C, Human health.

N2a: Covered fish species

General Observations: The potential for mercury methylation and local bioaccumulation to affect fish and wildlife is described in the Mercury Conceptual Model (see Table 2 and associated text). Although current methylmercury levels on Liberty Island (analogue for future state of areas to be restored) are relatively low (Slotton et al. 2002, Alpers et al., 2008, figure 5), there is potential for enhanced production of methylmercury in areas of high marsh that will be inundated infrequently (only during highest tides). The process of drying out between wetting events tends to oxidize species of sulfur, iron, carbon, and mercury, leading to higher potential to form methylmercury upon rewetting. Once formed, methylmercury biomagnifies in the aquatic food web and ecological effects may occur in some sensitive species. Thus, the specific geomorphology of restoration sites and in particular the degree to which shallow depressions and poorly drained areas of high marsh are part of the restoration projects directly influences the degree of mercury methylation.

Magnitude: 1 - Minimal
No toxicological studies have been conducted with any of the covered species regarding acute toxicity. So mercury concentrations in covered fish species are compared here against concentrations producing mortality in other fish species. Mercury concentrations in ppm-wet weight for white sturgeon, Chinook salmon and steelhead collected during 2006 were 0.165-0.279, 0.094-0.396 and 0.06-0.13, respectively (Melwani et al. 2007). No tissue data for either longfin or Delta smelt were found. It is assumed both species will have tissue concentrations similar to other fish taxa living one year and feeding primarily on zooplankton. Mercury concentrations in juvenile threadfin shad and juvenile

largemouth bass in the Delta are 0.012-0.076 and 0.035-0.230, respectively (Slotton et al., 2006). In comparison death in rainbow trout (steelhead) in laboratory studies occurred at 4-ppm wet weight and the NOAEC for death in brook trout at 2.7 ppm (in Wiener and Spry, 1996). In conclusion there exists about a 10X safety factor exists between fish tissue concentrations measured in the Delta and values reported to cause mortality in lab studies.

Regarding chronic toxicity, again no toxicological studies exist with any of the covered fish species. Therefore, have compared reported tissue concentration for individual species against known laboratory effects in other taxa. Decreased feeding efficiency and some hormones response changes observed at 0.25-0.27 ppm wet weight (page 30 of Alpers et al., 2008). Decreases in growth occurred in fathead minnows at 0.6-0.7 ppm Hammerschmidt et al., 2002) and in juvenile walleye at 2.4 ppm (Friedmann et al., 1996). In conclusion, some up/down regulation of genes and alterations in feeding behavior are possible in the most contaminated individuals.

Certainty: 2 - Low
Scientists have a low certainty that the magnitude of this outcome is minimal (i.e. magnitude may be higher). The uncertainty is due to the limited tissue data are available for most covered fish species. However, review of data on other similar taxa suggests there is a large safety factor regarding acute toxicity.

There are limited toxicological data available for most of the important sub-lethal processes and none of this has been collected for covered species. The limited tissue data set makes it difficult to determine the proportion of population potentially at risk.

N2b: Methyl mercury, non-covered species

General Observations: The potential for mercury methylation and local bioaccumulation to affect fish and wildlife is described in Alpers et al., 2008 (see Table 2 and associated text).

Magnitude: 3 - Medium
Fifty-eight percent of Forster's terns in San Francisco Bay are at risk of reproductive impairment from consuming fish with elevated mercury levels (Ackerman et al., 2008). Although it is unknown whether Forster's terns nest in Siusun Marsh, they have been observed in the area and are likely to forage there. Mercury levels in small fish consumed by terns are of similar magnitude in parts of Suisun Marsh (Davis et al. 2007) compared with those in South San Francisco Bay (Ackerman et al., 2007). Other bird species filling the Forster's tern niche such as egrets, herons, and grebes may be at risk in Siusun Marsh from increased methylmercury exposure. Mercury could cause a sustained, minor population effect on a large area.

In laboratory studies, mink have reproductive failure and die when fed fish diets of 0.5 and 1-ppm mercury, respectively (Dansereau et al., 1999). For comparison, mercury concentrations in 64% of largemouth bass, 23% of white catfish, and 35% of channel catfish caught in the Bay-Delta watershed have between 0.23 and 0.93 ppm mercury (Davis et al., 2008).

Most of the studies were conducted in the South San Francisco Bay and Petaluma River marshes with a focus on species native to that area, specifically Clapper and Black rail (endangered and threatened, respectively). These studies have shown that rails seem particularly susceptible to methyl mercury. Although neither of these species occurs in Siusun Marsh, the related Virginia rail (not a listed species) is present.

Biogeochemical processes create varying conditions and a subset of these conditions promotes mercury methylation and this is the key factor used in evaluating the magnitude of this actions effect. Mercury methylation in tidal wetlands is driven in large part by geomorphology and the resulting inundation regime. Methyl mercury production needs approximately one to four weeks of dryness to re-set the biogeochemical conditions necessary for mercury methylation (specific time frame not determined; table 2 in Alpers et al., 2008). Available topographic data have not been analyzed to the level necessary to describe the setting more precisely.

Certainty: 2-3 Low-Med
Scientific understanding of methylmercury effects on some bird and mammal species is high, based on peer-reviewed studies from the San Francisco Bay Area and elsewhere. However methylmercury effects on other bird, reptile, and mammal species are unknown. The nature of the outcome is greatly dependent on highly variable ecosystem processes.

N2c: Methyl mercury, Human Health

General Observations: This action could increase mercury content of sport fish.

Magnitude: 2 - Low
Fish consumption advisories for the Delta recommend that children under the age of 17 and women of child bearing age consume no largemouth bass, smallmouth bass, spotted bass or Sacramento pikeminnow. Others are warned to limit their consumption of these species to one meal a month (OEHHA, 2006, 2008a,b). Between 10,000 and 20,000 fishermen in the Delta are presently eating fish with more than 10X the recommended methylmercury reference dose (RfD) (Klasing and Brodberg, 2008) and could experience some sublethal mercury poisoning (personal communication, Dr. Fraser Shilling).

The probability of increased methylmercury production and export into the food web is the same as that described above for covered fish species and non-covered species.

Certainty: 3 - Medium
There is uncertainty regarding the magnitude and direction of change in mercury content of sport fish, although levels are more likely to increase than decrease. For a given increase in mercury content of sport fish, risk to human health is quantified based on peer-reviewed studies (Gassel et al. 2007, 2008). It is unknown how many anglers would access the project area and what fish they would catch and consume.

The role of restoration projects under this Conservation Measure in contributing to mercury levels in fish species consumed by humans needs to be explored in relation to other mercury sources for those fish species.

Important Gaps in Information and/or Understanding

Data needed to more fully evaluate tidal marsh restoration actions

- Residence times (average and spatial variance in that value) are necessary to determine how much and what kind of food would be produced on site and exported from the site. Residence time projections also affect temperature and dissolved oxygen conditions and these are important attributes of physical habitat. Finally, residence times for particles of water could inform assessment of "residence" times for fish. There is a non-linear relationship between fish "residence time" and the benefit of the rearing habitat as, at high "residence times" new habitat may serve to delay important migratory activities whereas at very low residence times, the new habitat will have reduced benefit because fish (or at least those that behave like particles) will experience the habitat for only a short period.
- Current and projected daily/weekly temperature projections specific to each restoration site.
- Centrarchid models to understand predator-prey-habitat interactions.
- Striped bass model to understand predator-prey-habitat interactions.
- Expected retention time on restored tidal areas to understand likely productivity and food export potential to local sloughs.
- Predation rates in Suisun Marsh vicinity to understand baseline predation pressure in this region.
- More spatially comprehensive hydrodynamics to understand whether changed flow patterns will reduce or simply redistribute predator pressure.
- Hydrologic and sediment information about turbidity levels, duration, and consequences on species as related to the following: Increased ability for Delta smelt to locate food due to increased turbidity from increased velocities in larger channels.
- Prior to implementation, conduct a complete Phase I Environmental Assessment with on-site sampling to assess legacy and other soil contaminants (i.e. mercury and pesticides).
- *Corbicula* monitoring data from previous restoration sites in the Delta, such as Liberty Island or Little Holland Tract, would provide greater information about the probability of colonization on this Cache Slough site.
- Data on mercury bioaccumulation in waterbirds in the Delta would allow an assessment of transfer of methylmercury to higher trophic level wildlife and an assessment of ecotoxicological risk to reproduction.
- Better data on where and when Delta smelt lay their eggs would better allow us to assess the potential impact of inland silverside predation.

Research Needs

- Restoration techniques that will prevent colonization by invasive species.
- Management practices that can control invasive vegetation, clams, and predators (centrarchids and inland silversides) and limit colonization of these sites.

- Run (and life-history) specific studies of Central Valley Chinook salmon and studies of steelhead use of tidal marsh habitats would be extremely valuable to defining magnitude of impacts to these populations and increasing certainty. Various tools (including genetic markers and otolith signatures of population origin) could be used to assess both growth and survival of salmonids in these habitats as well as changes in life history characteristics (survival and fecundity) over the course of the life cycle that arise from residence in tidal marsh habitats. Currently, all of the evidence for benefits of tidal marsh on salmonids comes from steelhead and fall run populations well to the North (where high temperatures and invasive predators are not as problematic). Translating these results to all CV salmonid populations is unwarranted and could lead to disastrous "restoration" projects.
- Data on nutrient flow from the marsh plain to juvenile fish rearing in the adjacent channels is essential to determining the value of restored marshes as a food source for larvae of pelagic fish (like longfin and Delta smelt).
- Evaluate the effectiveness of water management strategies on managed wetlands to reduce the production of low dissolved oxygen events associated with managed wetlands operations and transfer what is learned into best management practices for the broader managed wetlands community in Suisun Marsh. In addition, it is likely the reduction of low DO events will result in conditions less favorable for MeHg production and thus reduce MeHg loading to the surrounding aquatic environment. This hypothesis needs testing.
- Greater understanding and more research is needed about the availability and production of food in tidal marshes. Export of organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta has not been studied.
- Potential negative effects of methylmercury exposure on covered fish species remain largely unknown. Based on published studies involving other (non-covered) fish species, there is reason for concern regarding possible chronic effects caused by methylmercury exposure, including: endocrine disruption, reduced reproductive success, reduced predator avoidance, and reduced feeding efficiency. (See Mercury Conceptual Model, Alpers et al. 2008, Table 4, page 30). Research is especially needed to determine possible effects caused by exposure during early life stages.
- A better understanding is needed regarding the relationship of mercury methylation and bioaccumulation to the duration of wetting and drying events in areas that are intermittently inundated (i.e. tidal marsh and floodplain). Laboratory and field studies of mercury cycling involving sediments in tidal marsh and floodplain environments should quantify the duration of drying time and the extent of dryness necessary to change the oxidation-reduction character of iron, sulfur, carbon, and mercury in sediments such that microbial activity associated with mercury methylation is enhanced.
- A better understanding is needed of mercury cycling, bioaccumulation and ecological effects on waterbirds in tidal marsh habitats.
- Tropho-dynamic model of ecological interactions linking primary production to the food web structure and production flows into, through, and out of the tidal marsh system.
- Landscape-level models that address the effects of variation in structural features of the tidal marsh environment (e.g., tidal channel complexity, channel width, channel length, edge: area ratios, etc.) on the population or production dynamics of specific plants and animals.

Assess Reversibility and Opportunity for Learning

Reversibility

No/Hard: The following on-the-ground actions would be needed to reverse this action:

1) levees would need to be reconstructed
2) newly created tidal sloughs would have to be regraded
3) sites would have to be dewatered
4) wetland vegetation would have to be removed
5) monitoring pre, during, and post construction

Although this reconstruction is technically possible, there would be significant financial and regulatory costs. Prior to action reversal, the following planning activities would be needed:

1) geotechnical evaluations for levee reconstruction
2) engineering design
3) evaluate land use options for areas subject to subsidence reversal actions
4) environmental permitting and associated agency ESA consultation,
5) mitigation planning

Levee repair costs are estimated to range between $1,000 and $9,000 per linear foot (Snow 2006).

Opportunity for Learning

High:

Suisun Marsh is divided into over 150 public and private properties. Therefore, opportunities for research leading to significant advances in the knowledge base are available if experimental treatments take advantage of adjacent properties with otherwise similar hydrology and water quality. The in-progress study by Seigel et al. (2008) is a small scale attempt along these lines to test alternative water and vegetation management options on adjacent ownerships. Across potentially 9,000 acres of restoration opportunity, several research questions and testable hypotheses are available including:

1. What is the water quality supplied to and discharged from managed and tidal wetlands?
2. What is the amount of available mercury in the soils?
3. What is the amount of available organic matter in the soils for contributing to oxygen demand?
4. What is relationship between dissolved oxygen sags, site vegetation, and MeHg production?
5. What mixing characteristics are required to adequately disperse low DO water? There are also approximately 6000 acres of remnant tidal marshes that exhibit unknown DO and MeHg dynamics. There are key questions about the tradeoff between managed wetland water operations and natural tidal marsh land-water interface dynamics, especially regarding MeHg production.

Implementation of this project could be designed such that different engineering designs could be compared. Numerous physical and biological components could be monitored and ideally the monitoring data would be used to assess and refine modeling simulations of the restoration as a part of a comprehensive adaptive management program. See text in HRCM 4 for details.

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Appendices

Appendix A: Summary Tables Organized by Outcome

Table A1. Positive Outcomes

Outcome	Magnitude	Certainty
P1: Increase rearing habitat area (including physical and biotic attributes) for covered fish species.		
a. Delta smelt	3	1
b. Longfin smelt.	1	2
c1: Winter-run	1	1
c2: Spring-run Chinook Salmon.	3	1
c3: Fall-run Chinook salmon.	3	1
c4: Late Fall-run	1	1
d: Sacramento splittail.	3	2
e: Green Sturgeon	2	2
f: White Sturgeon	2	2
P2: Increase the availability and production of food in Suisun Bay by exporting organic material via tidal flow from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Bay		
a. Viewpoint #1	3-4	3
b. Viewpoint #2	1-2	1
P3: Locally provide areas of cool water refugia (Feb-Jun)		
a: Delta smelt	2	1
b1: Spring-run,	2	1
b2. Fall-run Salmon	2	1
b3. Steelhead.	2	1
P4: Reduce periodic low dissolved oxygen events		
a. Fall-run Chinook Salmon.	1	2
b. Spring-run Chinook Salmon.	0	4
c: Winter-run Chinook Salmon	1	2
d: Late Fall-run Chinook Salmon	1	2
e: Steelhead	2	2
f: Longfin smelt	2	2
g: Delta smelt	1	2
h: Sacramento splittail.	2	3
i: Green Sturgeon	2	1
j: White Sturgeon	3	1

Table A2. Negative Outcomes

Outcome	Magnitude	Certainty
N1: Establishment of undesirable species (such as Egeria) that will prey or compete or alter habitat conditions for covered fish.		
A: Submerged Aquatic Vegetation	1	4
b: Non-native Centrarchids	1	4
c: Corbicula	4	2
d: Inland Silversides	2	2
N2: Potential for mercury methylation and local bioaccumulation.		
a: Covered fish species	1	2
b: Other species (not covered).	3	2 to 3
c: Human health.	2	3

Appendix B - Outcomes with Zero Magnitude

OP1: Locally provide areas of cool water refugia for winter-run salmon.

Magnitude = 0- Zero.
There will be no benefits of this restoration to winter-run salmon because this run passes through the region during a window of time when temperatures are not believed to be highly stressful to salmonids.

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

OP2: Locally provide areas of cool water refugia for late fall-run salmon.

Magnitude = 0- Zero.
There will be no benefits of this restoration to late fall-run salmon because this run passes through the region during a window of time when temperatures are not believed to be highly stressful to salmonids

Certainty = 1-Minimal
As noted above, certainty is reduced due to a great dependence on highly variable ecosystem processes. While a reasonable understanding at the general level is prevalent, the range of data needed to evaluate at the action scale is lacking.

HRCM 11:
Riparian and Emergent Vegetation

Scientific Evaluation Worksheet

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Action: HRCM 11 - Riparian and emergent vegetation establishment along existing levees.

Evaluation Team: Floodplains Workgroup
Campbell Ingram (chair), Denise Reed (coach), Carie Battistone (notetaker), Eric Ginney, Ted Sommers, Rosalie Del Rosario, Dennis McEwan, Bill Harrell, Dan Welsh, Yvette Redler, and Vance Russell.

Date of Last Revision: March 1, 2009

Action Description and Clarifying Assumptions

Establish native riparian woody vegetation and emergent vegetation along a 5 mile segment of levee constructed along the Sacramento River in the West Delta (somewhere between Isleton and Ryde), and along a 5 mile segment of levee along Old River near Bacon Island.

Assumptions

1. The language regarding BDCP constructed levees was determined to be irrelevant and was removed from the action description.
2. LWD installed "at low elevation surfaces of the levee (e.g., levee benches)" will be anchored with cable because it will be in a narrow, navigable waterway and integrated within a project levee.

Approach

1. Plant riparian vegetation along the levee to increase overhead cover and instream shaded riparian aquatic habitat
2. Provide for the establishment of tidal emergent vegetation along low elevation surfaces of the levee (e.g., levee benches).
3. Install large woody debris at low elevation surfaces of the levee (e.g., levee benches)

Intended Outcomes as Stated in Conservation Measure

1. Provide (rearing?) habitat for salmonids, splittail, and other covered fish species
2. Provide cover for covered fish species from predators.
3. Provide organic carbon input into adjacent channels in support of food web processes that would provide food to covered fish species.

Positive

P1. Increased establishment of instream structure through export of LWD to benefit covered species.
P2. Increase splittail spawning habitat on narrow floodplain margin.
P3. Increase rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment for Old River).
P4. Increased production and export of terrestrial invertebrates into the aquatic ecosystem for rearing splittail, green and white sturgeon, Chinook salmon and steelhead.
P5. Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (offsite), longfin smelt, and delta smelt (consider loss to entrainment on Bacon option).

Negative

N1. Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail, if flows through sloughs are not sufficient to prevent colonization by non natives.

N2. Increased exposure risk to contaminants (including Selenium) due to longer residence time in this area (for Bacon option only).

Conceptual Model Information Regarding Intended Outcomes

The basic drivers and outcomes are described in the DRERIP conceptual models, as listed below:

Models used:
Corbicula and Corbula
Delta smelt
Fish Habitat Linkages
Floodplain
Longfin smelt
Salmon Model (Rosenfield 2007)
Selenium
Splittail
Sturgeon
Steelhead
Tidal Marsh

Other sources:
Beckon 2008 (manuscript in prep.)
CDFG 2004
Feyer et al 2003
Healy 1991
Jackson 1992
Kjelson et al 1982
Moyle 2002, 2004
Moyle et al 2004, 2006
Murphy and Meehan 1991
NMFS 1997
Opperman and Merenlender 2004
Quinn 2005
Quinones and Mulligan 2005
Sommer et al 2002, 2004, 2007
Sommer and Harrell (unpubl.)
USFWS 1997
Winemiller and Rose 1992
Wang 1986

Assumptions

Provided in BDCP Conservation Measure
None provided.

Added by Evaluation Team
None provided.

Problem(s) with Action as Written:

None provided.

Scale of Action:

Small

Rationale:
Small extent (5 miles along each Old River and West Delta), reversibility high. Existing conditions along these segments include sporadic riparian habitat.

Evaluation Summary Tables

Summary tables listing magnitude and certainty scores for each outcome, by species, are provided in Appendix A. Details regarding each of the listed scores, and the rationales for the scores, are provided in the discussion of positive and negative outcomes on the following pages.

Positive Outcomes Identified, Not Separately Evaluated

Below is an outcome that was identified, but not listed in the worksheet, because it was merged with another outcome for full evaluation.

- OP1: Increased establishment of woody riparian and emergent vegetation to provide high quality rearing habitat for covered species. This outcome was merged with P2 and P3.

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?
YES

Nature of Change: Not provided

Potential Positive Ecological Outcome(s)

Outcome P1: Increased establishment of instream structure through export of LWD to benefit covered species.

This outcome is divided into two suboutcomes, one for green sturgeon and one for white sturgeon.

P1. All covered fish species

The approach and assumptions for HRCM11 do not indicate that the channel will be allowed to evolve, and the levees are not being set back. No changes to the currently impaired flood hydrology are included in the action. Thus, the ability for natural channel processes (DRERIP Floodplain Model, Figure 2) to erode banks and recruit & export the increased riparian vegetation as LWD will be minimal.

The action will actively place LWD "…at low elevation surfaces of the levee (e.g., levee benches)." This will increase spawning and rearing habitat for covered species (page 34, DRERIP Salmon model; DRERIP Splittail model pages 2-6; and perhaps delta smelt: DERIP Delta Smelt model page 2-5); however, this local habitat will not be available for export to other areas because of its fixed nature.

Magnitude = 1
Based on the approach and assumptions for HRCM11, it is very unlikely that these static, local habitat improvements will increase LWD export to downstream areas (DRERIP Floodplain Model Figure 2).

Certainty = 1
Nature of outcome (export of cabled wood) would be very dependent on flooding of a magnitude that is rare.

Outcome P2: Increase splittail spawning habitat on narrow floodplain margin.

P2. Splittail

Floodplain model page 25 and Splittail model pages 9 and 12 describe how additional floodplain habitat supports splittail spawning. Assume that there will be floodplain habitat available, but action as described does not indicate that there will be seasonally-inundated FP habitat. Splittail will spawn on flooded vegetation (Moyle et al. 2004) if floodplain is not accessible.

Increased establishment of woody riparian and emergent vegetation to provide high quality rearing habitat for covered species is an intermediate outcome.

Magnitude = 2
Area is limited.

Certainty = 3-4

Outcome P3: Increase rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment on Old River).

P3a. Splittail

Floodplain model page 25 and Splittail model pages 9 and 12 describe how additional floodplain habitat supports splittail spawning. Assume that there will be floodplain habitat available, but action as described does not indicate that there will be seasonally-inundated FP habitat. Splittail will spawn on flooded vegetation (Moyle et al. 2004) if FP is not accessible.

Increased establishment of woody riparian and emergent vegetation to provide high quality rearing habitat for covered species is an intermediate outcome.

Magnitude = 2
Greatest importance is in dry years when floodplains aren't available.

Certainty = 3-4
Sommer et al. 2002, 2007 shows Splittail prefer shallow flooded habitat.

P3b. Green Sturgeon

Juvenile sturgeon are benthic feeders so creation of additional benthic habitat would be beneficial (Sturgeon model page 8), Channelization of the estuary has reduced foraging habitat for green sturgeon (Green Sturgeon model page 20). Juveniles use intertidal habitats along the Sacramento River and many areas in the Delta (Green Sturgeon Model page 4.

Magnitude = 2
Small spatial extent.

Certainty = 1
Limited data on rearing preferences.

P3c. White Sturgeon

Juvenile sturgeon are benthic feeders so creation of additional benthic habitat would be beneficial (Sturgeon model page 8). Although it is unknown whether white sturgeon will utilize habitats this shallow. They were never captured in YOLO Bypass studies (Sommer and Harrell Unpub data). Although it's not mentioned in the White Sturgeon model, it is likely that White Sturgeon will utilize the same habitats for foraging as described below for Green Sturgeon. Shallow water habitats and low tidal areas are likely nursery habitat (White Sturgeon Model page 15).

Magnitude = 2
Small spatial extent

Certainty = 1
Limited data on rearing preferences

P3d. Steelhead

Tidal marshes can provide rearing habitat and foraging opportunities to fishes that enter marsh channels (Fish Habitat Linkages Model). The primary food organisms of juvenile salmonids are drifting aquatic insects and the larval stages of terrestrial insects (Quinn 2005).

Riparian vegetation is important to salmonids (inc steelhead) by contributing terrestrial insects into the stream and logs and branches that shape channel morphology, retaining organic matter, providing essential cover, stabilizing banks, maintaining undercut banks, and modifying water temperatures through shading (Murphy and Meehan 1991).

Allochthonous inputs from streamside vegetation are important to salmonids because they provide food for the aquatic invertebrate food base (Murphy and Meehan 1991). Given their similarities in life history, it can be assumed that they are utilizing the same habitats as juvenile salmon, and many of the references below for Chinook salmon would apply to steelhead as well.

Magnitude = 3
Rearing habitat in the delta is so reduced, this could have a sustained minor population effect.

Certainty = 2
Not much in the literature regarding steelhead use of estuaries for rearing.

P3e. Chinook Salmon

Juvenile salmon use emergent vegetation in large channels like Sacramento. 1) fry/parr use emergent vegetation to rear; 2) smolts may also use emergent vegetation.

Several studies suggest that emigrating salmon derive great benefit from connection with vegetated riparian areas…it provides a variety of benefits including shading, terrestrial food web inputs and habitat structure (Opperman and Merenlender 2004, Quinones and Mulligan 2005).

Environments that offer habitat structure, such as emergent vegetation or dead woody debris, allow juvenile salmon to escape predators and avoid high flows. Chinook salmon prefer habitat with dead and living plant matter over habitats that offer relatively simple bank and bottom surfaces (Opperman and Merenlender 2004, Quinones and Mulligan 2005).

As juvenile Chinook salmon grow, they move into deeper water with higher velocities, but still seek shelter & refugia to minimize energy expenditure. (Healy 1991). Re: Sacramento River juveniles in West Sacramento. Smaller sized fry along margins, larger juvenile in main channel (USFWS 1997).

Juvenile Chinook within pools in the American River were associated with instream cover such as rootwads, logs or submerged vegetation, or with overhead cover, and were also associated with eddies or other areas with steep velocity gradients. Such positions allow fish to hold in slower water but make forays into faster water to capture drifting insects (Jackson 1992).

Magnitude = 2-3
For Sacramento River only; Old River contingent on conveyance and operational scenario. Sustained minor population effect spatially on habitat but addresses a key limiting factor (suitable rearing habitat); 5 miles on mainstem Sacramento is small spatial scale, compared to the > 60 mile migratory corridor along Sacramento River within the legal Delta, or within >250 river miles to the Upper Sacramento spawning habitats.

Certainty = 2-3
For Sacramento River only; Old River contingent on conveyance and operational scenario. Studies in the Delta and Central Valley have shown the connection between channel and riparian habitats are important for juvenile rearing. Numerous studies have indicated that shallow riparian habitat benefits fry Chinook (Sommer 2005, Quinones 2005, Kjelson 1982). Loss of this habitat has been indicated as a major source of decline in CV Chinook.(NMFS 1997, CDFG 2004). Shallow water habitats including river floodplains and riparian margin provide rearing habitat. Growth rates for juvenile salmon are higher and emigration rates are slower when in shallow water rearing habitats (Kjelson 1982, Sommer et al 2005).

Outcome P4: Increased production and export of terrestrial invertebrates into the aquatic ecosystem for rearing splittail, green and white sturgeon, Chinook salmon and steelhead.

P4a. Splittail

Adult consumption of earthworms is common (Moyle et al. 2004). Consumption of other invertebrates is common in all life stages (Feyrer et al. 2003).

Magnitude = 3

Certainty = 3

P4b. Green/white Sturgeon

Invertebrates are common food items for small sturgeon, but it’s unclear how much they use terrestrial prey (White Sturgeon Model page 8)

Magnitude = 1

Certainty = 2
Sturgeon are benthic feeders and it’s unknown how much they will feed on surface drift. More than 1 because there is diet data for sturgeon.

P4c. Steelhead

Moyle et al. 2004, page 277 states that stream-dwelling O. mykiss feed mostly on drifting aquatic organisms and terrestrial insects.

Magnitude = 2
Given that existing rearing habitat in the Delta is very limited, this restoration action could have a sustained minor population effect for this species.

Certainty = 3
Steelhead use of estuaries for rearing is not well described in the literature.

P4d. Chinook Salmon

Consumption of terrestrial invertebrates in drift is very common (Sommer et al. 2001). Diet has a large effect on growth and survival.

Magnitude = 2
Spatial extent is low.

Certainty =3-4

Outcome P5: Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (offsite), longfin smelt, and delta smelt (consider loss to entrainment on Bacon Island option).

The text and scores provided here are applicable to all covered fish species. Tidal Marsh subsidizes the broader estuarine ecosystem. This includes benthic and terrestrial invertebrates and zooplankton (Tidal Marsh Model page 9)

Magnitude = 1
Spatial extent is low.

Certainty = 3

Potential Negative Ecological Outcome(s)

Outcome N1: Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail, if flows through sloughs are not sufficient to prevent colonization by non natives.

The floodplain model does not address non native predation or competition on the floodplain. Evidence from Yolo and Cosumnes about non-natives taking advantage of floodplain (ref Sommer et al 2004, Moyle et al 2006). Floodplain Model: Page 10 talks about sources of invasive species. Foodweb Model is focused on estuarine systems.

N1a. Delta Smelt

Delta smelt model: fish are adapted to sustain high mortality during the adult stage (Winemiller and Rose 1992). Predation is one of two primary factors for population dynamics (Figure 7). The most likely ancestral delta smelt predators would have been piscivorous birds, salmonid fishes, and, secondarily, longfin smelt as a larval predator and predatory freshwater fishes like Sacramento pikeminnow, Sacramento perch, and striped bass (Moyle 2002). All of the above listed species could be expected to inhabit the enhanced channel margin habitat.

Magnitude = 2

Certainty = 3

N1b. Longfin Smelt

Longfin model - Predation is a source of direct mortality to eggs and larvae. Some fish species (e.g., suckers, splittail and sturgeon) may feed on LFS eggs. Larval LFS are not strong swimmers (Wang 1986) and are thus highly vulnerable to predation. Striped bass and inland silverside are probably major predators on LFS larvae. Terns, gulls, and cormorants may also prey on this life stage. There appears to be a correlation between high flows and the abundance and distribution of LFS; high flows also decrease the success of LFS predators by increasing turbidity (Page 8.) There is little information in the model specific to competition with non-natives, competition for food resources is expected to have decreased with the recent decline in LFS (Page 14.), competition for spawning sites is unknown (Page 10.). Predation and competition are characterized as medium importance and medium understanding (Figure 5.); floodplain predation and competition are not specifically addressed.

Magnitude = 3

Certainty = 2

N1c. Splittail

Splittail model - Predation by non native fish is characterized as low with high understanding for juveniles and as medium with medium understanding for adults (Figures 5, 6 and 7.) Bird predation appears limited until water recedes and floodplains begin to isolate from main channels at which point fish are exposed to wading birds. [Moyle 2004].

Magnitude = 2

Certainty = 3

N1d. Green/white Sturgeon

White sturgeon – model indicates probable distribution in this reach (Figure 7), green sturgeon model indicates probable distribution in this reach (Figure 2). Need to view model again for competition and predation information.

Magnitude = 1

Certainty = 2

N1e. Steelhead/Chinook Salmon

Chinook salmon and steelhead. The CS and steelhead model indicates Non-native predation and competition with invasive species and hatchery produced salmonids is of medium importance in rearing and emigration estuarine habitats, including floodplain (Figure 2a).

Magnitude = 2-3

Certainty = 2

Outcome N2: Increased exposure risk to contaminants (including Selenium) due to longer residence time in this area (for Bacon Island option only).

The text and scores provided here are applicable to all covered fish species. Selenium (Se) loading of the Bay-Delta ecosystem is driven mainly by loads entering the Delta from the San Joaquin River (SJR), which in turn receives most of its Se input from agricultural drainwater entering the river through Mud Slough (Se model, Fig. 1). The location of the Bacon Island component of this project is in the South Delta in proximity to Se inputs from the SJR. Despite this location, the magnitude of potential effects of Se on covered fish species from this project relative to baseline is minimal.

The proposed action is limited in its spatial scale and does not involve habitat modification other than planting trees along existing levees, creating levee benches, and installing large woody debris. These actions would not increase Se loading or bioavailability. However, exposure of covered fish to Se might increase due to longer residence time of the fish in the enhanced habitat.

Salmonids are relatively sensitive to Se compared to other fish species (Se model, page 19). Beckon (2008 abstract from CALFED science conference; manuscript in prep) evaluated Se data from the SJR and concluded that, although discharges of Se to the SJR have been reduced over the last 15 years, Se will pose a substantial risk to salmon that are reintroduced to restored middle reaches of the river unless Se loads are further reduced and/or sufficient dilution flows are provided. The magnitude of potential effects of Se from this project at Bacon Island may be lower than would occur at projects along the middle reaches of the SJR (i.e., sites in the vicinity of Mud Slough) because this project occurs in the South Delta, downstream of dilution sources from the Merced, Tuolumne and Stanislaus Rivers. However, this spatial difference does not provide strong protection because Se bioaccumulates in food chains is recycled in the ecosystem, and can have significant lag times between when loading occurs and when effects are seen.

The seasonal use of the habitat may also reduce the potential magnitude of Se impacts to covered fish species, especially juvenile salmonids. Seasonal use of the Delta by juvenile salmonids occurs mainly during high flow periods (January-June)(salmon model, page 11); whereas highest concentrations of Se occur during low flow periods (Se model, page 6). However, this seasonal difference does not provide strong protection because Se bioaccumulates in food chains, is recycled in the ecosystem, and can have significant lag times between when loading occurs and when effects are seen.

The invertebrate prey of juvenile salmonids are water-column-feeding or detritus-feeding species that are relatively less contaminated than certain suspension or deposit-feeding bivalves (Se model, Table 5 and Fig. 1). Adult splittail and sturgeon feed on bivalves and would be expected to have greater exposure to Se in their diet than salmonids. This project is intended to provide rearing habitat for juvenile sturgeon and splittail rather than habitat for adults, but may also result in increased residence time by spawning and foraging adults. However, the bivalve species present at this freshwater location would be Corbicula fluminea rather than Corbula amurensis (Corbula and Corbicula models). C. fluminea is less efficient at bioaccumulating Se than C. amurensis (Se model, page 14).

Se dynamics in the Bay-Delta system are fairly well understood, but there is uncertainty about how changes in management of SJR flows, water exports, and potential future actions to solve the drainage problem on the west side of the San Joaquin Valley could affect Se loading and cycling in the Delta (Se model, pp 3 and 4). A quantitative analysis of the increased risk of Se toxicity resulting from this project would require estimates of the increase in the amount of time covered fish spend at this location relative to the baseline condition, as well as estimates of future river flows, water exports, and Se loads. Such an analysis is beyond the scope of this worksheet exercise, but should be considered if the project is recommended for evaluation in the NEPA process.

Magnitude = 1

Certainty = 3

Important Gaps in Information and/or Understanding

Research Needs

- Major gaps – rearing habitat for steelhead? Rearing habitat for juvenile sturgeon?
- Better diet information is needed for riparian and channel margin habitat use of SH, green and white sturgeon;
- More information is needed about relative importance of food to population level effects for all of the species.
- Transport studies are needed to evaluate the footprint of food transport.
  Timing duration of rearing for SH, green and white sturgeon.

Assess Reversibility and Opportunity for Learning

Reversibility

Yes/Easy.

Comments: This action is easily reversible.

Opportunity for Learning

Low

Comments LWD placements on levee repair projects exist in many other locations, thus, the action does not provide a unique research opportunity.

References Cited

Appendix A

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P6	All	Increase availability and production of food (POM, phytoplankton, zooplankton, small fish, etc) for Chinook salmon, steelhead, green and white sturgeon, splittail (offsite), longfin smelt, and delta smelt (consider loss to entrainment on Bacon Island option)	1	3
P2	All	Increased establishment of instream structure through export of LWD to benefit covered species	1	1
P5d	Chinook salmon	Increased production and export of terrestrial invertebrates into the aquatic ecosystem for rearing splittail, green and white sturgeon, Chinook salmon and steelhead	2	3-4
P4e	Chinook salmon	Increase rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment for Old River)	2-3	2-3
P5b	Green & White Sturgeon	Increased production and export of terrestrial invertebrates into the aquatic ecosystem for rearing splittail, green and white sturgeon, Chinook salmon and steelhead	1	2
P4b	Green Sturgeon	Increase rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment for Old River)	2	1
P5a	Splittail	Increased production and export of terrestrial invertebrates into the aquatic ecosystem for rearing splittail, green and white sturgeon, Chinook salmon and steelhead	3	3
P4a	Splittail	Increase rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment for Old River)	2	3-4
P3	splittail	Increase splittail spawning habitat on narrow floodplain margin	2	3-4
P5c	Steelhead	Increased production and export of terrestrial invertebrates into the aquatic ecosystem for rearing splittail, green and white sturgeon, Chinook salmon and steelhead	2	3
P4d	Steelhead	Increase rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment for Old River)	3	2
P4c	White Sturgeon	Increase rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment for Old River)	2	1

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Negative Outcomes				
N2	All	Increased exposure risk to contaminants (including Selinium) due to longer residence time in this area (for Bacon Island option only)	1	3
N1a	Delta smelt	Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail, if flows through sloughs are not sufficient to prevent colonization by non natives	2	3
N1d	Green & White Sturgeon	Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail, if flows through sloughs are not sufficient to prevent colonization by non natives	1	2
N1b	Longfin smelt	Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail, if flows through sloughs are not sufficient to prevent colonization by non natives	3	2
N1c	Splittail	Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail, if flows through sloughs are not sufficient to prevent colonization by non natives	2	3
N1e	Steelhead & Chinook salmon	Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail, if flows through sloughs are not sufficient to prevent colonization by non natives	2-3	2

HRCM 12:
Sutter and Steamboat Sloughs

Scientific Evaluation Worksheet

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Action: HRCM12: Channel margin habitat in Sutter and Steamboat Sloughs.

Evaluation Team: Floodplain Workgroup

Campbell Ingram (chair), Denise Reed (coach), Carie Battistone (notetaker), Eric Ginney, Ted Sommers, Rosalie Del Rosario, Dennis McEwan, Bill Harrell, Dan Welsh, Yvette Redler, and Vance Russell.

Date of Last Revision: March 1, 2009

Action Description and Clarifying Assumptions

Enhance channel margin habitats along between 12 and 36 miles of Steamboat and Sutter Sloughs to improve habitat conditions for covered fish species.

Option #1: 12 miles = 6 miles of channel, each side

Option #2: 36 miles = 18 miles of channel, each side

Approach

1. Modify channel geometry in Steamboat and Sutter Sloughs to improve hydrodynamic and structural complexity.
2. Allow for establishment of native emergent vegetation in intertidal elevations.
3. Establish woody riparian vegetation along banks that do not already support woody riparian vegetation.

Intended Outcomes as Stated in Conservation Measure

1. Increase the extent of shaded riverine aquatic cover and increasing instream structural complexity through contributions of instream large woody material.
2. Provide inputs of organic material (e.g., leave and twig drop) in support of aquatic foodweb processes.
3. Increase production and export of terrestrial invertebrates into the aquatic ecosystem.
4. Improve connectivity with upstream habitat areas, including existing and future restored habitats.
5. Reduce the risk for predation on covered fish species by non-native fish predators.
6. Reduce the risk for entrainment of juvenile salmonids by providing a migration corridor that bypasses the intakes of a new north Delta diversion point, the Delta Cross Channel, and Georgiana Slough.

Positive

P1. Increased establishment of instream structure through export of LWD to benefit covered species.

P2. Additional splittail spawning habitat on narrow floodplain margin.

P3. Additional rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment).

P4. Increased production and export of terrestrial invertebrates into the aquatic ecosystem for rearing splittail, green and white sturgeon, Chinook salmon and steelhead

Negative

N1. Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail, if flows through sloughs are not sufficient to prevent colonization by non natives (by creating more predator habitat)

N2. Increased mortality of covered species due to increased exposure risk to contaminants due to longer residence time in this area

Conceptual Model Information Regarding Intended Outcomes

The basic drivers and outcomes are described in the DRERIP conceptual models, specifically, the salmonid model.

Assumptions

Provided in BDCP Conservation Measure
Not provided.

Added by Evaluation Team
Not Provided.

Problem(s) with Action as Written:

Not provided.

Scale of Action:

Large

Rationale: Not provided.

Evaluation Summary Tables

Summary tables listing magnitude and certainty scores for each outcome, by species, are provided in Appendix A. Details regarding each of the listed scores and the rationales for the scores are provided in the discussion of positive and negative outcomes on the following pages.

Positive Outcomes Identified, Not Separately Evaluated

Below is an outcome that was identified, but not listed in the worksheet, because it was merged with another outcome for full evaluation.

- OP1: Increased establishment of woody riparian and emergent vegetation to provide high quality rearing habitat for covered species. This outcome was merged with P2 and P3.

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

YES

Nature of Change:

Not provided.

Potential Positive Ecological Outcome(s)

Outcome P1: Increased establishment of instream structure through export of LWD to benefit covered species.

The text and scores provided here are applicable to all covered fish species (i.e. species were not evaluated separately). The approach and assumptions for HRCM12 indicates that the channel will be reconfigured to increase HD and structural complexity; however, it does not include any levee setbacks and will not allow for the channel to evolve. No changes to the currently impaired flood hydrology are included in the action. Thus, the ability for natural channel processes (DRERIP Floodplain Model, Figure 2) to erode banks and recruit & export the increased riparian vegetation as LWD will be minimal. Note: score for salmonids maybe splittail. Good evidence that woody debris is important for upstream areas, less for Delta.

Magnitude = 3
Based on the approach and assumptions for HRCM12, there will be an increase in riparian vegetation on the channel margin. While flood hydrology will not be changed by HRCM12, the channel morphology will be changed, ostensibly such that high water events will be able to recruit LWD and export it to downstream areas (DRERIP Floodplain Model Figure 2). This will result in an effect on a large area/multiple patches.

Certainty = 2
Understanding is high, but nature of outcome would be dependent on the uncertain timing of flooding events.

Outcome P2: Additional splittail spawning habitat on narrow floodplain margin.

P2a1: Splittail 12 mile

DLO Relationship and General Observations:
Floodplain model page 25 and Splittail model pages 9 and 12 describe how additional floodplain habitat supports splittail spawning; Assume that there will be floodplain habitat available, but action as described does not indicate that there will be seasonally-inundated FP habitat. Splittail will spawn on flooded vegetation (Moyle et al. 2004) if FP is not accessible.

Increased establishment of woody riparian and emergent vegetation to provide high quality rearing habitat for covered species is an intermediate outcome.

Magnitude = 2
See general observations above.

Certainty = 3
See general observations above.

P2a2: Splittail - 36 mile

Floodplain model page 25 and Splittail model pages 9 and 12 describe how additional floodplain habitat supports splittail spawning; Assume that there will be floodplain habitat available, but action as described does not indicate that there will be seasonally-inundated FP habitat. Splittail will spawn on flooded vegetation (Moyle et al. 2004) if FP is not accessible.

Increased establishment of woody riparian and emergent vegetation to provide high quality rearing habitat for covered species is an intermediate outcome.

Magnitude = 3
See general observations above.

Certainty = 3
See general observations above.

Outcome P3: Additional rearing habitat for splittail, green and white sturgeon, Chinook salmon and steelhead (consider loss to entrainment).

P3a1: Splittail - 12 mile

Greatest importance is in dry years when floodplains are not available.

Increased establishment of woody riparian and emergent vegetation to provide high quality rearing habitat for covered species is an intermediate outcome.

Magnitude = 2
See general observations above.

Certainty = 3
See general observations above.

P3a2: Splittail - 36 mile

Greatest importance is in dry years when floodplains are not available.

Magnitude = 3
See general observations above.

Certainty = 3
See general observations above.

P3b. Green Sturgeon (12 and 36 mile the same)

Juvenile sturgeon are benthic feeders so creation of additional benthic habitat would be beneficial (Sturgeon model page 8). Channelization of the estuary has reduced foraging habitat for Green Sturgeon (Green Sturgeon Model page 20). Juveniles use intertidal habitats along the Sacramento River and many areas in the Delta (Green Sturgeon Model page 4).

Magnitude = 2
Small spatial extent

Certainty = 1
Limited data on rearing preferences

P3c. White Sturgeon (12 and 36 mile the same)

Juvenile sturgeon are benthic feeders so creation of additional benthic habitat would be beneficial (Sturgeon model page 8). Although it is unknown whether white sturgeon will utilize habitats this shallow. They were never captured in Yolo Bypass studies (Sommer and Harrell, unpublished data). Although it's not mentioned in the White Sturgeon model, it is likely that white sturgeon will utilize the same habitats for foraging as described for green sturgeon. Shallow water habitats and low tidal areas are likely nursery habitat (White Sturgeon Model page 15).

Magnitude = 2
Small spatial extent

Certainty = 1
Limited data on rearing preferences

P3d. Steelhead (12 and 36 mile the same)

Tidal marshes can provide rearing habitat and foraging opportunities to fishes that enter marsh channels (Fish Habitat Linkages Model). The primary food organisms of juvenile salmonids are drifting aquatic insects and the larval stages of terrestrial insects (Quinn 2005).

Riparian vegetation is important to salmonids (inc steelhead) by contributing terrestrial insects into the stream and logs and branches that shape channel morphology, retaining organic matter, providing essential cover, stabilizing banks, maintaining undercut banks, and modifying water temperatures through shading (Murphy and Meehan 1991). .

Allochthonous inputs from streamside vegetation are important to salmonids because they provide food for the aquatic invertebrate food base (Murphy and Meehan 1991). Given their similarities in life history, it can be assumed that they are utilizing the same habitats as juvenile salmon, and many of the references below for Chinook salmon would apply to steelhead as well.

Magnitude = 2
Rearing habitat in the delta is reduced. This could have a sustained minor population effect.

Certainty = 2
Not much in the literature regarding steelhead use of estuaries for rearing.

P3e. Chinook Salmon (12 and 36 mile the same)

Greatest importance is in dry years when floodplains are not available.

Magnitude = 3
Sutter and Steamboat are one of several emigration routes juvenile salmon can choose, and are among the few that provide rearing habitat. Habitat improvements would improve rearing success in these corridors. Limited spatial or temporal habitat effects.

Certainty = 3
Numerous studies have indicated that shallow riparian habitat benefits fry Chinook (Sommer 2005, Quinones 2005, Kjelson 1982). Loss of this habitat has been indicated as a major source of decline in CV Chinook.(NMFS 1997, CDFG 2004). Shallow water habitats including river floodplains and riparian margin provide rearing habitat. Growth rates for juvenile Salmon are higher and emigration rates are slower when in shallow water rearing habitats (Kjelson 1982, Sommer et al 2005).

Outcome P4: Increased production and export of terrestrial invertebrates into the aquatic ecosystem for rearing splittail, green and white sturgeon, Chinook salmon and steelhead.

P4a1: Splittail - 12 mile

Adult consumption of earthworms is common (Moyle et al. 2004). Consumption of other invertebrates is common in all life stages (Feyrer et al. 2003).

Magnitude = 2
See general observations.

Certainty = 3
See general observations.

P4a2: Splittail - 36 mile

Adult consumption of earthworms is common (Moyle et al. 2004). Consumption of other invertebrates is common in all life stages (Feyrer et al. 2003).

Magnitude = 3
See general observations.

Certainty = 3
See general observations.

P4b. Green Sturgeon (12 and 36 mile the same)

Invertebrates are common food items for small sturgeon, but it's unclear how much they use terrestrial prey (White Sturgeon Model page 8).

Magnitude = 1
See general observations.

Certainty = 2
Sturgeon are benthic feeders and it is unknown how much they will feed on surface drift. More than 1 because there is diet data for sturgeon

P4c. White Sturgeon (12 and 36 mile the same)

DLO Relationship and General Observations:
Invertebrates are common food items for small sturgeon, but it's unclear how much they use terrestrial prey (White Sturgeon Model page 8).

Magnitude = 1
See general observations.

Certainty = 2
Sturgeon are benthic feeders and it is unknown how much they will feed on surface drift. More than 1 because there is diet data for sturgeon.

P4d. Steelhead

Moyle et al. 2004, page 277 states that stream-dwelling O. mykiss feed mostly on drifting aquatic organisms and terrestrial insects.

Magnitude = 2
See general observations.

Certainty = 2
See general observations.

P4e.1 Chinook Salmon 12 Mile

Consumption of terrestrial invertebrates in drift is very common (Sommer et al. 2001). Diet has a large effect on growth and survival.

Magnitude = 2
See general observations.

Certainty = 3-4
See general observations.

P4e2: Chinook Salmon - 36 Mile

Consumption of terrestrial invertebrates in drift is very common (Sommer et al. 2001). Diet has a large effect on growth and survival.

Magnitude = 3
See general observations.

Certainty = 3-4
See general observations.

Potential Negative Ecological Outcome(s)

Outcome N1: Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail, if flows through sloughs are not sufficient to prevent colonization by non natives (by creating more predator habitat).

Note: Scored under current operations/flows. If flows were to increase then predator risk would decrease. Longfin are unlikely to be in this area so magnitude was scored lower. Predation could have negative affect, but not certain what balance is between non-native/native abundance shifts. Many migration studies in this area are assuming predation is the cause of mortality. Concern is that we are increasing predation rate in these areas by routing fish (up to 50% of the population) in an area that predators exist in. However, we do not know if this will be a population level affect.

N1a. Longfin Smelt

Longfin model - Predation is a source of direct mortality to eggs and larvae. Some fish species (e.g., suckers, splittail, sturgeon) may feed on LFS eggs. Larval LFS are not strong swimmers (Wang 1986) and are thus highly vulnerable to predation. Striped bass and inland silverside are probably major predators on LFS larvae. Terns, gulls, and cormorants may also prey on this life stage. There appears to be a correlation between high flows and the abundance and distribution of LFS; high flows also decrease the success of LFS predators by increasing turbidity (Page 8.) There is little information in the model specific to competition with non-natives, competition for food resources is expected to have decreased with the recent decline in LFS (Page 14.), competition for spawning sites is unknown (Page 10.). Predation and competition are characterized as medium importance and medium understanding (Figure 5.); floodplain predation and competition are not specifically addressed.

Magnitude = 2

Certainty = 2

N1b. Splittail

The floodplain model does not address non native predation or competition on the floodplain. Evidence from Yolo and Cosumnes about non-natives taking advantage of floodplain (ref Sommer et al 2004, Moyle et al 2006). Floodplain Model: Page 10 talks about sources of invasive species. Foodweb Model is focused on estuarine systems.

Splittail model—Predation by non native fish is characterized as low with high understanding for juveniles and as medium with medium understanding for adults (Figures 5, 6 and 7.) Bird predation appears limited until water recedes and floodplains begin to isolate from main channels at which point fish are exposed to wading birds (Moyle 2004).

Magnitude = 2

Certainty = 3

N1c. Green/White Sturgeon

Models indicate probable distribution in the mainstem Sacramento River adjacent to these sloughs (Figure 7, white sturgeon model, Figure 2, green sturgeon model). There is no direct evidence of utilization of these sloughs by green sturgeon or white sturgeon.

Magnitude = 1

Certainty = 2

N1d. Steelhead/Chinook Salmon

The Chinook salmon and steelhead model indicates Non-native predation and competition with invasive species and hatchery produced salmonids is of medium importance in rearing and emigration estuarine habitats, including floodplain (Figure 2a).

Magnitude = 2-3

Certainty = 2

Outcome N2: Increased mortality of covered species due to increased exposure risk to contaminants due to longer residence time in this area.

The text and scores provided here are applicable to all covered fish species. The primary risk of this type of project at these locations is increased exposure to pesticides due to increased fish use and residence time in the enhanced habitat. The proposed habitat enhancements would not themselves result in significant changes in contaminant cycling or exposure. The habitat is being enhanced to facilitate spawning by splittail and rearing by splittail and other species. Surrounding lands are agricultural, including orchards and other crops. Pyrethroids, a class of pesticides used as dormant sprays on orchards, can be toxic to fish, especially to early life stages (Pyrethroids model, page 16). Pyrethroid concentrations would be expected to peak during the winter/spring storm season and after peak agricultural application in the summer and fall (Pyrethroids model, page 2). Late-winter and spring are also the times splittail would use the enhanced floodplain habitat to spawn (Splittail model, page 1).

There are critical data gaps on pyrethroids and other pesticides that make it difficult to evaluate risk to covered fish (Pyrethroids model, page 32; Chemical stressors model, page 25). In general, little is known about the toxic effects of contaminants known to be present in the Delta on resident Delta species, and even less is known about the sublethal effects of contaminants (Chemical stressors model, page 25).

Magnitude = 1
See general observations.

Certainty = 3
See general observations.

Important Gaps in Information and/or Understanding

Research Needs

- Major gaps – rearing habitat for steelhead? Rearing habitat for juvenile sturgeon?
- Better diet information is needed for riparian and channel margin habitat use of SH, green and white sturgeon.
- More information is needed about relative importance of food to population level effects for all of the species.
- Transport studies are needed to evaluate the footprint of food transport.
- Timing duration of rearing for SH, green and white sturgeon.
- Better understanding of rearing habitat restoration while minimizing predatory fish abundance.

Assess Reversibility and Opportunity for Learning

Reversibility

Not provided

Opportunity for Learning

High: A spatial reach (linear in shape) offers space to conduct this type of study.

References Cited

CDFG 2004
Jackson 1992
Kjelson et al 1982
Lister and Genoe 1970
Newman 2008
NMFS 1997
Quinones 2005
Sommer 2005
Sommer 2005
Vogel 2008

Appendix A

HRCM 13:
Vernails to Mossdale

Scientific Evaluation Worksheet

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P1a2: Splittail - 28 mile *4*
P1b. Green Sturgeon (Same for 14 or 28 mi scenario) *4*
P1c. White Sturgeon (Same for 14 or 28 mi scenario) *4*
P1d. Steelhead (Same for 14 or 28 mi scenario) *5*
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P4b. Green Sturgeon (Same for 14 or 28 mi scenario) *7*
P4c. White Sturgeon (Same for 14 or 28 mi scenario) *8*
P4d. Steelhead (Same for 14 or 28 mi scenario) *8*
P4e. Chinook Salmon (Same for 14 or 28 mi scenario) *8*

POTENTIAL NEGATIVE ECOLOGICAL OUTCOME(S) 9

OUTCOME N1: INCREASED EXPOSURE RISK TO CONTAMINANTS (INCLUDING SE) DUE TO LONGER RESIDENCE TIME IN THIS AREA. 9
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OUTCOME N3: INCREASED HABITAT FOR NON-NATIVE PREDATORS/COMPETITORS TO NATIVE FISHES (LONGFIN SMELT, SPLITTAIL, GREEN/WHITE STURGEON, STEELHEAD, CHINOOK SALMON). 10
N3a. Longfin Smelt *11*
N3b. Splittail *11*

N3c. Green/white Sturgeon (scored the same) *11*
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Action: HRCM13: Channel margin habitat between Vernalis and Mossdale

Evaluation Team: Floodplain Workgroup

Campbell Ingram (chair), Denise Reed (coach), Carie Battistone (notetaker), Eric Ginney, Ted Sommers, Rosalie Del Rosario, Dennis McEwan, Bill Harrell, Dan Welsh, Yvette Redler, and Vance Russell.

Date of Last Revision: March 1, 2009

Action Description and Clarifying Assumptions

Enhance channel margin habitats along between 14 and 28 miles of the San Joaquin River in the San Joaquin River ROA to improve habitat conditions for covered fish species.

1. 14 miles = 7 miles of channel, each side
2. 28 miles = 14 miles of channel, each side
3. Area between Vernalis to Mossdale that includes 1,800 acres of existing floodplain
4. 7 to 14 miles are linear measures (river miles, no setbacks, no area)
5. All South Delta work will be contingent on significant reduction in south Delta entrainment (need to evaluate some negative outcomes with 1) Old River isolated and 2) current configuration and reduced pumping (i.e., dual conveyance)).
6. No setbacks. Assume 50% of area improved in patches.
   - Backwaters within existing small floodplain areas
   - Low velocity areas within channel
   - Shallow low velocity benches
   - LWD for in-stream structural cover
   - Shade trees adjacent to channel margin
7. There are not institutional barriers preventing implementation

Approach

1. Modify channel geometry to improve hydrodynamic and structural complexity and to create low velocity habitat areas designed to provide spawning habitat for splittail and rearing habitat for splittail and salmonids; and
2. Establishing woody riparian vegetation along banks that do not support woody riparian vegetation to provide shaded riverine aquatic and instream cover for covered fish species.

Intended Outcomes as Stated in Conservation Measure

Positive

P1: Increase availability of high quality rearing habitat for Chinook salmon, steelhead, splittail, green and white sturgeon (includes instream cover, shade, food; consider loss to entrainment).

P2: Increase availability of spawning habitat for splittail.

P3: Improved resting habitat for migrating adult Chinook salmon (upstream), steelhead (up and downstream), and green and white sturgeon.

P4. Increased food production and availability (fall of OM, terrestrial invertebrates) for Chinook salmon, steelhead, splittail and green and white sturgeon (consider loss to entrainment).

Negative

N1: Increased exposure risk to contaminants (including Selenium) to longer residence time in this area.

N2: Increased frequency and magnitude of low dissolved oxygen in SDWSC due to increased POM and impact on salmon, steelhead, and green and white sturgeon passage.

N3: Increased habitat for non-native predators/competitors to Chinook salmon, steelhead, green and white sturgeon, and splittail.

Conceptual Model Information Regarding Intended Outcomes

The basic drivers and outcomes are described in the DRERIP conceptual models, specifically, the salmonid model. Numerous studies have indicated that shallow riparian habitat benefits fry Chinook (Sommer 2005, Quinones 2005, Kjelson 1982). Loss of this habitat has been indicated as a major source of decline in Central Valley Chinook (NMFS 1997, CDFG 2004).

Assumptions

Provided in BDCP Conservation Measure

Not provided.

Added by Evaluation Team

Not provided.

Problem(s) with Action as Written:

Modification may depend on width of channel – benches may not be feasible if setbacks are not constructed.

Scale of Action:

7 mile reach – (50% extent = 7 miles of bank) Medium
14 mile reach - (50% extent = 14 miles of bank) Medium

Rationale:

Some reasonable conditions seem to exist in this area at the moment (floodplain, evidence of meandering on maps, presence of riparian habitat), increment over current condition.

Evaluation Summary Tables

Summary tables listing magnitude and certainty scores for each outcome, by species, are provided in Appendix A. Details regarding each of the listed scores, and the rationales for the scores, are provided in the discussion of positive and negative outcomes on the following pages.

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

YES

Nature of Change:

Conditions have been studied.

Potential Positive Ecological Outcome(s)

Outcome P1: Increased establishment of woody riparian and emergent vegetation to provide high quality rearing habitat for covered species.

P1a1: Splittail - 14 mile

Sommer et al. 2002, 2007 shows Splittail prefer shallow habitat, however there was no evidence of preferences for distinct vegetation types.

Magnitude = 1
Depending on extent of action; not changing the inundation frequency and pattern.

Certainty = 3-4

P1a2: Splittail - 28 mile

Sommer et al. 2002, 2007 shows Splittail prefer shallow habitat, however there was no evidence of preferences for distinct vegetation types.

Magnitude = 2
Depending on extent of action; not changing the inundation frequency and pattern

Certainty = 3-4

P1b. Green Sturgeon (Same for 14 or 28 mi scenario)

In the San Joaquin, the green sturgeon appears to be extirpated (green sturgeon Model page 3).

Magnitude = 2
Depending on extent of action; not changing the inundation frequency and pattern

Certainty = 1
Limited data on rearing preferences

P1c. White Sturgeon (Same for 14 or 28 mi scenario)

Juvenile sturgeon are benthic feeders so creation of additional benthic habitat would be beneficial (Sturgeon model page 8). Although it is unknown whether white sturgeon will utilize habitats this shallow. They were never captured in Yolo Bypass studies (Sommer and Harrell unpublished data). Although it's not mentioned in the White Sturgeon Model, it is likely that white sturgeon will utilize the same habitats for foraging as described below for green sturgeon.

Shallow water habitats and low tidal areas are likely nursery habitat (White Sturgeon Model page 15). Most sturgeon spawning is focused on the Sacramento, (page 9 of

White Sturgeon Model) therefore restoration benefits in the San Joaquin would not be as great.

Magnitude = 2
Depending on extent of action; not changing the inundation frequency and pattern.

Certainty = 1
Limited data on rearing preferences

P1d. Steelhead (Same for 14 or 28 mi scenario)

Tidal marshes can provide rearing habitat and foraging opportunities to fishes that enter marsh channels (Fish Habitat Linkages Model). The primary food organisms of juvenile salmonids are drifting aquatic insects and the larval stages of terrestrial insects (Quinn 2005).

Riparian vegetation is important to salmonids (inc steelhead) by contributing terrestrial insects into the stream and logs and branches that shape channel morphology, retaining organic matter, providing essential cover, stabilizing banks, maintaining undercut banks, and modifying water temperatures through shading (Murphy and Meehan 1991). .

Allochthonous inputs from streamside vegetation are important to salmonids because they provide food for the aquatic invertebrate food base (Murphy and Meehan 1991). Given their similarities in life history, it can be assumed that they are utilizing the same habitats as juvenile salmon, and many of the references below for Chinook salmon would apply to steelhead as well.

Magnitude = 3
Given that existing rearing habitat in the Delta is so limited, this action could have a sustained minor population effect on this species.

Certainty = 2
Steelhead use of estuaries for rearing is not well described in the literature.

P1e. Chinook Salmon (Same for 14 or 28 mi scenario)

Chinook Salmon fry inhabited marginal areas of the river, particularly back eddies, behind fallen trees, undercut tree roots, or other areas of bank cover. As they grew larger, they move away from the shore into midstream and higher velocity areas (Lister and Genoe 1970). San Joaquin Technical Annual reports suggest fall-run fry are rearing in the Delta because they are documented leaving San Joaquin tributaries, are later found in Mossdale (Caswell Annual Report 2007, SJRG 2004, 2005, 2006). Peak seasonal catches of fry at Stanislaus in 2005 and Tuolumne River in 2006 during January and March were not picked up at Mossdale in great numbers. Mossdale peaks occurred in April and May of smolt sized fish (SJRG annual reports 2005, 2006).

Fall-run Chinook salmon juveniles are present in the area. San Joaquin fall-run Chinook juveniles enter Delta either as: 1) fry/parr) with high winter flows, typically in January through March (size of 20 to 60 mm fork length, or as 2) smolts after mid March(> 60 mm fork length; (Caswell Annual Report 2007, SJRG 2004, 2005, 2006).

Juvenile Chinook within pools in the American River, were associated with instream cover such as rootwads, logs or submerged vegetation, or with overhead cover, and were also associated with eddies or other areas with steep velocity gradients. Such positions allow fish to hold in slower water but make forays into faster water to capture drifting insects (Jackson 1992). Among the wide variety of suitable substrates and habitat types for rearing, young salmon appear to seek out low velocity areas (Sommer 2005).

Fall-run Chinook salmon juveniles would use the channel margin habitats to rear. Chinook salmon use the delta inversely proportional to their size (Williams 2006). The restored channel margin habitat would create rearing habitat for fry/parr that enter the Delta in the winter. These fry would be able to feed and grow in the channel margins, and their larger size would increase the likelihood of survival in the ocean.

Several studies suggest that emigrating salmon derive great benefit from connection with vegetated riparian areas--it provides a variety of benefits including shading, terrestrial food web inputs and habitat structure. (Opperman and Merenlender 2004, Quinones and Mulligan 2005).

Fall-run Chinook fry (<70mm) rear primarily in the upper fresh-water Delta…peak fry rearing is (Feb-March) young fry appear to be most abundant in shallow water/shoreline habitat, rearing occurs for two months or more. (Kjelson et al 1982). Levee development in the central valley…disrupts the natural processes of the river. These changes generally reduce the range of habitat conditions typically found along natural shorelines, especially by eliminating the shallow, slow-velocity river margins used by juvenile fish as refuge and to escape from fast currents, deep water, and predators (Stillwater Sciences 2006). Growth rates for juvenile Salmon are higher and emigration rates are slower when in shallow water rearing habitats (Kjelson 1982, Sommer et al 2005).

Note: Citations regarding channel margin habitat are from riverine systems and not the Delta. Therefore importing woody debris not as important.

Magnitude = 2-3
Temporally significant, expected sustained minor population effect.

Certainty = 2-3
Steelhead use of estuaries for rearing is not well described in the literature.

Outcome P2: Increase availability of spawning habitat for splittail.

P2. Splittail (Same for 14 or 28 mi scenario)

Floodplain model page 25 and Splittail model pages 9 and 12 describe how additional floodplain habitat supports splittail spawning. Good evidence that woody debris is important for upstream areas, less for Delta.

Magnitude = 3

Certainty = 3-4

Outcome P3: Improved resting habitat for migrating adults (Chinook Salmon upstream, steelhead up and downstream, Green/White sturgeon).

The text and scores provided here are applicable to all covered fish species. Shelter from predators may come in the form of deep pools, cut banks, and submerged dead and living woody material. Riparian vegetation may shade “holding” habitat and ameliorate temperature gain in this habitat. Streamside vegetation also provides woody material salmon may use for cover from predators or high flows.(Rosenfield draft salmon model page 67).

Adult salmonids migrating upstream are assumed to make greater use of pool and mid-channel habitat than channel margins (Stillwater Sciences 2004), particularly larger salmon such as Chinook salmon, as described by Hughes (2004).(NMFS Draft OCAP page 36). This statement contradicts need for channel margin habitat for adults.

Adult migration corridors should provide satisfactory water quality, water quantity, water temperature, water velocity, cover/shelter and safe passage conditions in order for adults to reach spawning areas (NMFS 2008).

Magnitude = 1-3

Certainty = 1-2
Lack of information in literature regarding resting habitat needs of migrating adult salmon.

Outcome P4: Increased food production and availability (fall of OM, terrestrial invertebrates) for Chinook salmon, steelhead, splittail, green/white sturgeon. Consider loss to entrainment.

P4a. Splittail (Same for 14 or 28 mi scenario)

Floodplain Model pages 20-25 describe floodplain food production. Floodplain Model pages 25 and 27 describe utilization and higher survival for splittail on floodplains.

Magnitude = 1
Given limited temporal effect in frequency and no change in hydrology. Action represents a change in vegetation type only.

Certainty = 3

P4b. Green Sturgeon (Same for 14 or 28 mi scenario)

Floodplain Model pages 20-25 describe floodplain food production. No evidence of juvenile use of floodplains. Catch in Yolo are adults (Harrell and Sommer unpublished). This mechanism described for Chinook salmon is assumed to apply to green sturgeon

(Sommer et al 2005 and Floodplain Model). In the San Joaquin, the green sturgeon appears to be extirpated (Green Sturgeon Model page 3).

Note: Citations regarding channel margin habitat are from riverine systems not Delta and therefore importing woody debris not as important.

Magnitude = 1

Certainty = 3)

P4c. White Sturgeon (Same for 14 or 28 mi scenario)

Floodplain Model pages 20-25 describe floodplain food production. No evidence of juvenile use of floodplains. Catch in Yolo are adults (Harrell and Sommer unpublished). This mechanism described for Chinook salmon is assumed to apply to green sturgeon (Sommer et al 2005 and Floodplain Model).

Magnitude = 1

Certainty = 1

P4d. Steelhead (Same for 14 or 28 mi scenario)

Floodplain Model pages 20-25 describe floodplain food production. Nothing in the literature that describes steelhead feeding on floodplains, however, it can be assumed that they are utilizing the same food sources as juvenile salmon, given their life-history similarities. Moyle et a. 2004 states that stream-dwelling RT feed mostly on drifting aquatic organisms, terrestrial insects, and bottom dwelling organisms which are in abundance on floodplains.

Magnitude = 1
Given limited temporal effect in frequency and no change in hydrology). Action represents a change in vegetation type only.

Certainty = 2
Non peer reviewed

P4e. Chinook Salmon (Same for 14 or 28 mi scenario)

Floodplain Model pages 20-25 describe floodplain food production. Floodplain Model pages 27 and 29 describe utilization and higher growth rates for Chinook salmon on floodplains. Chinook salmon likely take advantage of small fishes on the FP (Splittail Model page 8 and Moyle et al. 2004).

Magnitude = 1
Given limited temporal effect in frequency and no change in hydrology. Action represents a change in vegetation type only.

Certainty = 3
Given data on flooding and studies elsewhere.

Potential Negative Ecological Outcome(s)

Outcome N1: Increased exposure risk to contaminants (including Se) due to longer residence time in this area.

Although the text and scores provided here are applicable to all covered fish species, it should be noted that Salmonids more sensitive to selenium. Selenium (Se) loading of the Bay-Delta ecosystem is driven mainly by loads entering the Delta from the San Joaquin River (SJR), which in turn receives most of its Se input from agricultural drainwater entering the river through Mud Slough (Se model, Fig. 1). This project is along the mainstem SJR downstream of these Se inputs.

The proposed action involves habitat modification that enhances floodplains and creates more low velocity, shallow water habitats. These types of habitats create a better environment for Se partitioning in food chains than would occur in bed sediment of the river channel. Exposure of covered fish to Se might increase due to higher bioaccumulation of Se in invertebrate prey and longer residence time of the fish in the enhanced habitat.

Salmonids are relatively sensitive to Se compared to other fish (Se model, page 19). Beckon (2008 abstract from CALFED science conference; manuscript in prep) evaluated Se data from the SJR and concluded that, although discharges of Se to the SJR have been reduced over the last 15 years, Se will pose a substantial risk to salmon that are reintroduced to restored middle reaches of the river unless Se loads are further reduced and/or sufficient dilution flows are provided. The magnitude of potential effects of Se from this project between Vernalis and Mossdale may be lower than would occur at projects along the middle reaches of the SJR mainstem (i.e., sites in the vicinity of Mud Slough) because this project occurs downstream of dilution sources from the Merced, Tuolumne and Stanislaus Rivers. However, this spatial difference does not provide strong protection because Se bioaccumulates in food chains, is recycled in the ecosystem, and can have significant lag times between when loading occurs and when effects are seen.

The seasonal use of the habitat may also reduce the potential magnitude of Se impacts to covered fish species, especially juvenile salmonids. Seasonal use of the Delta by juvenile salmonids occurs mainly during high flow periods (January-June)(salmon model, page 11); whereas highest concentrations of Se occur during low flow periods (Se model, page 6). However, this seasonal difference does not provide strong protection because Se bioaccumulates in food chains, is recycled in the ecosystem, and can have significant lag times between when loading occurs and when effects are seen.

The invertebrate prey of juvenile salmonids are water-column-feeding or detritus-feeding species that are less contaminated than certain suspension or deposit-feeding bivalves (Se model, Table 5 and Fig. 1). Adult splittail and sturgeon feed on bivalves and would be expected to have greater exposure to Se in their diet than salmonids. This project is intended to provide rearing habitat for juvenile sturgeon and splittail rather than habitat for adults, but may also result in increased residence time by spawning and foraging adults. However, the bivalve species present at this freshwater location would be *Corbicula fluminea* rather than *Corbula amurensis* (*Corbula* and *Corbicula* models). *C. fluminea* is less efficient at bioaccumulating Se than *C. amurensis* (Se model, page 14).

Se dynamics in the Bay-Delta system are fairly well understood, but there is uncertainty about how changes in management of SJR flows, water exports, and potential future actions to solve the drainage problem on the west side of the San Joaquin Valley could affect Se loading and cycling in the Delta (Se model, pp. 3 and 4). A quantitative analysis of the increased risk of Se toxicity resulting from this project would require estimates of the increase in the amount of time covered fish spend at this location relative to the baseline condition, as well as estimates of future river flows, water exports, and Se loads. Such an analysis is beyond the scope of this worksheet exercise, but should be considered if the project is recommended for evaluation in the NEPA process.

Magnitude = 2

Certainty = 3

Outcome N2: Increased exposure risk to contaminants (including Selenium) to longer residence time in this area.

The text and scores provided here are applicable to all covered fish species. Presence of fish species needs to be considered. Page 33 salmon model talks about DO as migration barrier and timing issue (juveniles not migrating when DO is an issue) Also see page 60 re adults. More of issues for adult and juvenile salmon.

Magnitude = 1

Certainty = 4
Would not cause affects on species based on seasonality (more of a late summer fall issue).

Outcome N3: Increased habitat for non-native predators/competitors to native fishes (longfin smelt, splittail, green/white sturgeon, steelhead, Chinook salmon).

Note 1 The floodplain model does not address non native predation or competition on the floodplain. Evidence from Yolo and Cosumnes about non-natives taking advantage of floodplain (ref Sommer et al 2004, Moyle et al 2006). Floodplain Model: Page 10 talks about sources of invasive species. Foodweb Model is focused on estuarine systems.

Note 2 Scored under current operations/flows. If flows were to increase then predator risk would decrease. Longfin are unlikely to be in this area so magnitude was scored lower. Predation could have negative affect, but not certain what balance is between non-native/native abundance shifts. Many migration studies in this area are assuming predation is the cause of mortality. Concern is that we are increasing predation rate in these areas by routing fish (up to 50% of the population) in an area that predators exist in. However, we do not know if this will be a population level affect.

N3a. Longfin Smelt

Longfin model—predation is a source of direct mortality to eggs and larvae. Some fish species (e.g. suckers, splittail, sturgeon) may feed on LFS eggs. Larval LFS are not strong swimmers (Wang 1986) and are thus highly vulnerable to predation. Striped bass and inland silverside are probably major predators on LFS larvae. Terns, gulls, and cormorants may also prey on this life stage. There appears to be a correlation between high flows and the abundance and distribution of LFS; high flows also decrease the success of LFS predators by increasing turbidity (Page 8.) There is little information in the model specific to competition with non-natives, competition for food resources is expected to have decreased with the recent decline in LFS (Page 14.), competition for spawning sites is unknown (Page 10.). Predation and competition are characterized as medium importance and medium understanding (Figure 5.); floodplain predation and competition are not specifically addressed.

Magnitude = 2

Certainty = 2

N3b. Splittail

Splittail model - Predation by non native fish is characterized as low with high understanding for juveniles and as medium with medium understanding for adults (Figures 5, 6 and 7.) Bird predation appears limited until water recedes and floodplains begin to isolate from main channels at which point fish are exposed to wading birds (Moyle 2004).

Magnitude = 3

Certainty = 2

N3c. Green/white Sturgeon (scored the same)

Green and white sturgeon – models indicate probable distribution in the mainstem Sacramento River adjacent to these sloughs (Figure 7, white sturgeon model, Figure 2, green sturgeon model). There is no direct evidence of utilization of these sloughs by green sturgeon or white sturgeon.

Magnitude = 1

Certainty = 2

N3d. Steelhead/Chinook salmon (scored the same)

Chinook salmon and steelhead. The DRERIP salmonid model indicates non-native predation and competition with invasive species and hatchery produced salmonids is of medium importance in rearing and emigration estuarine habitats, including floodplain (Figure 2a).

Magnitude = 2-3

Certainty = 2

Important Gaps in Information and/or Understanding

Data Needs

Lack of information on migrating adults through the Delta and the use of habitat as they journey through to spawning grounds.

Research Needs

- The basis of the assumption for the flooding frequency could be refined (Table 2, BDCP doc).
- Major gaps – rearing habitat for steelhead? Rearing habitat for juvenile sturgeon?
- Hg accumulation in fish has been documented, but does not indicate effect on fish.
- Degree of contaminants affects on POD.
- Degree of sediment settling on floodplains.
- Degree of predation/competition within floodplains on native covered fish species by non-native fish species.
- Better diet information is needed for floodplain use of SH, green and white sturgeon;
- More information is needed about relative importance of food to population level effects for all of the species.
- Transport studies are needed to evaluate the footprint of food transport from floodplains.
- Timing duration of rearing for SH, green and white sturgeon.
- Acoustic tagging studies that target adults as they enter estuary/Delta.

Assess Reversibility and Opportunity for Learning

Reversibility

Not provided

Opportunity for Learning

Low

Comments: There is a spatial reach (linear in shape) where it is feasible to conduct this type of study.

References Cited

Caswell Annual Report 2007
CDFG 2004
Hughes 2004
Jackson 1992
Kjelson et al 1982
Lister and Genoe 1970
NMFS 1997
NMFS 2008
Quinones 2005
San Joaquin River Group 2004, 2005, 2006
Sommer 2005
Stillwater Sciences 2006
Stillwater Sciences 2004

Appendix A

OSCM 1:
Reduce Ammonia Discharges

Scientific Evaluation Worksheet

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Action: Reduce Ammonia Discharges

Evaluation Team: Water Quality & Invasives Workgroup

James Haas - Chair , Bruce Herbold – Coach, Chris Foe, Charles Alpers; Inge Werner, Frances Brewster, Karen Larsen, Chrisinte Joab, David Fullerton, Holly Gellerman, Ron Smith, Jan Thompson, Lori Clammurro (note taker)

Date of Last Revision: February 23, 2009

Action Description and Clarifying Assumptions

Implement advanced treatment processes at Sac Regional County Sanitation District (SRCSD) Wastewater Treatment Plant to reduce the concentrations and load of ammonia in effluent discharged into the Sacramento River to levels that do not directly or indirectly harm covered fish species.

Approach

Implement advanced treatment processes at the SRCSD WWTP to remove ammonia from effluent before discharging into the Sacramento River

Intended Outcomes as Stated in Conservation Measure

1. Increased food abundance for delta and longfin smelt by increasing the abundance of diatoms. *Note: the group re-worded this outcome to: Reductions of ammonia in the Sacramento River will increase diatom production and abundance (Outcome P1)*
2. Reduced direct mortality by ammonia of delta and longfin smelt, white and green sturgeon, salmonids (all races), and splittail *Note: the group re-worded this outcome to: Reduction in direct toxic effects on fish species (Outcome P6)*

Conceptual Model Information Regarding Intended Outcomes

1. Food Web conceptual model (Durand, 2008) – Section 1.32 and Section 4.13
2. Delta smelt model – pages 8, 29-30

Assumptions

Provided in BDCP Conservation Measure

1. *Implied: with* SRCSD *as the largest identified source of ammonia loads into the Delta, controlling only this source would result in increased food abundance and reduced direct mortality on covered fish species.*

Added by Evaluation Team

1. Assumed that increased diatom abundance increases zooplankton production and abundance.
2. Assumed that increased zooplankton abundance increases smelt abundance.
3. There is an assumption from data linkages and correlations that ammonia levels at Hood drive ammonia levels in Suisun Bay (Fullerton correlations). There is not consensus among scientists on this point.

Problem(s) with Action as Written:

1. Despite evidence that SCRSD is the largest single source of ammonia discharge to the Delta, discharging 10-times more ammonia than all other Delta wastewater treatment plants (WWTPs) combined (Jassby 2008), this action should be expanded to include other WWTPs, as well as other potential ammonia sources (e.g. refineries in Suisun and Grizzly Bays, smaller discharges). There may be other sources of significant magnitude that wouldn't show up in the correlations prepared by Fullerton.
2. The action, as written, does not account for the primary drivers of phytoplankton production, including light/turbidity, residence time/transport, salinity, and invasive clams.
3. The action needs to account for how the primary drivers of phytoplankton production vary in specific geographic regions of the estuary. Consequently, the action should be separated into at least two, and most likely three, distinct geographic areas: 1) the freshwater portion of the estuary, including the Sacramento River; 2) the low-salinity zone portion of the estuary, ranging from ~Big Break (River Kilometer 81) and Three Mile Slough to Chipps Island; and 3) areas west of Chipps Island, including Suisun and Grizzly Bays. Corbula/clam grazing is the prominent limitation to food production in areas west of Chipps Island (Kimmerer pers. comm.. and Alpine and Cloern 1992), but the role of clams is less well understood in upstream portions of the estuary. It is therefore believed that ammonia/um has the potential to play a much greater role in the upper estuary than in the lower estuary.
4. "Advanced treatment processes" is not defined (i.e., would the WWTP effluent undergo a full denitrification process?). There could be implications for food web productivity from a potential lack of nutrients resulting from denitrification.
5. *Based on three years of monitoring, the Lower Sacramento River has the highest ammonia/ium levels, followed by Carquinez Strait, then Old River. Nowhere else in the Delta has significantly elevated ammonia/ium concentrations (concentration range [highest of 0.5-0.6 mg/L total ammonia/ium]). With salinity intrusion, ammonia/ium levels are also elevated in the Bay as compared to Suisun.*
6. *Ammonia effects on submerged and floating aquatic vegetation (SAV & FAV) could be leading to potential impacts on covered species from predation.*

Scale of Action:

Large

Rationale:

The action is of significant duration and frequency (continuous), and spatial extent (under the assumption that the source of ammonia from SCRSD extends to Suisun & Grizzly Bay, in accordance with correlations Dave Fullerton has found between ammonia levels at Hood and in Suisun Bay) – this action could provide a major reversal over existing conditions, but only as it relates to the concentrations and loads of ammonia in the Sacramento River.

Evaluation Summary Tables

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

NO

Nature of Change:

Primary production is still controlled primarily by turbidity (Cloern et al 1985, Cloern 2001, 1996) and transport times in the deep water and a combination of those factors, plus grazing by the benthos for most of the year (Thompson 2005) – but species composition of primary production may change. The action is not expected to change any of these physical drivers of primary production.

However, the action could provide a significant improvement over existing conditions in terms of ammonia loads (and possibly nitrate, depending on treatment level) discharged into the Sacramento River.

Potential Positive Ecological Outcome(s)

Outcome P1: Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the freshwater portion of the estuary (Lower Sacramento River)

Evaluation of the action was split into three distinct geographic regions of the estuary to better describe the potential role of ammonium (as opposed to other primary drivers such as light/turbidity, clam grazing, and residence time) in limiting phytoplankton production. The evaluation was also divided into each level of the food web to better describe the different levels of uncertainty as the effect of ammonium moves up the food web from diatom production, to zooplankton production, to fish abundance within the geographic regions. Magnitude and certainty for the diatom and zooplankton effects are provided in the discussion to help explain the magnitude and certainty scores assigned to the covered species within the geographic area. The species scores only are rolled up into Table 1. Although this action was written to address the two smelt species, positive outcomes are possible for juvenile salmonids as well.

The three geographic regions used for the purposes of this analysis are:

1) The freshwater portion of the estuary, including the Sacramento River(hereafter identified as Outcome P1);
2) The low-salinity zone portion of the estuary, ranging from ~Big Break (River Kilometer 81) and Rio Vista to Chipps Island (hereafter identified as Outcome P2); and
3) Areas west of Chipps Island, including Suisun and Grizzly Bays (hereafter identified as Outcome P3).

The relationship between ammonium and productivity are supported by the Delta Food Web conceptual model, Dugdale et al 2007, Wilkerson et al 2006, and correlations between ammonium and chlorophyll a prepared by David Fullerton (unpublished data).

Dugdale and Wilkerson have observed that ammonium above 4 micromole/L suppresses diatom blooms in Suisun, San Pablo and Central Bays by inhibiting diatom uptake of nitrate.

Per discussion with Wim Kimmerer, light limitation has been the primary driver of phytoplankton production throughout the system. Post-1987, diatom production went down as the result of clam grazing; now, as a result, there is much more nano- and micro-plankton as opposed to larger cells, decreasing the efficiency of the food web. Effects of Corbula grazing can extend at least as far upstream as Rio Vista in some years. In the low-salinity zone, production is happening in shallow areas. In the freshwater/river influenced portions of the estuary, where clam grazing is less of a driver, it's possible that ammonium is a limiting factor in the production of phytoplankton. However, the shorter residence time in this part of the estuary throughout much of the year is no doubt a large factor in the low phytoplankton growth rate.

Clams eat diatoms not out of preference, but as a function of diatoms' settling rate. Because they settle to the bed of the water body, there is a lot less effort for clams to "catch" this food source. Upstream of Chipps Island, however, not as much is known about what controls the growth of phytoplankton, partly because the hydrology is so complicated. Corbula may affect phytoplankton production through tidal influence as far upstream as Decker Island and possibly as far as Rio Vista in most years. However, there are stations along the Sacramento River, outside of the influence of Corbula, where chlorophyll a levels have also gone down. In addition, corbula biomass is not high enough in every year, or in every spring to influence phytoplankton levels upstream to Rio Vista. The grazing rate of the freshwater clam, Corbicula fluminea, may also influence primary production but its importance as a phytoplankton consumer in the river channel is not well defined.

Dave Fullerton presented data showing relationships between ammonium and chlorophyll a, pre- and post-1987 (the approximate year of introduction of Corbula). For San Pablo Bay, the relationships were the same pre-and post-1987; chlorophyll a production was higher when ammonium concentrations were below 4 micromoles/L. For the lower Sacramento River, it appeared chlorophyll a production improved when ammonium dropped down to 2-3 micromoles/L. In Suisun Bay pre-1987, it appeared that chlorophyll a production peaked when ammonium was less than 2 micromoles/L, but the y-intercept decreases post-1987, indicating that clam grazing may have “muted” the response of chlorophyll a production to reduced ammonium levels. Despite a demonstrated impact from clam grazing in Suisun Bay, Fullerton’s correlations suggest that reducing ammonium below 4 micromoles/L may provide the opportunity for more chlorophyll a production, even with the clams in place; however, there was not consensus amongst the scientists on this point.

Chris Foe noted that Alex Parker’s sampling of ammonium along transects of the Sacramento River, show a decrease in ammonium as you move downstream to Suisun/Grizzly Bay, and an increase in concentration downstream of Suisun/Grizzly Bay, suggesting a potential “mid-Suisun” source.

P1a. Effect of reducing ammonium on diatom production:

Magnitude = 3
Certainty = 1

The Sacramento Regional County Sanitation District is the major source of ammonium in this area (Jassby 2008). SRCSD ammonium reaches to the lower Sacramento River, Cache Slough, and the lower San Joaquin River (SJR). There is less confidence that SRCSD ammonium reaches Suisun and Grizzly Bay. SRCSD appears to be the largest single source of total ammonia in the Delta (90% of Sacramento River load, per Jassby 2008).

In the freshwater/river influenced portions of the estuary, where clam grazing is less of a driver, ammonium has a greater potential to be a limiting factor in the production of phytoplankton year round. It’s possible that ammonium might be a limiting factor in portions of the Delta that have longer residence time and are relatively clear (low turbidity), but it’s not well known how much and which areas in the Delta have these characteristics. Turbidity in this part of the estuary has been declining (Jassby 2008); however, the short residence time in the deep river channels is still likely a critical factor in determining where and if phytoplankton growth occurs. The importance of Corbicula’s grazing on primary producers in shallow areas is also not well known.

Ammonium is a control factor of phytoplankton productivity in Suisun, San Pablo and Central Bays (Wilkerson et al 2006, Dugdale et al 2007); however, it is not known if ammonium exerts the same control on phytoplankton production further upstream in the Sacramento River. Preliminary analyses by the Dugdale-Wilkerson Lab indicate that the phytoplankton near the treatment plant are able to grow sufficiently well with high concentrations of ammonium present, but that does not appear to be the case at Rio Vista. It is not yet known how far up the Sacramento River from Suisun Bay ammonium may be an important factor in inhibiting phytoplankton production. Phytoplankton community composition may be important in this fresher part of the estuary. Quantitatively, researchers have not figured out where ammonium comes into play.

Herbicides and metals may also play a role, (e.g. diuron, rice herbicides, copper). Widespread phytoplankton toxicity to the green algae, *Selenastrum capricornutum,* was found at Delta sites monitored by the Irrigated Lands Program. No information is available on differential toxicity to diatoms and microcystis.

Jassby contends, "In the past, flows into Suisun Bay generally diluted the higher phytoplankton concentrations within the bay; now they bring in higher phytoplankton concentrations from upstream" (Jassby 2008). If Jassby's assertion is correct, then increasing phytoplankton production in the Lower Sacramento River, away from the influence of corbula, may have a larger magnitude effect on the low salinity zone foodweb than was historically the case.

While there is greater certainty on the source of ammonium in this part of the estuary, there is great uncertainty regarding the magnitude of the potential role of ammonium in the upper estuary, due to the complicated hydrology of this area (characterized by deep, fast-moving water). This short residence time limits the time that a parcel of water may produce phytoplankton before it enters a new light, nutrient, and grazer environment. Given the nature of the primary drivers of primary production in this area (light/turbidity, residence time, and nutrients – only one of which would change with this action), significant questions remain as to whether controlling ammonia/ium discharges would really address the problem of low primary productivity in the Delta.

P1b. Effect of increasing diatom production on zooplankton abundance:

Magnitude = 2
Certainty = 2

The decline in diatoms in Suisun Bay (c) apparently caused a decline in abundance of at least some zooplankton (Kimmerer and Orsi 1996). At present the zooplankton populations appear to be severely food-limited, at least in the Low-Salinity Zone (b) (Kimmerer 2006, unpublished). However, the change in species composition of the zooplankton since Corbula arrived means that the system may not go back to its previous state. Furthermore, since gains in phytoplankton biomass (as opposed to specific growth rate) are likely to be modest because of continued clam grazing, the response of the zooplankton will likely be small. This is a suitable area for research but nobody should expect a large boost to the foodweb without further information.

The importance of Corbicula's grazing on primary producers in shallow areas is also not well known (Thompson pers. comm.). We don't know if Corbicula are widely distributed in Cache slough. Corbicula babies are found up the Sacramento River as far as we sampled; however, they don't grow in most of this part of the river. Based on Chris Foe's dissertation, it seems likely that they are food limited in the Sacramento River. Whether increasing food will increase clam or zooplankton populations is unknown as part of the issue is transport of food to the clams on the bottom which has to be done at an appropriate time scale relative to the concentration of food.

P1c. Effect of increasing zooplankton abundance on fish abundance:

Delta smelt:

Magnitude = 3
Certainty = 1

There is evidence that Delta smelt are food-limited based on analyses of their liver glycogen levels (Bennett et al 2008). In addition, spring zooplankton abundance is decreasing just as temperatures are starting to rise, and Delta smelts' bioenergetic needs are increasing. According to Herbold (pers. comm..) April/May and August may be a particularly important bottleneck for Delta smelt. Delta smelt often occur in this part of the estuary in April and May. Given their currently very low population level, increasing the base of their foodweb has the potential to have a sustained minor population effect. This action also has the potential to increase productivity in multiple patches of habitat (lower Sacramento River directly, and confluence and Suisun Bay through transport of productivity). There is minimal certainty because understanding is not widely accepted and outcome is dependent on variable ecosystem processes such as residence time and water clarity.

Longfin smelt:

Magnitude = 2
Certainty = 2

Kimmerer (2002b) found evidence of bottom-up trophic limitations on longfin smelt productivity in this Estuary (see p. 26 Longfin smelt conceptual model, Rosenfield, 2008). The potential magnitude of effect on longfin in the lower Sacramento River would be smaller than for Delta smelt because longfin do not generally occur in this part of the estuary. However, increased productivity in the lower Sacramento River has the potential to flow into Suisun Bay and the confluence area where longfin smelt do occur. Magnitude is low because action addresses productivity in a minor way with limited spatial habitat effects. Since they don't occur in this area, there is greater certainty that the magnitude of effect is low.

Salmon spp.

Magnitude = 2
Certainty = 1

Juvenile salmonids consume a significant amount of crustaceans in their diet, but Information is limited regarding their dependence on the specific zooplankton species preferred by Delta smelt.

Steelhead

Magnitude = 2
Certainty = 1

Juvenile steelhead consume a significant amount of crustaceans in their diet, but information is limited regarding their dependence on the specific zooplankton species preferred by Delta smelt.

Splittail and Sturgeon spp

Magnitude = 1
Certainty = 4

Splittail are both benthic and pelagic feeders. If the pelagic foodweb is limited they are able to take advantage of the benthic foodweb; therefore this action is not likely to increase splittail abundance. Sturgeon are primarily benthic feeders; therefore it is quite certain that they are unlikely to benefit from increases in the pelagic foodweb.

Outcome P2: Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in low-salinity portion of the estuary (confluence).

P2a. Effect of reducing ammonium on diatom production:

Magnitude = 3
Certainty = 1

The source of ammonium to this area is still likely largely from the Sacramento Regional County Sanitation District, but other treatment plant discharges in Suisun may also be important.

Phytoplankton can be produced in this section of the estuary or transported into the reach from the river upstream, the bay downstream, or the western delta. In this part of the system the major controls on diatom abundance and production are turbidity/light, residence time, and benthic grazing. The effect of clam grazing on phytoplankton in Suisun and Grizzly Bays often extends into this confluence area due to tidal mixing. Benthic grazing is important in many years; however, this area potentially has a longer window in the spring when benthic biomass and grazing rates may be low enough to allow a spring bloom if light, residence time and ammonium levels are favorable. A similar phenomena seems to occur in the western Delta where *Corbicula fluminea* limit the biomass of phytoplankton in Franks Tract where we might expect the shallow water and residence time would be favorable for phytoplankton growth (Lucas et al. 2002). *C. fluminea* grazing may also play a role in limiting phytoplankton biomass in this area. Decreasing sediment load and turbidity may make ammonium more important as light becomes less limited.

This area likely has the largest opportunity for ammonium to be a significant limiting factor when light conditions and grazing pressures are relaxed in the spring. In lab grow out experiments, the algal community in this area appears to respond to ammonium in a similar fashion to the diatoms on Suisun Bay. Unlike near the treatment plant discharge itself, preliminary analyses by the Dugdale-Wilkerson Laboratory indicate that ammonium may be inhibiting phytoplankton production in this area.

Herbicides and metals may also play a role, (e.g. diuron, rice herbicides, copper). Widespread phytoplankton toxicity to the green algae, *Selenastrum capricornutum,* was found at Delta sites monitored by the Irrigated Lands Program. No information is available on differential toxicity to diatoms and microcystis.

P2b. Effect of increasing diatom production on zooplankton abundance:

Magnitude = 2
Certainty = 2

The decline in diatoms in Suisun Bay apparently caused a decline in abundance of at least some zooplankton (Kimmerer and Orsi 1996). At present the zooplankton populations appear to be severely food-limited, at least in the Low-Salinity Zone (b) (Kimmerer 2006, unpublished). However, the change in species composition of the zooplankton since Corbula arrived means that the system may not go back to its previous state. Furthermore, since gains in phytoplankton biomass (as opposed to specific growth rate) are likely to be modest because of continued clam grazing, the response of the zooplankton will likely be small. This is a suitable area for research but nobody should expect a large boost to the foodweb without further information.

P2c. Effect of increasing zooplankton abundance on fish abundance:

Delta smelt:

Magnitude = 3
Certainty = 1

There is evidence that Delta smelt are food-limited based on analyses of their liver glycogen levels (Bennett et al 2008). In addition, spring zooplankton abundance is decreasing just as temperatures are starting to rise, and Delta smelts' bioenergetic needs are increasing. According to Herbold (pers. comm.), April/May and August may be a particularly important bottleneck for Delta smelt. Delta smelt often occur in this part of the estuary in April, May and August. Benthic biomass and grazing rates may be low enough to allow a bloom only in April and maybe May if light, residence time and ammonium levels are favorable. Increasing the base of their foodweb has the potential to have a sustained minor population effect, but the effect would be limited to short but critical periods in April and May of some years. There is minimal certainty because understanding is not widely accepted and outcome is dependent on variable ecosystem processes such as residence time and water clarity.

Longfin smelt:

Magnitude = 2
Certainty = 1

Kimmerer (2002b) found evidence of bottom-up trophic limitations on longfin smelt productivity in this Estuary (p. 26 Longfin smelt conceptual model). The potential magnitude of effect on longfin in the confluence area would be greater than for outcome P1c because longfin occur this area for a longer portion of their life cycle. Benthic biomass and grazing rates may be low enough to allow a bloom only in April and maybe May if light, residence time and ammonium levels are favorable. The critical time period of food limitation for longfin smelt is not known. Increasing the base of their foodweb has the potential to have a sustained minor population effect if food limitation in April and May is a critical bottleneck in longfin survival. There is minimal certainty because understanding is not widely accepted and outcome is dependent on variable ecosystem processes such as residence time and water clarity.

Salmon spp.

Magnitude = 2
Certainty = 1

Juvenile salmonids consume a significant amount of crustaceans in their diet, but Information is limited regarding their dependence on the specific zooplankton species preferred by Delta smelt.

Steelhead

Magnitude = 2
Certainty = 1

Juvenile steelhead consume a significant amount of crustaceans in their diet, but information is limited regarding their dependence on the specific zooplankton species preferred by Delta smelt.

Splittail and Sturgeon spp.

Magnitude = 1
Certainty = 4

Splittail are both benthic and pelagic feeders. If the pelagic foodweb is limited they are able to take advantage of the benthic foodweb; therefore this action is not likely to increase splittail abundance. Sturgeon are primarily benthic feeders; therefore it is quite certain that they are unlikely to benefit from increases in the pelagic foodweb.

Outcome P3: Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the brackish portion of the estuary (Suisun and Grizzly Bays).

P3a. Effect of reducing ammonium on diatom production:

Magnitude = 2
Certainty = 2

Suisun & Grizzly Bay phytoplankton are heavily grazed by clams. Except for a short period in spring when clam biomass and grazing rates are lower, it may be irrelevant whether phytoplankton are growing on nitrate or ammonium, because any production occurring here will be consumed by clams before it would yield food web benefits to covered species. If clam grazing rates are reduced in spring, the magnitude score for this region could be increased.

There is uncertainty as to how much of the ammonium in this part of the system is from Sacramento Regional County Sanitation District versus from other discharges within Suisun Bay such as Central Contra Costa Sanitary District. If other sources of ammonia are included in this action, the "certainty" score for this region could be revisited.

P3b. Effect of increasing diatom production on zooplankton abundance:

Magnitude = 2
Certainty = 2

The decline in diatoms in Suisun Bay apparently caused a decline in abundance of at least some zooplankton (Kimmerer and Orsi 1996). At present the zooplankton populations appear to be severely food-limited, at least in the Low-Salinity Zone (Kimmerer 2006, unpublished). However, the change in species composition of the zooplankton since Corbula arrived means that the system may not go back to its previous state. Furthermore, since gains in phytoplankton biomass (as opposed to specific growth rate) are likely to be modest because of continued clam grazing, the response of the zooplankton will likely be small. This is a suitable area for research but nobody should expect a large boost to the food web without further information.

P3c. Effect of increasing zooplankton abundance on fish abundance:

Delta smelt:

Magnitude = 2
Certainty = 2

There is evidence that Delta smelt are food-limited based on analyses of their liver glycogen levels (Bennett et al 2008). In addition, spring zooplankton abundance is decreasing just as temperatures are starting to rise, and Delta smelts' bioenergetic needs are increasing. According to Herbold (pers. comm.), April/May and August may be a particularly important bottleneck for Delta smelt. Delta smelt often occur in this part of the estuary in April, May and August. Benthic biomass and grazing rates may be low enough to allow a bloom only in April and maybe May if light, residence time and ammonium levels are favorable. It is highly unlikely that phytoplankton biomass would increase in August in response to lower ammonium levels because grazing pressure is too high at this time. Increasing the base of the Delta smelt's foodweb has the potential to have a sustained minor population effect, but the effect would be limited to short but critical periods in April and May of some years. There is minimal certainty because understanding is not widely accepted and outcome is dependent on variable ecosystem processes such as residence time and water clarity. If the clam grazing pressure were reduced, reductions in ammonium may have a larger effect.

Longfin smelt:

Magnitude = 3
Certainty = 1

Kimmerer (2002b) found evidence of bottom-up trophic limitations on longfin smelt productivity in this Estuary (see p. 26 Longfin smelt conceptual model). The potential magnitude of effect on longfin in Suisun and Grizzly Bays would be greater than for outcome P2c because longfin occur this area for a significant part of their life cycle. Benthic biomass and grazing rates may be low enough to allow a bloom only in April and maybe May if light, residence time and ammonium levels are favorable. The critical time period of food limitation for longfin smelt is not known. Increasing the base of their foodweb has the potential to have a sustained minor population effect if food limitation in April and May is a critical bottleneck in longfin survival. There is minimal certainty because understanding is not widely accepted and outcome is dependent on variable ecosystem processes such as residence time and water clarity.

Salmon spp.

Magnitude = 2
Certainty = 1

Juvenile salmonids consume a significant amount of crustaceans in their diet, but Information is limited regarding their dependence on the specific zooplankton species preferred by Delta smelt.

Steelhead

Magnitude = 2
Certainty = 1

Juvenile steelhead consume a significant amount of crustaceans in their diet, but information is limited regarding their dependence on the specific zooplankton species preferred by Delta smelt.

Splittail and Sturgeon spp.

Magnitude = 1
Certainty = 4

Splittail are both benthic and pelagic feeders. If the pelagic foodweb is limited they are able to take advantage of the benthic foodweb; therefore this action is not likely to increase splittail abundance. Sturgeon are primarily benthic feeders; therefore it is quite certain that they are unlikely to benefit from increases in the pelagic foodweb.

Outcome P4: Reduction in ammonia would decrease blooms of nuisance species such as microcystis or non-native zooplankton***

In some systems, nuisance/toxic algae blooms are linked to high concentrations of inorganic nutrients including ammonium (in addition to availability of sunlight & elevated water temp.) with strong correlation between total N and microcystin concentration between 1.5 and 4.0 mg TN/L (Camargo & Alonso 2006, Lehman, pers comm., Takamura et al 1987)

P4a. Microcystis

All Covered Fish Species
Potential benefits of this action do not apply if all Sacramento WWTP discharge were to be diverted into an new North Delta diversion facility. However, it depends on how much of the Sacramento River ends up in the diversion; could change with high flows in Yolo Bypass.

Magnitude = 2
Limited spatial or temporal effects
Lehman et al 2008: Nutrients secondary factor in development of microcystis

Certainty = 3
Relatively high certainty that magnitude of effect is low, from published literature (Lehman et al 2008)

P4b. Non-Native Zooplankton

All Covered Fish Species

Potential benefits of this action do not apply if all Sacramento WWTP discharge were to be diverted into an new North Delta diversion facility. However, it depends on how much of the Sac R ends up in the diversion; could change with high flows in Yolo Bypass.

Magnitude = 2
Limnoithona doesn't appear to have correlation with ammonia, unlike eurytemora and pseudodiaptomus (Fullerton, field data); however, Thompson considers the strong spatial gradient associated with distribution of eurytemora and pseudodiaptomus to confound interpretation of the ammonia relationship.

Certainty = 1
No info or data to substantiate

Outcome P5: Reduction in direct toxic effects on zooplankton species

Information regarding this outcome includes:
EPA 1999 Ammonia criteria
Werner et al., Final Report, 2008 found that growth of H. azteca was correlated with ammonia/ium at some Delta stations.
Johnson, Fullerton ambient data

Buhl 2002: Synergistic effects of ammonia mixing with other toxicants could increase the risk for aquatic invertebrates.

Prenter et al., 2004: Simultaneous or pre-exposure to other stressors such as pathogens can increase ammonia/ium toxicity

P5a. Pelagic Foraging Fish (Smelt and salmonid species)

Magnitude = 2
Could affect large geographic area. Other invertebrates such as hyalella azteca are highly sensitive to ammonia in chronic exposures (USEPA 1999). Effects on hyalella growth have been detected and related to ammonia in the Delta (Werner et al 2008).

Certainty = 3
Information for specific zooplankton species and life cycle exposures is minimal; however, effects on invertebrates (such as Hyalella) in the delta have been documented.

P5b. Benthic Foraging Fish (Splittail and Sturgeon spp.)

Magnitude = 1
No indication that benthic invertebrates are impacted by ammonia

Certainty = 2
Information for benthic species and life cycle exposures is minimal.

Outcome P6: Reduction in direct toxic effects on fish species

Information regarding this outcome includes:
EPA 1999 ammonia criteria
Werner et al. Draft Final Report, 2009: Sacramento WWTP effluent did not cause acute effects on larval Delta smelt survival at environmentally relevant concentrations, and effect concentrations (LC50, LOEC) of ammonia/ium are above concentrations measured in the lower Sacramento River (Werner et al., POD Progress Report, September 2008).

Average ambient ammonia/um and unionized ammonia concentrations in the Sacramento River below SRWTP are within a safety factor of approximately 10 based on acute effect concentrations reported for 50-d old Delta smelt larvae and other sensitive fish species (Werner et al. 2008, 2009).

No information is currently available for chronic effect concentrations.
Delta smelt model – p. 29

Passell et al 2007 concluded that NH3 toxicity must be considered seriously for its potential ecological impacts on the Rio Grande and as a mechanism contributing to the decline of the Rio Grande fish community in general and the Rio Grande silvery minnow specifically.

Buhl 2002: Synergistic effects of ammonia mixing with other toxicants could increase the risk for aquatic species.

Prenter et al., 2004: Simultaneous or pre-exposure to other stressors such as pathogens can increase ammonia/ium toxicity.

Reported unionized ammonia concentrations in the Sacramento River immediately below the SRWTP are 0.0085±0.005 and could exceed chronic safe values for Delta smelt. During January-June 2008, maximum unionized ammonia concentrations measured at Hood and Grand Island (POD site 711) were 0.019 mg/L and 0.021 mg/L, respectively (Werner I., UCD-ATL, unpublished data).

The chronic criterion for the Tittabawasee River in Michigan for fathead minnow embryos and larvae was established at 0.095 mg/L unionized ammonia (Passell et al. and references therein. Fathead minnows are approximately 5 times less sensitive to ammonia/um than Delta smelt (50 d old).

Dodds and Welch (2000) suggest that chronic effects of unionized ammonia on fish may occur at concentrations as low as 0.005 mg/L, which is below average concentrations in the Sacramento River below the WWTP.

The USEPA (1999) reports that some data have indicated that unionized ammonia can have adverse effects on aquatic life at concentrations as low as 0.001–0.006 mg/L.

Chronic effects: For fish, the US EPA (1999) reports mean acute-to-chronic ammonia/ium ratios for warm water fish that range between 2.7 (channel catfish, *Ictalurus punctatus*) and 10.9 (fathead minnow, *P. promelas*). Cold water species such as rainbow trout, with acute ammonia/ium sensitivity similar to Delta smelt, have a ratio between 14.6 and 23.5, respectively (US EPA, 1999; Passell et al., 2007). If a safety factor of 23.5 were applied to acute ammonia effect concentrations for Delta smelt larvae (unionized ammonia 96-h LC_{50}: 0.15 mg/L) then the resulting threshold concentration would be 0.0064 mg/L unionized ammonia.

Thurston and Russo (1983) demonstrated that large rainbow trout were measurably more sensitive than other life stages.

P6a. Delta smelt

Magnitude = 3
Delta smelt larvae at 50 dph are >5-fold more sensitive to ammonia/ium than larval fathead minnow (UCD-ATL, unpublished data), and about as sensitive as salmonid species, which are considered the most sensitive fish species with species mean acute values of 11.23, 17.34 and 20.26 mg/L total ammonia/ium (pH 8.0) for rainbow trout

(*Oncorhynchus mykiss*), Chinook salmon (*O. tshawytscha*) and Coho salmon (*O. kisutch*) (US EPA, 1999).

High probability for Delta smelt exposure. Salmon and smelt are the most sensitive fish species, and ammonia/ium levels in the delta are at least as high as that reported in other systems.

Certainty = 2
Information for fish species life cycle exposure is minimal.

P6.b Longfin Smelt

Magnitude = 1
longfin limited in spatial and temporal overlap with Sacramento Regional ammonia.

Certainty = 3
Reasonable certainty there are minimal impacts on longfin smelt Sac Regional's ammonia.

P6c. Salmonids

Magnitude = 2
Salmon and smelt most sensitive (salmon data from other systems – should revisit the literature). But levels in the Delta are at least as high as that reported in other systems.

Certainty = 3
No info or data from inside the delta to substantiate effects to salmon, but their sensitivity has been demonstrated to be comparable to that of Delta smelt.

P6d. Green & White Sturgeon

Magnitude = 1

Certainty = 3
Reasonable certainty that there are minimal impacts on GS/WS from Sac Regional's ammonia.

P6e. Splittail

Magnitude = 1
Splittail due to small percentage of population being directly exposed.

Certainty = 3
Reasobable certainty that there are minimal impacts on splittail from Sac Regional's ammonia.

Potential Negative Ecological Outcome(s)

Outcome N1: Removal of valuable nutrients as a function of WWTP outputs

All Covered Fish Species
See Delta smelt model, p. 30 (cites Van Nieuwenheyse 2007, with regard to positive influence of nutrients)

Both Outcome N1 and N2 are dependent on treatment. N1) are you doing nitrification or denitrification? If nitrification, magnitude is still minimal. System is not Nitrogen limited.

Magnitude = 1
Likely low magnitude if Sacramento River is not nutrient limited above the WWTP (Dalgren data)
Depends on treatment process chosen; more nutrients possible.

Certainty = 4
Dalgren data (unpublished – down to Freeport)
High certainty that there are high Nitrogen levels in the Sacramento River entering the system from upstream of the Sac Regional discharge.

Outcome N2: Nitrification will reduce ammonia, but increased nitrate could result in growth of undesirable algal blooms and macrophytes

All Covered Fish Species
Both Outcome N1 and N2 are dependent on treatment. Nutrients are an important factor supporting the growth on invasive macrophytes. Treatment that removes ammonia but increase nitrates could support macrophyte growth. Microcystis blooms can be attributed in part to increased nutrient inputs, and can cause fish mortality due to toxin production and reduced dissolved oxygen as a bloom decays.

Magnitude = 2
Limited spatial or temporal habitat effects based on current distribution of microcystis and invasive macrophytes.

Certainty = 2
Dalgren data (unpublished – down to Freeport) shows high nutrient loading to the delta; Sac Regional discharges nutrients to the delta, but how that contribution affects overall productivity relative to other nitrogen sources is not known.

Outcome N3: Increased phytoplankton productivity will increase clam biomass and uptake of selenium, impairing reproduction in benthic foraging fish species.

Splittail, Green Sturgeon, White Sturgeon

See:
Corbula model, p.13.
Corbicula Model, p. 12.
Selenium Model, p.14.
Splittail Model, p. 7.
Green Sturgeon Model, p. 9.
White Sturgeon Model, p. 9.

Magnitude = 3
Elevevated selenium concentrations in splittail and sturgeon suggest the possibility that reproductive impairment might be occurring; the population-levels effects of such exposure have not been evaluated

Certainty = 4
Greater contaminant uptake by clams, shifts in diets of splittail and sturgeon to clams, and elevated selenium in these benthic foraging species have been document within the delta system.

Important Gaps in Information and/or Understanding

Data Needs

- Other sources of ammonia are currently not included in the action; there could be others besides SRCSD that are important sources, (e.g. agriculture, dairies) in addition to SRCSD. The relative importance of all sources of ammonia should be evaluated.
- Ammonia model (Stuart Siegel's draft model for ammonia was circulated to the group)
- Analysis of data correlating ammonia, salinity, flow, temperature, and light penetration (numerical modeling to manipulate variables to ascertain importance of ammonia)
- Question of whether ammonia levels at Hood actually affect ammonia levels in Suisun Bay.
- Chronic effects of ammonia on fish species and zooplankton (in progress with Mike Johnson).

Research Needs

Integrated research should be undertaken to develop a numerical model of ammonia affects on the delta food web and covered species so that the multiple factors influencing production can be manipulated/isolated from other factors, and the respective roles of each factor can be determined for the different portions of the estuary. The model should address:

(a) Ammonia effects on food web production and species within the phytoplankton and zooplankton communities;
(b) Relative importance of ammonium versus nitrate;
(c) Sources, transport, and fate of ammonia through the Delta (into SF Bay), including the extent to which ammonium levels at Hood translate to effects in Suisun bay;
(d) Overall contribution of in-delta versus out-of-delta nutrient loading;
(e) Relationships of covered fish species to specific zooplankton;
(f) The adverse effects of clams on phytoplankton and diatom productivity and subsequent effects on zooplankton;
(g) Relationship between nitrate loading, macrophytes, and microcystis.

Approaches to consider include mesocosm studies and/or tracer studies using radio-labeled or stable isotopes.

Assess Reversibility and Opportunity for Learning

Reversibility

No/Hard

Comments: Very costly to implement and very difficult to reverse

Opportunity for Learning

High

Comments

References Cited

Models used:
Food web model – Section 1.32 and Section 4.13
Delta smelt model – pages 8, 29-30
Corbula model, p.13.
Corbicula Model, p. 12.
Selenium Model, p.14.
Splittail Model, p. 7.
Green Sturgeon Model, p. 9.
White Sturgeon Model, p. 9.

Other sources:
Sanitary Reports 2001, 2006
Dave Fullerton's correlations between ammonia/ium and chlorophyll a
Dugdale et al 2007
Kimmerer, pers. comm..
[Stuart Siegel's preliminary Ammonia model]
Thompson, pers. comm..

Buhl, K. J. 2002. The relative toxicity of waterborne inorganic contaminants to the Rio Grande silvery minnow (Hybognathus amarus) and fathead minnow (Pimephales promelas) in a water quality simulating that in the Rio Grande, New Mexico. Final Report to the U.S. Fish and Wildlife Service, Study Number 2F33-9620003. U.S. Geological Survey, Columbia Environmental Research Center, Yankton, South Dakota, USA.

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Werner I., L. Deanovic, D. Markiewicz, M. Stillway, N. Offer, R. Connon, S. Brander, 2008. Final Report. Pelagic Organism Decline (POD): Acute and Chronic Invertebrate and Fish Toxicity Testing in the Sacramento-San Joaquin Delta 2006-2007. UC Davis – Aquatic Toxicology Laboratory, Davis, CA.

Werner I., L. Deanovic, D. Markiewicz, M. Stillway, Joy Khamphanar, Nathan Offer, Richard Connon, Sebastian Beggel, 2008. Progress Report. Pelagic Organism Decline (POD): Acute and Chronic Invertebrate and Fish Toxicity Testing in the Sacramento-San Joaquin Delta 2008-2010. UC Davis – Aquatic Toxicology Laboratory, Davis, CA, September 10, 2008.

Werner I., L. Deanovic, M. Stillway, D. Markiewicz, 2009.The Effects of Wastewater Treatment Effluent-Associated Contaminants on Delta smelt. Draft Final Report, Central Valley Regional Water Quality Control Board, January 28, 2009.

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P4b	All	Reduction in ammonia would decrease blooms of nuisance species such as microcystis* or non-native zooplankton**	2	1
P4a	All	Reduction in ammonia would decrease blooms of nuisance species such as microcystis* or non-native zooplankton**	2	3
P3b	All	Effect of increasing diatom production on zooplankton abundance	2	2
P2b	All	Effect of increasing diatom production on zooplankton abundance	2	2
P6c	Chinook Salmon	Reduction in direct toxic effects on fish species	2	3
P3c	Chinook salmon	Effect of increasing zooplankton abundance on fish abundance	2	1
P2c	Chinook salmon	Effect of increasing zooplankton abundance on fish abundance	2	1
P1c	Chinook Salmon	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the freshwater portion of the estuary (Lower Sacramento River)	2	1
P6a	Delta smelt	Reduction in direct toxic effects on fish species	3	2
P3c	Delta smelt	Effect of increasing zooplankton abundance on fish abundance	2	2
P2c	Delta smelt	Effect of increasing zooplankton abundance on fish abundance	3	1
P1c	Delta smelt	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the freshwater portion of the estuary (Lower Sacramento River)	3	1
P1b	Delta smelt	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the freshwater portion of the estuary (Lower Sacramento River)	2	2
P3a	Delta smelt & Longfin smelt	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the brackish portion of the estuary (Suisun and Grizzly Bays)	2	2
P2a	Delta smelt & Longfin smelt	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in low-salinity portion of the estuary (confluence).	3	1

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes (contd.)				
P1c	Delta smelt & Longfin smelt	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the freshwater portion of the estuary (Lower Sacramento River)	3	1
P1a	Delta smelt & Longfin smelt	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the freshwater portion of the estuary (Lower Sacramento River)	3	1
P5a	Delta smelt, Longfin smelt, & Chinook salmon	Reduction in direct toxic effects on zooplankton species	2	3
P6d	Green & White Sturgeon	Reduction in direct toxic effects on fish species	1	3
P6b	Longfin smelt	Reduction in direct toxic effects on fish species	1	3
P3c	Longfin smelt	Effect of increasing zooplankton abundance on fish abundance	3	1
P2c	Longfin smelt	Effect of increasing zooplankton abundance on fish abundance	2	1
P1c	Longfin smelt	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the freshwater portion of the estuary (Lower Sacramento River)	2	2
P6e	Splittail	Reduction in direct toxic effects on fish species	1	3
P2c	Splittail & Sturgeon	Effect of increasing zooplankton abundance on fish abundance	1	4
P2	Splittail & Sturgeon	Effect of increasing zooplankton abundance on fish abundance	1	4
P1c	Splittail & Sturgeon	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the freshwater portion of the estuary (Lower Sacramento River)	1	4
P3c	Steelhead	Effect of increasing zooplankton abundance on fish abundance	2	1
P2c	Steelhead	Effect of increasing zooplankton abundance on fish abundance	2	1
P1c	Steelhead	Reductions in total ammonia in the Sacramento River will increase Delta smelt and longfin smelt abundance by increasing diatom production and abundance in the freshwater portion of the estuary (Lower Sacramento River)	2	1

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Negative Outcomes				
N1	All	Removal of valuable nutrients as a function of WWTP outputs	1	4
N2	All	Nitrification will reduce ammonia, but increased nitrate could result in growth of undesirable algal blooms and macrophytes	2	2
N3	All	Increased phytoplankton productivity will increase clam biomass and uptake of selenium, impairing reproduction in benthic foraging fish species	3	4

OSCM 2:
Reduce the Load of Endocrine Disrupting Compounds

Scientific Evaluation Worksheet

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Action: Reduce the Load of Endocrine Disrupting Compounds

Evaluation Team: Water Quality and Invasives Workgroup

James Haas - Chair , Bruce Herbold – Coach, Chris Foe, Charles Alpers; Inge Werner, Frances Brewster, Karen Larsen, Chrisinte Joab, David Fullerton, Holly Gellerman, Ron Smith, Jan Thompson, Lori Clammurro (note taker)

Date of Last Revision: February 19, 2009

Action Description and Clarifying Assumptions

Implement advanced treatment processes at wastewater treatment plants in the Delta to reduce the loads of endocrine disrupting compounds (EDCs) discharged into the Delta to levels that do not harm covered fish species.

Approach

Implement advanced treatment processes at the wastewater treatment plants.

Intended Outcomes as Stated in Conservation Measure

1. Increased reproductive success of covered fish species.
2. Reduced endocrine issues (transgender, reproductive, etc.) caused by endocrine disruptors in delta and longfin smelt, white and green sturgeon, salmonids (all races), and splittail.

Outcomes added by evaluation team:

3. Reduced effects of endocrine disrupting chemicals to food web organisms/invertebrates.
4. Ancillary benefits – if you're removing EDCs you're also removing other harmful chemicals (e.g. methylmercury, personal care products, ammonia, antibacterial, flame retardants, pharmaceuticals, etc.) depending on the treatment process selected. (See also OSCM1 (ammonia), OSCM3 (MeHg), OSCM4 (pesticides and herbicides), and OSCM5 (urban runoff) actions.) – *Potentially a large ancillary benefit, but is treatment specific and will be difficult to analyze impacts to species. Group suggested keeping this outcome as an important consideration, but chose not to assign scoring to it*

General Conceptual Model Support for Intended Outcomes

Werner I, Anderson S, Larsen K, and Oram J. 2008. Chemical stressors conceptual model. Sacramento (CA): Delta Regional Ecosystem Restoration Implementation Plan.

- page 6, "Effluents from municipal wastewater treatment plants are significant sources of ammonium as well as complex mixtures of contaminants that affect reproductive endocrine function (Kidd et al., 2007; Huang and Sedlak, 2001 and references therein)."
- Page 6, "Exposure of fish populations to low concentrations of such compounds can have dramatic effects. In a multi-year field study, Kidd et al (2007) showed that chronic exposure of fathead minnow to 5-6 ng/L 17alphaethynylestradiol (EE2, a synthetic estrogen used in birth-control pills) led to near extinction of this species from the experimental lake. Huang and Sedlak (2001) measured concentrations of up to 4.05 ng/L 17beta-estradiol (E2, the natural estrogen) and 2.45 ng/L EE2 in treatment plant effluent after secondary treatment/chlorination, while concentrations were mostly below 1 ng/L in effluents treated with more sophisticated methods."
- Page 22, "One of the more potent synthetic estrogens found in surface waters is 17 alpha-ethynylestradiol (EE2), a biologically persistent analogue of estradiol that is widely used in oral contraceptives, which is not completely removed by sewage treatment plants (Newman and Unger, 2003)."

Werner I, and Oram J. 2008. Pyrethroid insecticides conceptual model. Sacramento (CA): Delta Regional Ecosystem Restoration Implementation Plan.

- Page 30, "*Reproductive toxicity and endocrine disruption:* Moore and Waring (2001) demonstrated that the pyrethroid cypermethrin reduced the fertilization success in Atlantic salmon after a 5-day exposure to 0.1 ppb. In a study on bluegill sunfish, Tanner and Knuth (1996) found delayed spawning and reduced larval survival after two applications of 1 ppb esfenvalerate. Results of a study performed by Werner et al. (2002b) suggest that dietary uptake of esfenvalerate (148 ppm) may lead to a decrease in fecundity in adult medaka (*Oryzias latipes),* and a decrease in the percentage of viable larvae."
- Page 30, "Day (1989) showed that concentrations of <0.01 ppb permethrin and other pyrethroids reduced reproduction and rates of filtration of food by daphnids. A concentration of 0.05 ppb esfenvalerate led to a significant decrease in reproductive success (number of neonates) of *Daphnia carinata* (Barry et al., 1995). Reynaldi and Liess (2005) demonstrated that fenvalerate delayed the age at first reproduction in *Daphnia magna*, and reduced fecundity at a LOEC of 0.1 ppb (complete mortality occurred at 1 ppb). Population growth rate was inhibited at 0.6 ppb (24 h), and recovery occurred after 21 d. Results of chronic toxicity studies in mysid shrimp show that exposure to cypermethrin had adverse effects on reproductive parameters. For decreased number of young, a chronic NOEC value of 1.5 pptrillion (ng/L) was reported in two studies (USEPA, 2005)."

Unassigned. 2008. Semi-Final Species Life History Conceptual Model: Delta smelt (*Hypomesus transpacificus).*

- Page 25, "Endocrine-disrupting chemicals present in treated wastewater can interfere with fish maturation and reproduction (Jobling et al. 1998). A recent study in a Canadian lake showed that very low concentrations of EDCs caused rapid population failure of fathead minnow *Pimephales promelas* (Kidd et al. 2007). One of the biomarkers of EDCs is intersex fish – fish with both male and female reproductive organs. A recent histopathologic evaluation of Delta smelt for the pelagic organism decline study found 9 of 144 maturing Delta smelt (6%) collected in the fall were intersex males (Baxter et al.

2008). This is evidence that Delta smelt are being exposed to EDCs. However, there are no long-term data to compare this data point to, so its significance is unknown."

Unassigned 2007. Draft Species Life History Conceptual Model: Longfin Smelt (*Spirinchus thaleichthys).*

- Page 34, Stressor Table for San Francisco Estuary Longfin Smelt Population, EDC Importance: 3, understanding: 3, certainty of importance: 2, life stages affected: all, geographic extent: Delta and lower estuary, season: all. "Toxicity thresholds remain to be determined. Duration and magnitude of exposure remain to be determined."

Unassigned, 2008. Administrative Draft Species Life History Conceptual Model: Chinook salmon and Steelhead *Oncorhynchus tshawytscha* and *Oncorhynchus mykiss*.

- Page 81, Stressor Table for Sacramento winter-run Chinook salmon, EDC Importance: 3, understanding: 3, certainty of importance: 2-3, life stages affected: fry, juvenile, geographic extent: Throughout river systems and Delta/Suisun, season: fall and winter. "Toxicity thresholds remain to be determined. Duration and magnitude of exposure remain to be determined."
- Page 103, Stressor Table for Sacramento fall-run Chinook salmon, EDC Importance: 3, understanding: 3, certainty of importance: 2-3, life stages affected: fry, juvenile, geographic extent: Throughout river systems and Delta/Suisun, season: fall and late-spring "Toxicity thresholds remain to be determined. Duration and magnitude of exposure remain to be determined."
- Page 126, Stressor Table for Sacramento late-fall run Chinook salmon, EDC Importance: 3, understanding: 3, certainty of importance: 2-3, life stages affected: fry, juvenile, geographic extent: Throughout river systems and Delta/Suisun, season: summer-winter. "Toxicity thresholds remain to be determined. Duration and magnitude of exposure remain to be determined."
- Page 129, Stressor Table for Sacramento spring-run Chinook salmon, EDC Importance: 3, understanding: 3, certainty of importance: 2-3, life stages affected: fry, juvenile, geographic extent: Throughout river systems and Delta/Suisun, season: all. "Toxicity thresholds remain to be determined. Duration and magnitude of exposure remain to be determined."
- Page 175, Stressor Table for Central Valley Steelhead, EDC Importance: 3, understanding: 3, certainty of importance: 2, life stages affected: fry, juvenile, geographic extent: Throughout river systems and Delta/Suisun, season: all. "Toxicity thresholds remain to be determined. Duration and magnitude of exposure remain to be determined."

Unassigned. 2008. Semi-Final Species Life History Conceptual Model: Sacramento Splittail *Pogonichthys macrolepidotus)*.

+ Page 24, Table 3: Stressor Understanding Matrix. Endocrine Disruptors: Importance:3, understanding: 1, predictability: 1

Unassigned. 2008. Semi-Final Species Life History Conceptual Model: North American Green Sturgeon *Acipenser medirostris*

+ Page 22, "Intersexual changes characterized by the formation of ovaries in males have been observed in shovelnose sturgeon and have been potentially linked to endocrine-disrupting organochlorine chemicals (Harshbarger et al. 2000)."

Assumptions

Provided in BDCP Conservation Measure
Implied: wastewater treatment plants are largest sources of EDCs.

Added by Evaluation Team
Plant specific information is needed to fully assess the magnitude and certainty of this action for each plant. For the purpose of this evaluation, the reviewers assessed the potential effect if this action was targeted to the Sacramento Regional Wastewater Treatment Plant since it is the largest discharger in the Delta and information on its treatment process was available to the reviewers at the time of this review

Problem(s) with Action as Written:

1. Advanced treatment is a general term used to describe several different possible treatment processes, each of which will reduce different types and quantities of endocrine disrupting compounds from the wastewater influent. Every treatment plant has unique influent characteristics and even plants utilizing identical treatment processes can have different effluent characteristics. Plant specific information is needed to fully assess the magnitude and certainty of this action for each plant.
2. Consider including other potential sources of EDCs (other than wastewater treatment plants) as part of this action. For example, pesticides and other contaminants in urban and agricultural runoff have been shown to cause endocrine disruption in aquatic organisms.

Scale of Action:

Medium-large, depending on the number of treatment plants upgraded.

Rationale:
Reduction in endocrine disrupting chemicals would be year-round, but extent would depend on number of treatment plants requiring upgrades, extent of EDC reductions achieved with the upgrades, and relative contribution of wastewater treatment plants to the total load of EDCs in the Delta.

Evaluation Summary Tables

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

NO

Nature of Change:

Unless additional treatment increased the use of recycled water (e.g. decreased the amount of wastewater discharged to the Delta), the action would not change inflows, hydrodynamic conditions or salinity regimes.

Potential Positive Ecological Outcome(s)

Outcome P1: Increased reproductive success of covered fish species

General Observations:

+ Kidd et al. 2007 linked endocrine disruption to reproductive success in fathead minnows in a whole lake exposure.
+ Lavado et al 2009 found estrogenic activity in water from Lower Napa River, Lower Sacramento River and Carquinez Strait nr. Benicia.
+ Brander et al 2008 observed choriogenin induction in male silversides from Suisun Marsh.
+ Delta smelt species model, Page 25, "Endocrine-disrupting chemicals present in treated wastewater can interfere with fish maturation and reproduction (Jobling et al. 1998). A recent study in a Canadian lake showed that very low concentrations of EDCs caused rapid population failure of fathead minnow *Pimephales promelas* (Kidd et al. 2007). One of the biomarkers of EDCs is intersex fish – fish with both male and female reproductive organs. A recent histopathologic evaluation of Delta smelt for the pelagic organism decline study found 9 of 144 maturing Delta smelt (6%) collected in the fall were intersex males (Baxter et al. 2008). This may be evidence that Delta smelt are being exposed to EDCs. However, there are no long-term data to compare this data point to, so its significance is unknown."
+ An et al., 2008 reference numerous studies that link secondary effluents to reproductive effects in wild fish.
+ Riordan (Calfed Science Conference 2008) reported endocrine disruption in male fathead minnows following in-situ exposures below the Sacramento WTP.
+ Huang et al., 2001 measured 0.08 ng/L ethinylestradiol in Delta water samples.
+ Johnson (pers. comm.) reported vitellogenin induction in 100% of male splittail from Suisun Bay.

Goodbred, Xie, Hemming, Dwyer
NOAA review paper (2002)

Refute or fail to support

+ Martinovic et al., 2007 observed reduced reproductive success in estrogen exposed male fathead minnows, but at estrogen levels significantly higher than those typically measured in WWTP effluent or ambient samples.
+ Williams et al., 2009 report that the treatment level may not be as important to intersex fish risk as the dilution capacity of the receiving water; however, their modeling study assigned the same removal efficiencies to secondary treatment with activated sludge as to all advanced treatment processes.

Magnitude = 2

+ Exposure to estrogen levels similar to those found downstream of wastewater treatment plants caused a population level collapse in fathead minnows (Kidd et al., 2007).
+ Data on EDC concentrations in Delta waterways are limited; however, Kolpin et al. (2002) detected organic wastewater contaminants in 80% of streams sampled in 30 states. 75% of streams had multiple detections with a median of 7 and maximum of 38

contaminants per sample. Cholesterol and 3 detergent metabolites accounted for more than 60% of the higher concentrations detected.

+ Several studies link endocrine disrupting chemical exposure to spawning competency in fathead minnows in laboratory exposures, but it is unclear whether those effects would translate to impacts on species reproductive success in the wild (Bistodeau et al., 2006)
+ deVlaming et al., 2007 state that population level effects of increased liver vitellogenin mRNA in juvenile rainbow trout is largely unknown.

Certainty = 2

+ Analysis of effluent from secondary treatment plants has detected concentrations of estrogenic hormones at levels that can cause vitellogenesis in fish (Huang et al., 2001). Huang et al (2001) also found that the concentration of estrogenic hormones in wastewater treatment effluent was generally related to the sophistication of the treatment system; biological nutrient removal, sand filtration, microfiltration, reverse osmosis and engineered wetlands all reduced estrogen levels more than secondary treatment alone. Servos et al. (2005), and numerous references, within report similar findings.
+ Numerous studies report endocrine disrupting compounds in surface waters (Batt et al., 2008; deVlaming et al., 2007; Dussault et al., 2008; Kolpin et al., 2002).
+ The literature is full of studies from outside the system that observe endocrine effects in fish downstream of treatment plant discharges (An et al., 2008; Douxfils et al., 2007; Williams et al., 2009; Matthiessen 2003), four are Delta specific (Riordan et al 2008, Brander et al 2008, Johnson pers. comm., and Lavado et al 2009).
+ Barber et al., 2007 report that reproductive response of male fathead minnows to wastewater treatment plant effluent indicates both beneficial and detrimental effects.

Summary Conclusions

Outcome P1:			
Ratings:	**Magnitude = 2**	**Certainty = 2**	
Explanation:	Magnitude score is influenced by the large geographic and temporal extent of potential positive outcomes. There is some information available for Delta smelt, splittail, and salmon (data from upstream areas); not as much information available for green or white sturgeon. This outcome is focused on reproductive success in terms of population-level effects. There is not as much literature for reproductive effects as there is for other endocrine-disrupting effects. The level of concern over intersex individuals, coupled with the large geographic extent, factored into the magnitude score. There is relatively high certainty that WWTP effluent is a major source of endocrine disruption in fish where endocrine disruption is observed. There is also relatively high certainty that advanced treatment processes more efficiently remove many EDCs than does secondary treatment alone. However, there is limited data on how extensive endocrine disruption is in wild fish populations, limited observations of actual effects within the Delta, and limited studies that link observed endocrine effects to population level impacts		

Outcome P2: Reduced endocrine issues (transgender, reproductive, etc.) caused by endocrine disruptors in delta and longfin smelt, white and green sturgeon, salmonids (all races), and splittail

General Observations:
[See P1, above]
+ An et al., 2008, vitellogenin induction increased with exposure time.
+ Matthiessen 2003 states that the adrenal system is vital to stress response, thyroid hormones influence neural development, metabolism, osmoregulation and smoltification. He cites a study that found intersex Chinook salmon on the Columbia River.
+ Ward et al., 2008 reported that exposure to 1.0 ug/L of 4-nonylphenol for only 1-hour disrupted the shoaling behavior of juvenile killifish. The response was restored after exposure ended. Ward also cites studies that detected 4-nonylphenol at concentrations from 0.5-343 ug/L near sewage outfalls.
+ Werner et al 2008, and references therein, report that pyrethroids were shown to have steroid receptor-binding activity *in vitro* (*14*). Their effects on the endocrine system are not uniform. While Fenpropathrin and permethrin act as weak estrogen agonists, allethrin and cypermethrin have antiestrogenic as well as antiandrogenic activity. Cyfluthrin and fenvalerate showed very weak antiestrogenic activity, but several metabolites and products of environmental degradation of permethrin and cypermethrin had up to more than 100-fold greater potencies than the parent compound (*13, 14, 44*). In mammals, pyrethroids affect sperm concentration, motility and morphology (*10*).

  In fish, Moore and Waring (*35*) demonstrated that the pyrethroid cypermethrin reduced the fertilization success in Atlantic salmon after a 5-day exposure to concentrations of 0.1 µg/L. In a study on bluegill sunfish, Tanner and Knuth (*45*) found delayed spawning and reduced larval survival after two applications of 1 µg/L esfenvalerate.

+ Webb et al. (2006) reported reduced concentrations of plasma androgens associated with muscle mercury concentrations > 0.187 ppm (wet weight) in Columbia River white sturgeon. This concentration is within the range discussed for this species in the delta (See OSCM3).

Refute or fail to support DLO
+ deVlaming et al., 2007 collected 113 ambient water samples from 66 sites in California, 26 of which represented some WWTP effluent contribution. Only 6 samples caused significant, though weak, endocrine response in juvenile trout and only 1 of those represented WWTP effluent. However, these fish were only exposed for 4-days.

Magnitude = 2-3
+ Bennett et al., 2008 report 6% of pre-adult Delta smelt analyzed in 2005 had ovatestis.
+ Johnson (pers. comm.) observed vitellogenin induction in 100% of male splittail from Suisun Bay.
+ Population level effects of transgender fish are not well understood.

+ The literature is full of studies that observe endocrine effects in fish downstream of treatment plant discharges.

Certainty = 3

The literature is full of studies (from outside of the system) that observe endocrine effects in fish downstream of treatment plant discharges.

Geographically, covers the same area as under Outcome P1; also, impacts limited to small fraction of the population (so question that there's a population-level effect)

Summary Conclusions

Outcome P2:			
Ratings:	**Magnitude = 2-3**	**Certainty = 3**	
Explanation:	Magnitude score is slightly more than in P1. P2 encompasses all endocrine effects, regardless of reproductive success [P1]. It looks at biomarker-type responses that may not have population-level or reproductive success issues; evidence suggests these are widespread, but it is unclear whether there is a population-level effect. Potential impacts are greater (than in P1) because more than reproductive success is being considered		

Outcome P3: Reduce effects of endocrine disrupting compounds to food web organisms/invertebrates

General Observations:

+ Oetken et al. (2004) reviewed the evidence for endocrine disruption in invertebrates. Some mollusk species were highly sensitive to the tributyl tin at extremely low concentrations (ng/L). In addition, TBT and insect growth regulators had effects on crustacean species at concentrations in the low ug/L in laboratory exposures. Whether these laboratory exposure conditions are met in the delta is unknown.
+ Canesi et al., 2007, reported effects of synthetic estrogen on muscle digestive gland.
+ Dussault et al., 2008 measured response in midge and amphipod and calculated hazard quotients based on exposure values from the literature for 4 compounds. They conclude that there is a potential risk to benthic invertebrates exposed to triclosan and carbamazepine, but not for atorvastatin or ethinylestradiol.
+ Adams et al., 2008 report that secondary treated wastewater effluent was not acutely toxic but did cause chronic toxicity to microalgae, macroalgae and scallop larval development. However, there was no evidence presented that the observed chronic effects were from endocrine disrupting compounds within the waste stream.
+ Werner et al 2008 cite numerous studies: Day (*46*) showed that concentrations of <0.01 µg/L permethrin and other pyrethroids reduced reproduction and rates of filtration of food by daphnids. A concentration of 0.05 µg/L esfenvalerate also led to a significant decrease in reproductive success (number of neonates) of *Daphnia carinata* (*47*). Reynaldi and Liess (*48*) demonstrated that fenvalerate delayed the age at first reproduction in *Daphnia magna*, and reduced fecundity at a LOEC (lowest observed effect concentration) of 0.1 µg/L (complete mortality occurred at 1 µg/L). Population growth rate was inhibited at 0.6 µg/L (24 h), and recovery occurred after

21 d. Results of chronic toxicity studies in mysid shrimp show that exposure to cypermethrin had adverse effects on reproductive parameters: For a decrease in the number of young, a chronic NOEC value of 1.5 ng/L was reported in two studies (*39*).

Refute or fail to support

+ Kidd et al., 2007 did not find major changes in the lower trophic levels and the food web following whole lake exposure to a synthetic estrogen at concentrations found downstream of WWTPs.

Magnitude = 2

+ Invertebrates are generally resilient to intermittent exposure to low concentrations of pesticides; amphipods (Hyallela azteca) showed the greatest sensitivity in mesocosm studies. Most species tested showed no effect or quick recovery following exposure to cypermethrin and/or esfenvalerate (Giddings et al. 2001). Oetken etal. (2004) noted: "With the exception of TBT effects on mollusks, which have been associated with a locally severe impact on community levels, and IGRs in terrestrial insects, there are only a few field examples of endocrine disruption in invertebrates."
+ Results of chronic toxicity studies in mysid shrimp show that exposure to cypermethrin had adverse effects on reproductive parameters: For a decrease in the number of young, a chronic NOEC value of 1.5 ng/L was reported in two studies (*Werner and Moran, 2008*).
+ Since hormones regulate the main events in the crustacean life cycle, chemicals that interfere with their biosynthetic and/or biotransformation pathways would consequently have impact on individual and population growth. Regardless of this, the understanding of basic crustacean endocrine systems and pathways is scarce and may vary considerably (Dahl et al 2008).

Certainty = 1

+ Dussault et al., 2008 state that considerable uncertainty exists regarding potential impacts to benthic invertebrates of chronic exposure to mixtures of biologically active contaminants

Summary Conclusions

Outcome P3a:			
Ratings:	**Magnitude = 2**	**Certainty = 1**	
Explanation:	Magnitude score is influenced by the large geographic and temporal extent of potential positive outcomes. There is some information available on effects on invertebrates outside the system, but limited data within the system. There is not as much literature for effects on invertebrates as there is for effects on fish.		

Outcome P4: Ancillary benefits – if you're removing EDCs you're also removing other harmful chemicals (e.g. methylmercury, personal care products, ammonia, antibacterial, pharmaceuticals, pesticides)

Because these "ancillary benefits" incorporate analyses under other water quality conservation measures (OSCMs1, 3, 4 and 5), the group opted not to assign a score for this outcome, but rather to refer the reader to those other worksheets.

Potential Negative Ecological Outcome(s)

The group did not identify any potential negative ecological outcomes for this action.

Important Gaps in Information and/or Understanding

Data Needs

There is limited data on the presence and concentrations of EDCs in Delta waterways and in Delta wastewater treatment plant effluent. It is unknown whether EDCs occur in the Delta at levels that pose concerns for covered species. And, it if they do occur at levels of concern, the relative contribution from each source is unknown.

- Bruce Herbold provided references for two studies showing intersex in Central Valley salmon (Sacramento River).

USFWS is finding EDCs in increasing levels and numbers of fish in the Delta, but there is not much information on population-level consequences of any of the endocrine disruptions in this estuary (our knowledge of levels of compounds isn't sufficient in this estuary), but see Kidd et al 2007.

Research Needs

There is a need to learn more about endocrine disrupting effects (other than estrogenic) in the covered species, such as androgenic and thyroid effects. Much more is currently known about estrogenic effects than other endocrine disrupting effects.

Information is needed on the linkages of monitoring endpoints such as vitellogenin or alteration of thyroid function and higher level effects such as reproductive success and ecological fitness in covered species or appropriate surrogate species.

EDC monitoring based on biological responses is needed to identify hotspots and sources as well as temporal and special distribution of EDCs.

Finally, there is acknowledgement that when EDCs are detected, it is very difficult to determine where they came from. It is expected that wastewater treatment plants contribute to the problem, but EDCs can also come from pyrethroids and other agricultural runoff, particularly dairies, which represent large potential untreated loadings. There is therefore a need to determine the relative contributions of wastewater treatment plants to other potential EDC sources such as hatcheries, pesticide sources, and dairies. However, while reducing wastewater treatment plant loads may not fix the problem in and of itself, addressing even small amounts of EDCs could be helpful because species effects occur at such low concentrations (low ng/L).

Research should be conducted to determine whether temperature is a confounding factor for EDC effects in salmonids in the Delta. Temperature affects the potential for intersex effects in salmonids (separate from contaminant effects), as documented in studies from outside of the system.

Assess Reversibility and Opportunity for Learning

Reversibility

NO – hard.

> ***Comments:*** Implementing advanced treatment at wastewater treatment plants to remove EDCs would be very costly, and is irreversible

Opportunity for Learning

Medium.

> **Comments**: It is difficult to observe cause and effect relationships in wild fish populations, especially for sublethal and chronic effects such as those likely to be caused by EDCs

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Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P4	All	Ancillary benefits – if you're removing EDCs you're also removing other harmful chemicals (e.g. methylmercury, personal care products, ammonia, antibacterial, pharmaceuticals, pesticides)	NA	NA
P3	All	Reduce effects of endocrine disrupting compounds to food web organisms/invertebrates	2	1
P2	All	Reduced endocrine issues (transgender, reproductive, etc.) caused by endocrine disruptors in delta and longfin smelt, white and green sturgeon, salmonids (all races), and splittail.	2-3	3
P1	All	Increased reproductive success of covered fish species	2	2

OSCM 3: Reduce the Load of Methylmercury

Scientific Evaluation Worksheet

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Action: Reduce the Load of Methylmercury

Evaluation Team: Water Quality & Invasives Workgroup

James Haas - Chair , Bruce Herbold – Coach, Chris Foe, Charles Alpers; Inge Werner, , Frances Brewster, Karen Larsen, Chrisinte Joab, David Fullerton, Holly Gellerman, Ron Smith, Jan Thompson, Lori Clammurro (note taker)

Date of Last Revision: February 17, 2009

Action Description and Clarifying Assumptions

Implement measures to reduce the load of methylmercury entering the Delta from upstream and in-Delta sources by 50 percent.

Approach

1. Modify the Cache Creek settling basin to improve mercury and sediment trapping efficiency.
2. Remediate mercury sources upstream of the Delta, including mercury-contaminated sediment hot spots in stream channels and mercury and gold mines.
3. Avoid or minimize methylation and transport of mercury in floodplain and intertidal marsh habitats that are restored through BDCP actions.
4. Work with the CVRWQCB to identify best management practices for other sources of methylmercury.

Intended Outcomes as Stated in Conservation Measure

1. Reduced direct mortality due to consumption of mercury by splittail, Delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon.
2. Reduced sublethal effects (genetic, tissue/organ damage, development, reproductive, growth, and immune) of mercury on splittail, Delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon.
3. *(Added by the group): Reduced toxic concentrations of methyl mercury in forage and sportfish to protect wildlife and humans from chronic sublethal toxicity.*

General Conceptual Model Support for Intended Outcomes

1. No information available for the covered fish species within this system. Mercury concentrations in covered fish species are assumed from concentrations documented to produce mortality in other fish species.
2. Little or no information available for the covered fish species within this system. Mercury concentrations in covered fish species are assumed from concentrations documented to produce sub-lethal effects in other fish species. Some decreases in feeding efficiency and some hormonal responses are possible in the most contaminated individuals (*need a citation here?*).

3. *OEHHA fish consumption advisories for humans; potential effects on birds as documented by Ackerman et al. 2008, and Burgess and Meyer 2008.*

Assumptions

Added by Evaluation Team

1. The action has several underlying assumptions. First, that the inorganic mercury content of sediment is an important factor in creation of methyl mercury by sulfate reducing bacteria. This assumption is supported by submodel #1 of the mercury conceptual model and by positive correlations between inorganic and methyl mercury concentrations in sediment in the Delta (Heim et al. 2007), by amendment of increasing concentrations of inorganic mercury to intact sediment cores in the laboratory and the measurement of increasing concentrations of methyl mercury in the overlying water column (Rudd et al., 1983; Bloom et al., 2003) and, finally, by about 10 papers in the peer reviewed literature where decreases in methyl mercury concentrations in fish were observed after the load of incoming inorganic mercury was reduced (reviewed in Wood et al., 2008).
2. The second assumption of the action is that methyl mercury production is not the same in all habitats. Seasonally flooded habitats like some wetlands, most floodplains and newly created reservoirs are disproportionately important methylation sites. These sites must also have hydrologic connectivity to the Delta. This assumption is supported by submodel # 1 of the mercury model (Alpers et al., 2008, pages 15 and 16) and work by Foe et al., 2008; Slotton et al. 2007.
3. The third critical assumption is that methyl mercury bioaccumulation is a food web dietary process. Methyl mercury concentrations in water (attached to phytoplankton) determine biomagnification further up the food chain including concentrations in sport and forage fish. This assumption is supported by submodel #2 (Alpers et al., 2008, pages 17 and 19) and by positive correlations between unfiltered methyl mercury concentrations in water and in standard sized largemouth bass in the Delta (Wood et al. 2008).

Problem(s) with Action as Written:

1. Methyl mercury production, transport, fate and bioaccumulation are not completely understood. There are likely to be other important factors controlling fish tissue concentrations that have not yet been identified. For example, longer water residence times in the Delta appear to be associated with lower aquatic methyl mercury levels, which may be related to photodegradation of methyl mercury (Foe et al. 2008). Therefore, changes in hydrology from operation of a peripheral canal or a dual conveyance system may produce unexpected changes in baseline conditions.
2. The action of a 50% reduction in methyl mercury is arbitrary. There is a gradient in both methyl mercury concentrations in water and fish across the Delta. Highest levels are in rivers and in areas of Delta immediately downstream of rivers and lower levels are at water export sites (State and Federal pumping facilities at Tracy and at Chipps Island, the main channel to Suisun and San Francisco Bay). Some areas of Delta may need more methyl mercury reduction than others.

3. A program of reducing methyl mercury by a defined amount requires an accurate assessment of baseline conditions. At present there are only 4 years of water and fish tissue data for the Delta. It is unknown whether the present limited data set has captured all the natural variability in baseline concentrations.

4. The fourth approach listed is to "*Work with the CVRWQCB to identify best management practices*…" is problematical. First, it is unclear whether best management approaches can be identified that will be successful. Of course, we will not know unless we try. Second, identifying best management practices without a way to implement them will never reduce methyl mercury. Recommend that the approach be modified to say, "*identify and implement most promising best management practices*…"

Scale of Action:

Large

Rationale:
This action is of a large spatial and temporal scale. Spatially the action is likely to have impacts across much of the Delta and into Suisun and Grizzly Bays. Temporally, reductions in total mercury loads into the Delta are also likely to have measurable impacts for decades and possibly even centuries to come.

Evaluation Summary Tables

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?
NO

Nature of Change: Insert short sentence here.
If successful the action is likely to reduce methyl mercury levels in water and fish but should not produce any fundamental changes to other key physical or biotic properties of the Delta.

Potential Positive Ecological Outcome(s)

Outcome P1: Reduced direct mortality due to consumption of mercury by splittail, Delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon.

P1. *All covered fish species*

No toxicological studies have been conducted with any of the target species. So, mercury concentrations in target fish are compared here against concentrations documented to produce mortality in other fish species. For toxicological comparison, death in rainbow trout in laboratory studies occurred at 4-ppm wet weight and the NOAEC for death in Brook trout was 2.7 ppm (in Wiener and Spry, 1996). Conclusion, about a 10X safety factor exists between tissue concentrations in the target fish species in Delta and values reported in the literature to cause mortality.

There was a question of whether this outcome should be separated into short- vs. longer-lived fish species, grouped by the data information and assumed value assignments (for similar fish taxa). It was agreed that fundamentally MeHg is not a fish problem; it's more of a problem for humans and birds – thus, separating the covered fish into short- vs. longer-lived fish for analysis would not add any value to this evaluation, and would not change the magnitude or certainty scores.

For these reasons, the magnitude and certainty scores are the same for all of the covered fish species.

Fall-run Chinook salmon: Mercury concentrations (ppm-wet weight) for Chinook salmon are 0.094-0.396 (Davis et al., 2002; SFEI, 2006).

Steelhead: Mercury concentrations (ppm-wet weight) for steelhead are .05 -.3 (Davis et al., 2002; SFEI, 2006).

Splittail: No information available.

White Sturgeon: Mercury concentrations (ppm-wet weight) for white sturgeon are 0.165 - .279 (Davis et al., 2002; SFEI, 2006).

Green Sturgeon: Green sturgeon is assumed to have a similar tissue concentration as white sturgeon. Mercury concentrations (ppm-wet weight) for white sturgeon are 0.165 - .279 (Davis et al., 2002; SFEI, 2006).

Delta smelt: No tissue data for Delta smelt was found. Assume Delta smelt will have similar tissue concentrations as other fish taxa living one year and feeding primarily on zooplankton. Mercury concentrations in juvenile threadfin shad and juvenile largemouth bass in Delta are assumed to have similar mercury burdens as Delta smelt and are 0.012-0.076 and 0.035-0.230, respectively (Slotton et al., 2006).

Longfin smelt: No tissue data for longfin smelt was found. Assume longfin smelt will have similar tissue concentrations as other fish taxa living one year and feeding primarily on zooplankton. Mercury concentrations in juvenile threadfin shad and juvenile largemouth bass in Delta are assumed to have similar mercury burdens as longfin smelt and are 0.012-0.076 and 0.035-0.230, respectively (Slotton et al., 2006).

Magnitude = 1

Few toxicological studies have been conducted with any of the target species, with the exception of rainbow trout. So, mercury concentrations in target fish are compared here against concentrations documented to produce mortality in other fish species. Mercury concentrations (ppm-wet weight) for white sturgeon, Chinook salmon and steelhead are 0.165-0.279, 0.094-0.396 and 0.05-0.3, respectively (Davis et al., 2002; SFEI, 2006). Bennett et al. (2001) reported Hg concentrations in Delta smelt ranging from 0.10-0.23 ppm (wet weight) No tissue data for either longfin or green sturgeon were found. Assume longfin smelt will have similar tissue concentrations as other fish taxa living one year and feeding primarily on zooplankton. Mercury concentrations in juvenile threadfin shad and juvenile largemouth bass in Delta are assumed to have similar mercury burdens as longfin smelt and are 0.012-0.076 and 0.035-0.230, respectively (Slotton et al., 2006). Green sturgeon is assumed to have a similar tissue concentration as white sturgeon.

For toxicological comparison, death in rainbow trout in laboratory studies occurred at 4-ppm wet weight and the NOAEC for death in Brook trout was 2.7 ppm (in Wiener and Spry, 1996). Conclusion, about a 10X safety factor exists between tissue concentrations in the target fish species in Delta and values reported in the literature to cause mortality.

Certainty = 2

Limited tissue data available for some species and none for others but an apparent large safety factor seems to exist been predicted fish tissue concentrations in Delta and values reported to be acutely toxic in the peer reviewed literature.

Summary Conclusions

Outcome P1:			
Ratings:	**Magnitude = 1**	**Certainty = 2**	
Explanation:	Limited tissue data available for some species and none for others, but an apparent 10x safety factor seems to exist been predicted fish tissue concentrations in the Delta and values reported to be acutely toxic in the peer reviewed literature.		

Outcome P2: Reduced sublethal effects (genetic, tissue/organ damage, development, reproductive, growth, and immune) of mercury on splittail, Delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon.

Few relevant toxicological studies have been conducted with any of the target species. So, mercury concentrations in target fish are compared here against concentrations documented to produce sublethal effects in other fish species. See Outcome P1 above for mercury tissue concentration ranges.

Magnitude = 2

Again, few relevant toxicological studies have been conducted with any of the target species. Therefore, have compared reported tissue concentration for individual species against documented sublethal effects in other fish taxa. See Outcome P1 above for mercury tissue concentration ranges. An exception is white sturgeon. Webb et al. (2006) reported reduced concentrations of plasma androgens associated with muscle mercury concentrations > 0.187 ppm (wet weight) in Columbia River white sturgeon. This concentration is within the range discussed for this species in the Delta. Decreased feeding efficiency and some hormones response changes were observed at 0.25-0.27 ppm wet weight (page 30 of mercury model). Decreases in spawning success and increases in time to first spawn occurred in fathead minnows at 1.96-4.26 ppm (Hammerschmidt et al., 2002) and decreases in tissue growth in juvenile male walleye at 2.4 ppm (Friedmann et al., 1996). In conclusion, some up/down regulation of genes and alterations in feeding behavior are possible in the most contaminated individuals in Delta but questionable whether these changes could have measurable population level effects.

Certainty = 2

Limited toxicological data available in literature for many important sublethal processes and none of this research has been collected on any of the species of interest. Moreover, there is only a very limited tissue data set for most of target species making it impossible to determine the proportion of population potentially at risk.

Summary Conclusions

Outcome P2:			
Ratings:	**Magnitude = 2**	**Certainty = 2**	
Explanation:	Some up/down regulation of genes and alterations in feeding behavior are possible in the most contaminated individuals in the Delta, but it is questionable whether these changes could have measurable population level effects. There is limited toxicological data available in literature for many important sublethal processes. Although a number of papers use rainbow trout as the test organism in laboratory exposures to evaluate chronic endpoints (e.g. see: Wobeser 1975; Rogers and Beamish 1982; Niimi and Kissoon 1994), little of this research has been collected on any of the other covered fish species. Moreover, there is only a very limited tissue data set for most of the species making it impossible to determine the proportion of population potentially at risk.		

Outcome P3: Reduce toxic concentrations of methyl mercury in forage and sportfish to protect wildlife and humans from chronic sublethal toxicity

Fundamentally, a high concentration of methyl mercury in fish tissue is not a problem for the fish itself; it's a problem for the humans and birds that eat them. Because these analyses are being conducted primarily for the covered fish species, this particular outcome is an important "other" consideration for decision makers, which must be weighed against the evaluation of impacts to the covered fish species (outcomes P1 and P2).

Magnitude = 3
Fish consumption advisories for the Delta recommend that children under the age of 17 and women of child bearing age consume no largemouth or smallmouth bass, spotted bass or Sacramento pikeminnow , others should limit their consumption of these species to one meal a month (OEHHA, 2006, 2008a,b). Between 10,000 and 20,000 fishermen in the Delta are presently eating fish at more than 10X the recommended methylmercury RfD and should, therefore, experience some sublethal mercury poisoning (personal communication, Dr Fraser Shilling).

A significant portion (>50%) of Forster's terns breeding in S Francisco Bay are at risk of reproductive impairment from consuming fish with elevated mercury levels (Ackerman *et al*., 2008). No Forster's terns nest in Delta, however, mercury levels in small fish consumed by Terns are higher in parts of the Delta, such as the Yolo Bypass, than in S. Francisco Bay suggesting that other bird species feeding in a similar ecological niche as Forster's terns may be at risk in the Delta.

Burgess and Meyer (2008) estimate that the production of young common loons (*Gavia immer*) is reduced by 50% if methylmercury concentrations in prey fish are 0.210-ppm wet weight. Again, I do not think that loons nest in the Delta but methyl mercury levels may be at levels posing risks to other fish eating birds.

Certainty = 3
Need human epidemiological studies in Delta to refine estimate of number of people consuming methylmercury above the RfD, determine whether actual poisons can be documented, and the severity of the incidents. Similarly, need more toxicological research in the Delta on impacts to obligate fish eating avian species.

Summary Conclusions

Outcome P3:			
Ratings:	**Magnitude = 3**	**Certainty = 3**	**Worth = H**
Explanation:	Fish consumption advisories for the Delta recommend that children under the age of 17 and women of child bearing age consume no largemouth or smallmouth bass, spotted bass or Sacramento pikeminnow, others should limit their consumption of these species to one meal a month (OEHHA, 2006, 2008a,b). Between 10,000 and		

	20,000 fishermen in the Delta are presently eating fish at more than 10X the recommended methylmercury RfD and should, therefore, experience some sublethal mercury poisoning (personal communication, Dr Fraser Shilling). A significant portion (>50%) of Forster's terns breeding in S Francisco Bay are at risk of reproductive impairment from consuming fish with elevated mercury levels (Ackerman *et al*., 2008). Mercury levels in small fish consumed by terns are higher in parts of the Delta, such as the Yolo Bypass, than in S. Francisco Bay, suggesting that other bird species feeding in a similar ecological niche as Forster's terns may be at risk in the Delta. Burgess and Meyer (2008) estimate that the production of young common loons (*Gavia immer*) is reduced by 50% if methylmercury concentrations in prey fish are 0.210-ppm wet weight. Methyl mercury levels in Delta fish may be at levels that pose risks to similar fish-eating birds.

Potential Negative Ecological Outcome(s)

The group did not identify any potential negative ecological outcomes for this action.

Important Gaps in Information and/or Understanding

Data Needs

Need to collect data on splittail, to determine whether there are possible sublethal effects (e.g. feeding efficiency, growth, or spawning success)

Research Needs

Need continued monitoring of methyl mercury concentrations in water and fish as more seasonal wetland are created in the Yolo Bypass and elsewhere and the hydrology of the Delta is changed with construction of a peripheral canal or dual conveyance system.

Need a numerical methyl mercury transport and fate model with a food web component. The model should combine source information, water transport and residence times, photodemethylation and particle settling to predict methyl mercury concentrations in water, sediment, and biota at various locations in the Delta under different hydrologic conditions.

Need species-specific studies on sublethal population-level effects of methylmercury in target fish species.

Need better estimates of the number of people at risk for mercury toxicity, the range of likely impairments and how to educate them to reduce the risk

Assess Reversibility and Opportunity for Learning

Reversibility

No/Hard.

> ***Comments:*** It depends on the specific approach. For example, if one approach to this action is to modify Cache Creek Settling Basin, this is a very costly action that cannot be reversed once it is completed. If the approach is to identify and implement BMPs in cooperation with the State & Regional Water Quality Control Board programs, funding for implementation of said BMPs could stop if it is determined that it is not effectively addressing the problem.

Opportunity for Learning

High.

Comments (refer to specific sources of information that support the above determination and identify high priority research questions and testable hypotheses).
Continued monitoring of methylmercury concentrations in water and fish will enable a better understanding of methylmercury in the system, and its impacts on the biota, as more seasonal wetlands are created and the Delta's hydrology changes with a new conveyance system.

A numerical methylmercury transport and fate model, with a food web component, may help predict methylmercury concentrations in water, sediment, and biota at various locations in the Delta under different hydrologic conditions.

More species-specific studies on sublethal and population-level effects of methylmercury are necessary to conclusively determine whether covered fish species are or are not experiencing sub-lethal effects.

Better estimates of the number of people at risk for mercury toxicity, and the range of likely impairments, can help educate at-risk populations as well as decision makers.

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Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P1	All	Reduced direct mortality due to consumption of mercury by splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon.	1	2
P2	All	Reduced sublethal effects (genetic, tissue/organ damage, development, reproductive, growth, and immune) of mercury on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon.	2	2
P3	Humans & birds	(Added) Reduce toxic concentrations of methyl mercury in forage and sportfish to protect wildlife and humans from chronic sublethal toxicity.	3	3

OSCM 4:
Reduce the Load of Pesticides and Herbicides

Scientific Evaluation Worksheet

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Action: Reduce the Load of Pesticides and Herbicides

Evaluation Team: Water Quality & Invasives Workgroup

James Haas - Chair , Bruce Herbold – Coach, Chris Foe, Charles Alpers; Inge Werner, Frances Brewster, Karen Larsen, Chrisinte Joab, David Fullerton, Holly Gellerman, Ron Smith, Jan Thompson, Lori Clammurro (note taker)

Date of Last Revision: February 19, 2009

Action Description and Clarifying Assumptions

Implement measures to reduce loads of pesticides and herbicides entering Delta waterways to levels that are not toxic to covered fish species

Approach

1. Support efforts by the CVRWQCB under its Irrigated Lands Regulatory Program to reduce inputs of toxics from agricultural return flows into the Delta and tributaries to levels at which they are not toxic to covered fish species.
2. Work with farmers, reclamation districts, and irrigation/drainage districts to develop voluntary agricultural chemical management plans to reduce the amounts of pesticides and herbicides reaching Delta waterways. Plans could include funding conservation easements, cost-sharing programs, and working with farmers and irrigation districts to:
    - Change pesticides and herbicides used to compounds less toxic to aquatic species and provide education on proper use;
    - Reduce amounts of pesticides and herbicides used through more direct application methods or implementation of integrated pest management techniques;
    - Reduce concentrations of pesticides and herbicides in return flows to Delta waterways through specific management practices;
    - Reduce return flows from agricultural fields to the Delta by using water-efficient technologies (e.g., drip irrigation); and
    - Reduce wind drift of pesticides and herbicides into Delta waterways

Intended Outcomes as Stated in Conservation Measure

1. Reduced direct mortality of splittail, Delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides
2. Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, Delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races).
3. Increased food abundance for splittail, Delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from reduced food web disruption.

General Conceptual Model Support for Intended Outcomes

1. Both the Chemical Stressors and the Pyrethroids DRERIP models indicate that contaminants may exert acutely toxic effects leading to mortality in individuals (p. 20 and p. 19, respectively).
2. Both the Chemical Stressors and the Pyrethroids DRERIP models indicate that contaminants may exert sublethal effects, with potential consequences for fitness, reproductive success, and survival of individuals (p. 20 and p. 19, respectively).
3. Both the Chemical Stressors and the Pyrethroids DRERIP models indicate that contaminants may exert effects on food web structure and dynamics; food web organisms are highly susceptible to pyrethroids in particular (p. 24 and p. 30, respectively).

Assumptions

Added by Evaluation Team

1. Safe levels for sensitive invertebrates can be generally assumed to be safe for the covered fish species with respect to acute toxicity.
2. Species for which larval stages occur outside the Delta towards the ocean are at less risk of pesticide exposure due to in-Delta sources.
3. Larvae and young juveniles are at greater risk than older juveniles or adult fish.
4. Pesticides of greatest concern do not biomagnify in the foodweb;
5. Effects of aquatic vegetation control are addressed in the evaluation of OSCM 13.

Problem(s) with Action as Written:

1. Need to include indirect effects (e.g. effects on food web organisms). Indirect effects via food organisms might have severe effects on covered species. Food limitation can lead to reduced survival and fitness at all life stages in their life-cycle.
2. BMPs are still under development, and their efficacy is not always known. Uncertainties and their resolution should be addressed.
3. The action should also incorporate programs to control submerged aquatic macrophytes.
4. *Very little information exists on exposure levels and impacts to most covered fish species.*
5. *The analysis needs to be site- and season-specific looking at existing data of what pesticides are being used where, and what covered species are present in these areas, would reduce uncertainty in real-world application.*

Scale of Action:

Large

Rationale:
This action is of a large spatial and temporal scale since much of the land use in the Delta and surrounding areas is agricultural. Spatially, the action is therefore likely to have impacts across much of the Delta and into Suisun and Grizzly Bays. Temporally, reductions in pesticide loads into the Delta are likely to have measurable impacts for decades and beyond.

Evaluation Summary Tables

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

NO

Nature of Change:
If successful, the action will reduce pesticide levels in water. This will likely affect the phytoplankton and aquatic animal community composition; however food web dynamics should not change in a significant way. It is currently not known if macrophyte abundance and distribution would be affected. The action should not produce any fundamental changes to other key physical or biotic properties of the Delta.

.

Potential Positive Ecological Outcome(s)

Outcome P1: Reduced direct mortality of splittail, Delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides

P1a. Delta Smelt

General Observations

General Contaminants Model Page11, "early life stages of many Delta fish species are in the system during late winter and spring, a time when stormwater runoff from agricultural and urban areas can transport contaminants such as dormant spray pesticides and PAHs/metals into the Delta" and "Such early life stages are generally far more sensitive to contaminants than adults."

Pyrethroids Model Pages 3-4, Pages 6-7, Sediments in general are considered to be a "sink" for pyrethroids due to their hydrophobic properties, and the presence of aquatic macrophytes, phytoplankton and detritus can lead to adsorption of pyrethroids to plant surfaces. However, pyrethroids may remain in solution for hours to days before they sequester to suspended particles.
Page 17, chemical mixtures may pose a much bigger threat than individual compounds
Page 18, pyrethroids may be acting synergistically with pathogens to compromise survivorship of fish populations through immunologic or physiologic disruption.
P. 19-25, fish highly susceptible to pyrethroids.

Delta Smelt species Model, page 23

Other References:
Laetz et al. 2008
Kuivila et al. 2004, demonstrates overlap of rice pesticides with presence of Delta smelt larvae.
Fox and Archibald, 1997

Also data from Irrigated Lands Program (CVRWQCB), SWAMP, Sacramento Watershed Program.

Magnitude = 3.

The occurrence of relatively high concentrations of insecticides and herbicides in the Delta has been documented since the 1990s and earlier. In addition, metals such as copper are widely used as pesticides, and have been applied directly to Delta waters in the past (and possibly present). The potential positive outcome of this action is likely to affect a large area, and could have a sustained positive effect on larval survival of covered fish.

Certainty = 3

There is little toxicological information for Delta smelt; however, existing data indicates that Delta smelt are more sensitive to some chemical pollutants than standard toxicity test species such as fathead minnows.

No direct evidence exists for acute effects of pesticides in the Delta such as “fish kills” after approximately 1988 (Fox and Archibald, 1997). This could be due to the fact that it is difficult to detect dead fish unless there is a massive die off in areas where people regularly go. Similarly, it is unlikely that mortality of larval stages could be detected and quantified, so we simply don’t know if this is occurring.

Single chemical effect thresholds and available data on pesticides in the system suggest that direct lethal effects on covered fish species are relatively unlikely, but this is only true when individual chemicals are considered. The effects of chemical mixtures, which have been shown to be present in the Delta, are likely to be additive or synergistic. (See: Laetz et al. 2008.) Additive or synergistic effects are likely to be species-specific, In addition, multiple stressor effects (e.g. pathogens, temperature stress) are likely.

P1b. Longfin Smelt

General Observations

General Contaminants Model Page11, “early life stages of many Delta fish species are in the system during late winter and spring, a time when stormwater runoff from agricultural and urban areas can transport contaminants such as dormant spray pesticides and PAHs/metals into the Delta” and “Such early life stages are generally far more sensitive to contaminants than adults.”

Longfin Smelt Species Model, pages 9 and 16.

Magnitude = 2

See discussion P1a. Since longfin smelt typically occur further west in the Delta system, the potential exposure to pesticides is less than for Delta smelt.

Certainty = 2

See discussion P1a. There is no or little toxicological information on the covered fish species for all of the species of concern; however, data exists for salmonids, white sturgeon and Delta smelt, all of which indicates that these species are more sensitive to chemical pollutants than standard toxicity test species. Sensitivity of longfin smelt to pesticides is likely comparable to that of tested species.

P1c. Splittail

General Observations

See discussion P1a. Splittail spawn in the Yolo Bypass, potentially exposing more sensitive early life stages to agricultural pesticides, including such legacy pesticides as DDT.

Splittail CM Page 15

Magnitude = 3

Concentrations of pesticides in the Yolo Bypass are considered below the concentrations associated with acute or chronic toxicity in fish; however, early life stages of splittail in the Yolo Bypass could be more sensitive than adults or juveniles. .

Smalling et al. 2007, Occurrence of pesticides in Yolo bypass.

Certainty = 2
Peer-reviewed studies document the occurrence of pesticides in the Delta and Yolo Bypass; specific studies have not been conducted on Splittail responses under the documented conditions. The synergistic effects of these compounds on listed species are unknown but potentially significant.

P1d. Green Sturgeon

General Observations
See discussion P1a. Sturgeon species in general have been found to be at least as sensitive as salmonids to chemical contamination (Dwyer et al. 2005), and more sensitive in some cases (Little and Calfee 2008a, b); however, green sturgeon have not been used as a test species in laboratory studies. Their sensitivity is assumed to be similar to white sturgeon. More sensitive life stages occur outside the Delta.. Sediment-associated contaminants may play a bigger role due to feeding on benthic organisms.

Green Sturgeon Species Model, page 37

Magnitude = 2
Assuming sensitivity similar to white sturgeon suggests potential effects due to herbicides used for aquatic vegetation control (Little and Calfee, 2008 a, b) (See OSCM13).

Certainty = 2
Species-specific toxicity studies on green sturgeon are lacking; assuming sensitivity similar to white sturgeon suggests potential sensitivity

P1e. White Sturgeon

General Observations
See discussion P1a and P1d. Columbia River white sturgeon have been evaluated for exposure to methylmercury (see OSCM3) and aquatic vegetation control herbicides (see OSCM13).

Magnitude = 3
The greater sensitivity of white sturgeon to compounds evaluated with standard laboratory species suggests the possibility of effects to sensitive life stages in some locations.(Dwyer et al. 2005; Little and Calfee, 2008 a, b)

Certainty = 3
Peer-reviewed studies have been reported for this species in the Columbia River.

P1f. Steelhead

DLO Relationship and General Observations
See discussion P1a. The most sensitive stages of steelhead occur outside the Delta.

Salmonid Species Model, page 14
NOAA Biological Opinion!

Magnitude = 2
Direct mortality, if any, would be highly localized; synergy of multiple compounds cannot be discounted (Laetz et al. 2008).

Certainty = 3
Rainbow trout are a commonly used species in laboratory toxicity tests, resulting in an extensive body of peer-reviewed literature, and water quality criteria are often established to be protective of salmonid species; effects, particularly synergistic effects of steelhead life stages in the Delta have not been evaluated.

P1g. Chinook Salmon, Sac. Winter run

General Observations
See discussion P1a and P1f. More sensitive life-stages occur outside the Delta.

Salmonid Species Model, page 12

Magnitude = 2
See discussion P1f.

Certainty = 3
Coho salmon are a commonly used test species with a body of peer reviewed literature available (for examples see Laetz et al 2009); sensitivity of Chinook salmon is probably similar to rainbow trout and coho salmon (Teather and Parrott 2006); limited information is available for juvenile Chinook salmon and effects of insecticides and copper. Information is available on mixture and multiple stressor effects (Clifford et al., 2005; Eder et al. 2007, other).

NOAA Technical Memorandum NMFS-NWFSC-8, Contaminant Exposure and Associated Biological Effects in Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) from Urban and Nonurban Estuaries of Puget Sound

P1h. Chinook Salmon, Sac. Spring run

General Observations
See discussion P1a, P1f, and P1g.

Salmonid Species Model, page 12

Magnitude = 2
See discussion P1f.

Certainty = 3
See discussion P1g.

P1i. Chinook Salmon, fall and late fall run

DLO Relationship and General Observations
See discussion P1a, P1f, and P1g.

Salmonid Species Model, page 12

Magnitude = 2
See discussion P1f.

Certainty = 3
See discussion P1g.

Outcome P2: Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, Delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)

P2a. Delta Smelt

General Observations:

Sublethal effects of pesticide exposure in fish can be expected at concentrations well below those associated with acute or chronic mortality. The population-level effects of such exposures are difficult to estimate without specific studies of the species and chemicals involved, both individually and in combination (Laetz et al. 2008).

General Contaminants Model Page11, "early life stages of many Delta fish species are in the system during late winter and spring, a time when stormwater runoff from agricultural and urban areas can transport contaminants such as dormant spray pesticides and PAHs/metals into the Delta" and "Such early life stages are generally far more sensitive to contaminants than adults.

General Contaminants Model Page 24, "Pesticides including pyrethroids (Werner and Oram, 2008), metals, in particular copper, and polychlorinated biphenyls (PCBs) are among those identified to cause immunosuppressive effects in fish (Anderson and Zeeman 1995; Banerjee 1999; Austin 1999). Zelikoff et al. (1998) found reduced disease resistance in fish exposed to the pyrethroid permethrin. The susceptibility of juvenile Chinook salmon and rainbow trout to infectious hematopoietic necrosis virus (IHNV) was dramatically increased in juvenile fish exposed to sublethal concentrations of esfenvalerate (Clifford et al. 2005) and copper (Hetrick et al. 1979)."

Werner et al. 2008 (POD final report) contains information on the effects of a pyrethroid and copper in Delta smelt.

Werner et al. 2009 (POD Progress report, Feb 2009, contains effect concentrations of various contaminants on Delta smelt, and a draft manuscript of Connon et al. on sublethal effects of esfenvalerate in Delta smelt.

Pyrethroids Model
P. 26-29 Sublethal Effects

Delta Smelt Species Model Page 23.

Magnitude = 4.

The potential positive outcome of this action is likely to affect a large area, but mostly smaller waterways and sloughs of the Delta. It could have a sustained positive effect on fitness of covered fish species. Delta smelt primarily spawn in one area (Sacramento Ship Channel/Cache Slough), where elevated levels of pesticides and invertebrate toxicity have been detected in recent years. The magnitude of this action for Delta smelt could therefore be large.

Certainty = 3
Sublethal effects of pesticides on salmonids, Delta smelt, and white sturgeon have been documented in laboratory studies at extremely low concentrations that are environmentally relevant in the Delta (OP and pyrethroid insecticides and copper). In addition, synergistic or additive effects have been documented between pesticides that occur in the Delta (OP, pyrethroids and carbamates). Chemical mixture and multiple stressor effects are likely. However, the nature of the outcome is constrained by the variability in the system.

P2b. Longfin Smelt

General Observations:
See discussion P1b. Longfin Smelt Species Model Page 9 and 16.

Magnitude = 2
See discussion P1b.

Certainty = 2
See discussion P1b.

P2c. Splittail

General Observations
See discussion P1c.
Splittail Species Model Page 15

Magnitude = 3
See discussion P1c.

Certainty = 2
See discussion P1c.

P2d. Green Sturgeon

DLO Relationship and General Observations
See discussion P1d.
Green Sturgeon Species Model page 37

Magnitude = 2
See discussion P1d

Certainty = 2
See discussion P1d.

P2e. White Sturgeon

General Observations
See discussion P1e.

Magnitude = 3
See discussion P1e; for discussion of endocrine disruption associated with mercury exposure see OSCM3.

Certainty = 3
See discussion P1e.

P2f. Steelhead

General Observations
See discussion P1f, P2a.
Salmonid Species Model Page 14

Magnitude = 3.
Deleterious effects on the olfactory system and escape response of salmonids have been demonstrated at copper concentrations that are common in the Delta, thus salmonids could be affected as well. No toxicological information exists on such effects in other anadromous fish species. Hecht, S.A., D.H. Baldwin, C.A. Mebane, T. Hawkes, S.J. Gross, and N.L. Scholz. 2007. An overview of sensory effects on juvenile salmonids exposed to dissolved copper:
Applying a benchmark concentration approach to evaluate sublethal neurobehavioral toxicity. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-83, 39 p. "To estimate toxicological effect thresholds for dCu in surface waters, benchmark concentrations (BMCs) were calculated. BMCs for juvenile salmonid olfactory function ranged 0.18–2.1 ìg/L, corresponding to reductions in predator avoidance behavior of approximately 8–57%. The BMC examples represent the dCu concentration (above background) expected to affect the ability of juvenile salmonids to avoid predators in freshwater. These concentration thresholds for juvenile salmonid sensory and behavioral responses fall within the range of other sublethal endpoints affected by dCu such as behavior, growth, and primary production, which is 0.75–2.5 ìg/L."
Also see NOAA Biological Opinion (2008) for effects of OP insecticides on salmonids.
Eder et al. 2007, 2009

Certainty = 3
See discussion P1f.

P2g. Chinook Salmon, Sac. Winter run

General Observations
See discussion P1f, P2a.
Salmonid Species Model Page 12.

Magnitude = 3
See discussion P2f.

Certainty = 3 (see discussion P1g).

P2h. Chinook Salmon, Sac. Spring run

General Observations
See discussion P1f, P2a.
Salmonid Species Model Page 12.

Magnitude = 3
See discussion P2f.

Certainty = 3
See discussion P1g.

P2i. Chinook Salmon, fall and late fall run

General Observations
See discussion P1f, P2a.
Salmonid Species Model Page 12.

Magnitude = 3
See discussion P2f.

Certainty = 3
See discussion P1g.

Outcome P3: Increased food abundance and quality for splittail, Delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from reduced food web disruption

P3a. All Covered Species

DLO Relationship and General Observations:
Food web model (contaminants is a driver in the models; referenced in 2.19 and linked to the Chemical Stressors Model)

Monitoring results from the Irrigated Lands Program shows frequent toxicity to phytoplankton and zooplankton in Delta water samples (CVRWQCB, Johnson Report (pending submission to CVRWQCB)).

General Contaminants Model
Page 3: Organophosphates (e.g. chlorpyrifos, diazinon) have been shown to be present at acutely toxic concentrations in tributaries and the Delta (Kuivila and Foe, 1995; Werner et al.,2000; California Regional Water Quality Control Board Agricultural Waiver Program, 2007).

"Many contaminants, in particular pesticides and heavy metals, are more likely to directly affect lower trophic levels, with potential negative effects on species composition and food web dynamics."

Pyrethroids Model
P. 19-31

Amweg, Erin L., Donald P. Weston, and Nicole Ureda. 2005. Use and toxicity of pyrethroid pesticides in the Central Valley, California, USA. Environmental Toxicology and Chemistry, 24(4):966-972 with erratum in 24(5). *Determined that pyrethroid levels at or near most laboratory detection levels can have lethal and sublethal effect on* Hyalella azteca*.Toxic levels are found in many ag-dominated water bodies in Central Valley*

Bergamaschi, B.A., K.M.Kuivila, and M.S.Fram. 1999. Pesticides associated with suspended sediments in the San Francisco Bay during the first flush, December 1995. Published in USGS Toxic Substances Hydrology Program-Proceedings of the Technical Meeting, Charleston, South Carolina, March 8-12, 1999, v.2 Contamination of Hydrologic Systems and Related Ecosystems, 1999. USGS Water-Resources Investigations Report 99-4018 B. They analyzed suspended sediment samples from Mallard Island during slack current for 19 compounds and found an average of 10. Total suspended sediment pesticide concentrations ranged from 9.8 to 43.8 ng/g with no apparent temporal pattern.

Mesocosm studies typically show rapid recovery of aquatic organisms from pesticide applications (Giddings et al.2001;Hanson et al. 2007).

Magnitude = 3

Invertebrates are typically more sensitive than fish to chemicals at a given concentration, so that levels protective of fish still cause adverse effects in invertebrates. Although recovery of invertebrate populations following a pesticide-induced depletion can be rapid, short-term depletion of food resources could be locally/seasonally important to listed species, particularly those that forage in the water column. The potential positive outcome of this action is likely to affect a large area, but mostly smaller waterways and sloughs of the Delta. It could have a positive effect on food supply for, and fitness of covered fish species.

Certainty = 2

Although information on toxic thresholds is available for only a few invertebrate species resident in the Delta, there is sufficient data showing that crustaceans such as cladocerans, amphipods and copepods are more sensitive to insecticides than fish. Bivalves tend to be less sensitive.

There is abundant evidence that water in smaller waterways of the Delta is at times acutely toxic to zooplankton and benthic crustaceans. In addition, data from the Irrigated Lands Program demonstrated frequent phytoplankton toxicity in the Delta. It is therefore likely that lower trophic levels are negatively affected by pesticides in the system. However, there is significant uncertainty with regard to population level effects of pesticides, the consequences of herbicides on phytoplankton community composition (and thus food quality for invertebrates). In addition, the relative importance of pesticide effects, versus other stressors such as clam filtration, on phytoplankton primary production and subsequent effects on zooplankton abundance and diversity is not known.

Potential Negative Ecological Outcome(s)

Outcome N1: Possible drying up of smaller creeks

All Covered Species

General Observations:
Tailwater recovery systems are the most commonly used BMP for controlling contaminated runoff, and tend to dry up smaller creeks

Magnitude = 3
Predictable water supplies and riparian habitat are scarce in the Central Valley for terrestrial wildlife. Agriculturally dominated small creeks and sloughs provide valuable scarce habitat. Drying them up through a tailwater recovery system, which is the most common BMP, could be real rough for wildlife that are not very mobile.

Second, small ag dominated creeks and sloughs are primary nursery areas for algae and zooplankton. If you remove that habitat or decrease the size of that habitat then you have less nursery areas to feed into the large, deep, cold moving rivers. (Chris Foe, pers.comm. No direct evidence to cite or reference for comment)..

Certainty = 1
Understanding is lacking.

Important Gaps in Information and/or Understanding

Data Needs

- Very little information exists on exposure levels and impacts to most covered fish species, particularly the effects of multiple chemicals, and pesticides in combination with other stressors such as pathogens and temperature..
- The analysis needs to be site- and season-specific looking at existing data of what pesticides are being used where, and what covered species are present in these areas, would reduce uncertainty in real-world application.

Assess Reversibility and Opportunity for Learning

Reversibility - Yes

Comments: If the primary reductions in pesticides are from BMPs with little investment in infrastructure or equipment, they could be easily reversed**.**

Opportunity for Learning - High

Comments: A monitoring program could evaluate species/site/product-specific reductions using before and after data; collection could be designed to evaluate other stressors such as water quality parameters concurrently with pesticide reductions. Direct and indirect (e.g. food web) effects could be evaluated.

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USFWS Biological Opinion Regarding the Effects on Listed Species from Implementation of the Pesticide Use Program on Federal Leased Lands, Tule Lake and Lower Klamath National Wildlife Refuges, Klamath County, Oregon, and Siskiyou and Modoc Counties, California. U.S. Fish and Wildlife Service, Klamath Falls Fish and Wildlife Office, Klamath Falls, Oregon, May 2007. 48 pp.

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Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P3a	All	Increased food abundance and quality for splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from reduced food web disruption	3	2
P2a	Delta smelt	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races).	4	3
P1a	delta smelt	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides.	3	3
P2i	Fall, late Fall-run Chinook salmon	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races).	3	3
P1i	Fall, late Fall-run Chinook salmon	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides.	2	3
P2d	Green Sturgeon	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races).	2	2
P1d	Green Sturgeon	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides.	2	2
P2b	Longfin smelt	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races).	2	2
P1b	Longfin smelt	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides.	2	2

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes (contd.)				
P2c	Splittail	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races).	3	2
P1c	Splittail	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides.	3	2
P2h	Spring-run Chinook salmon, Sac.	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races).	3	3
P1h	Spring-run Chinook salmon, Sac.	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides.	2	3
P2f	Steelhead	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races).	3	3
P1f	Steelhead	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides.	2	3
P2e	White Sturgeon	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races).	3	3
P1e	White Sturgeon	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides.	3	3
P2g	Winter-run Chinook salmon, Sac.	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of pesticides on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races).	3	3
P1g	Winter-run Chinook salmon, Sac.	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from pesticides.	2	3

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Negative Outcomes				
N1	All	Possible drying up of some smaller creeks	3	1

OSCM 5:
Reduce the Loads of Toxic Contaminants in Stormwater and Urban Runoff

Scientific Evaluation Worksheet

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Action: Reduce the Loads of Toxic Contaminants in Stormwater and Urban Runoff

Evaluation Team: Water Quality & Invasives Workgroup

James Haas - Chair , Bruce Herbold – Coach, Chris Foe, Charles Alpers; Inge Werner, Frances Brewster, Karen Larsen, Chrisinte Joab, David Fullerton, Holly Gellerman, Ron Smith, Jan Thompson, Lori Clammurro (note taker)

Date of Last Revision: March 22, 2009

Action Description and Clarifying Assumptions

Develop and implement stormwater management plans and additional measures to reduce loads of toxic contaminants in stormwater and urban runoff entering Delta waterways to levels below which they are toxic to covered fish species

Approach

Develop and implement stormwater management plans and additional measures.

Intended Outcomes as Stated in Conservation Measure

1. Reduced direct mortality of splittail, Delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from contaminants
2. Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, Delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)
3. Increased food abundance for splittail, Delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from reduced food web disruption
4. Increased food quality and abundance for important invertebrate species.

General Conceptual Model Support for Intended Outcomes

1. Both the Chemical Stressors and the Pyrethroids DRERIP models indicate that contaminants may exert acutely toxic effects leading to mortality in individuals (p. 20 and p. 19, respectively).
2. Both the Chemical Stressors and the Pyrethroids DRERIP models indicate that contaminants may exert sublethal effects, with potential consequences for fitness, reproductive success, and survival of individuals (p. 20 and p. 19, respectively).
3. Both the Chemical Stressors and the Pyrethroids DRERIP models indicate that contaminants may exert effects on food web structure and dynamics; food web organisms are highly susceptible to pyrethroids in particular (p. 24 and p. 30, respectively).

Assumptions

Provided in BDCP Conservation Measure

1. Stormwater runoff is the leading source of water pollution in the United States and is believed to be a large contributor to toxics in the Delta.
2. Stormwater runoff from urban residential areas is a larger source of pyrethroid pesticides than agricultural runoff.

Problem(s) with Action as Written:

1. It is difficult to evaluate approach no. 1 as no specific information is given with regard to stormwater management plans. The team therefore assumes that methods included in such plans will reduce the load of toxic contaminants entering waterways via stormwater runoff.
2. It is important to also reduce indirect effects of runoff-associated toxicants (e.g. on prey organisms of covered species)
3. “Additional measures” – what are these specifically?

4. Suggestion for re-writing: Make actions more specific (what exactly will be done?) and provide available information on the efficiency of these measures in reducing contaminant input into waterways.

Scale of Action:

Medium

Rationale:
This action is of a medium spatial and temporal scale since it is focused on storm and irrigation water outfalls in urban areas. Spatially, the action is therefore likely to have impacts in the vicinity of Stockton, Sacramento, and in the more developed areas adjacent to Carquinez Strait and Suisun Bay. Where urban runoff is directed into the sewer system, as is the case in Sacramento, stable contaminants also enter the Delta via treated wastewater treatment effluent. Temporally, reductions in urban runoff associated contaminant loads into the Delta are likely to have measurable impacts for decades and beyond.

Evaluation Summary Tables

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Relation to Existing Conditions

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

NO

Nature of Change:

If successful, the action will reduce contaminant levels in water and sediments. This will likely affect the phytoplankton and aquatic animal community composition in some areas of the Delta, however food web dynamics should not change in a significant way. The action should not produce any fundamental changes to other key physical or biotic properties of the Delta.

Potential Positive Ecological Outcome(s)

Outcome P1: Reduced direct mortality of splittail, Delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from contaminants.

P1. All Covered Fish spp.

General Observations

Chemical Stressors Model

Lack of occurrence and exposure Page 6, "Stormwater runoff from urban and industrialized areas, and inflow from tributaries (including the Delta) are the major sources of polycyclic aromatic hydrocarbons (PAHs) in San Francisco Bay (Oros et al., 2007). Oros et al (2007) report relatively low PAH concentrations in the Sacramento/San Joaquin Rivers and the Delta during the 1993-2001 monitoring period."

Pyrethroid Model

Page 4: Urban area uses of pyrethroids make up nearly half of the total amount of pyrethroids used in the Central Valley, thus making storm and irrigation runoff from urban areas an important potential source of pyrethroids.

Page 7, Sediments in general are considered to be a "sink" for pyrethroids due to their hydrophobic properties, and the presence of aquatic macrophytes, phytoplankton and detritus can lead to adsorption of pyrethroids to plant surfaces. However, pyrethroids may remain in solution for hours to days before they sequester to suspended particles.

Page 8, Urban use of pyrethroid insecticides and subsequent transport into surface waters

may be a significant contributor to the contamination of rivers with pyrethroids. A study on sediments in urban creeks in Sacramento (Weston, 2007) showed that all 28 sediment

samples taken had measurable concentrations of pyrethroids.

Page 17, chemical mixtures may pose a much bigger threat than individual compounds

Page 18, pyrethroids may be acting synergistically with pathogens to compromise survivorship of fish populations through immunologic or physiologic disruption.

P. 19-25, fish are highly susceptible to pyrethroids.

TDC Environmental. 2008. Pesticides in urban surface water: urban pesticides use trends annual report April 2008. Prepared for San Francisco Estuary Project.: Report cites another TDC report that concludes "use of pyrethroid insecticides in California urban areas is causing adverse effects in aquatic ecosystems receiving urban runoff."(page1).

McCarthy et al. 2008. Pre-spawn die-offs of salmonids in Seattle urban creeks due to urban stormwater runoff.

Fish kills (threadfin shad) have been recorded by Fish and Game in the San Joaquin River west of Stockton following the first major rainstorm of the season.

Magnitude = 2

Limited to areas that receive urban runoff, Sacramento, Stockton, Suisun Bay, Carquinez Strait, but also part of wastewater treatment effluent if stormwater is directed into sewer system (Sacramento) or directly into major sloughs and rivers (for example, Stockton). Could be of high importance if covered species use urban creeks or lower San Joaquin River. Chemicals of highest concern: copper, pyrethroids and unknown mixture effects.

Certainty = 2
Information exists for direct toxicity to invertebrates in urban streams in the area, but the direct effects on fish effects as these streams feed into the larger ecosystem are not known. Fish kills following storm runoff events have been recorded in recent years in the San Joaquin River.

Overall, little evidence exists for acute effects of stormwater runoff in the Delta such as "fish kills. This could be due to the fact that it is difficult to detect dead fish unless there is a massive die off in areas where people regularly go. Similarly, it is unlikely that mortality of larval stages could be detected and quantified, so we simply don't know if this is occurring.

Outcome P2: Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, Delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)

P2a. Delta Smelt

General Observations:
General Contaminants Model
Page 24, "Pesticides including pyrethroids (Werner and Oram, 2008), metals, in particular copper, and polychlorinated biphenyls (PCBs) are among those identified to cause immunosuppressive effects in fish (Anderson and Zeeman 1995; Banerjee 1999; Austin 1999). Zelikoff et al. (1998) found reduced disease resistance in fish exposed to the pyrethroid permethrin. The susceptibility of juvenile Chinook salmon and rainbow trout to infectious hematopoietic necrosis virus (IHNV) was dramatically increased in juvenile fish exposed to sublethal concentrations of esfenvalerate (Clifford et al. 2005) and copper (Hetrick et al. 1979)."

Pyrethroids Model
See notes under P1.
P. 26-29 Sublethal Effects

NOAA Technical Memorandum NMFS-NWFSC-83; An Overview of Sensory Effects on Juvenile Salmonids Exposed to Dissolved Copper.

Sandahl, J.F., Baldwin, D.H., Jenkins, J.J., and Scholz, N.L. 2007. A sensory system at the interface between urban stormwater runoff and salmon survival. Environmental Science and Technology, 41:2998-3004. Olfactory response in juvenile coho salmon exposed to 2 ug/l dissolved copper for 3-hours was reduced by 40%. This loss in olfactory sensitivity led to a failure to initiate predatory avoidance behaviors in response to chemical alarm cues. Sandahl et al. cite recent monitoring in northern California following a storm event that detected copper at a mean concentration of 15.8 ug/l, ranging from 3.4 - 64.5 ug/l. They also cite two recent studies that indicate that dissolved copper also impacts fish lateral line neurons that provide cues for shoaling, prey capture and predator evasion.

TDC Environmental. 2008. Pesticides in urban surface water: urban pesticides use trends annual report April 2008. Prepared for San Francisco Estuary Project.: Report cites another TDC report that concludes "use of pyrethroid insecticides in California urban areas is causing adverse effects in aquatic ecosystems receiving urban runoff."(page1).

Irrigation runoff from urban areas could be of importance to Delta smelt in Suisun Marsh.

Mixture effects may be far worse than those of individual toxicants (Laetz et al. 2009).

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Magnitude = 2
Limited to areas that receive urban runoff, Sacramento, Stockton, Suisun Bay, Carquinez Strait, but also part of wastewater treatment effluent if stormwater is directed into sewer system like in Sacramento. Could be of high importance if covered species use urban creeks (like in Seattle), but these are likely to be small subgroups.

More important for species that spend extended periods of time near urban areas or directly downstream from urban areas (Lower San Joaquin River, Suisun Marsh, Lower Sacramento River, Western Delta, Suisun Bay, Napa River) Chemicals of highest concern: copper, pyrethroids and unknown mixture effects..

Certainty = 2
See OSCM4; much of the same information is relevant, except the potential sources, distribution, and concentrations might differ.

Although there are some uncertainties regarding the magnitude of the evaluated outcomes based on specific in-Delta studies, the sensitivity of fish to pyrethroid pesticides and copper in water and the wide-spread occurrence in these compounds in urban runoff suggest that benefits to the species of concern would accrue from a reduction of contaminants flowing to the Delta in urban runoff.

P2b. Longfin Smelt

General Observations:
See discussion P2a.

Magnitude = 2
See discussion P2a.

Certainty = 2
See discussion P2a.

P2c. Splittail

General Observations:
See discussion P2a.

Magnitude = 2
See discussion P2a.

Certainty = 2
See discussion P2a.

P2d. Green Sturgeon

General Observations:
See discussion P2a.

Magnitude = 2
See discussion P2a.

Certainty = 2
See discussion P2a.

P2e. White Sturgeon

General Observations:
See discussion P2a.

Magnitude = 2
See discussion P2a.

Certainty = 2
See discussion P2a.

P2f. Steelhead

General Observations:
See discussion P2a.

Magnitude = 3
Typical Cu concentrations originating from road runoff from a California study were 3.4–64.5 µg/L, with a mean of 15.8 µg/L (Tiefenthaler et al. 2008). Taken together, the information reviewed and presented herein indicates that impairment of sensory functions important to survival of juvenile salmonids is likely to be widespread in many freshwater aquatic habitats. Impairment of these essential behaviors may manifest within minutes and continue for hours to days depending on concentration and exposure duration. Therefore, Cu has the potential to limit the productivity and intrinsic growth potential of wild salmon populations by reducing the survival and lifetime reproductive success of individual salmonids (Hecht et al. 2007;Sandahl et al. 2007).

Certainty = 3
See pesticide evaluation; much of the same information is relevant, except the potential sources, distribution, and concentrations might differ; sensitivity of salmonids to olfactory effects of copper at sub-lethal concentrations is well-document in laboratory exposures (Hansen et al. 1999).

P2g. Chinook Salmon, Sac, winter run

General Observations:
See discussion P2a.

Magnitude = 3
See discussion P2f.

Certainty = 3
See discussion P2f.

P2h. Chinook Salmon, Sac, spring run

General Observations:
See discussion P2a.

Magnitude = 3
See discussion P2f.

Certainty = 3
See discussion P2f.

P2i. Chinook Salmon, fall run

General Observations:
See discussion P2a.

Magnitude = 3
See discussion P2f.

Certainty = 3
See discussion P2f.

Outcome P3: Increased food abundance for splittail, Delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from reduced food web disruption and increased food quality and abundance for important invertebrate species.

P3a. All Covered species

General Observations:
Chemical Stressors Model Page 3: Organophosphates (e.g. chlorpyrifos, diazinon) have been shown to be present at acutely toxic concentrations in tributaries and the Delta (Kuivila and Foe, 1995; Werner et al.,2000; California Regional Water Quality Control Board Agricultural Waiver Program, 2007). "Many contaminants, in particular pesticides and heavy metals, are more likely to directly affect lower trophic levels, with potential negative effects on species composition and food web dynamics."

Occurrence and exposure and in support of P1: page 4, "In recent years, pyrethroids at toxic concentrations [*to invertebrates*] have been detected in the majority of sediment samples collected from urban creeks in the Bay/Delta region (Amweg et al., 2006; Woudneh and Oros, 2006a & b).

Pyrethroids Model

See notes under P1 and P2.

P. 19-31

Occurrence data and in support of P3: Weston, D.P., R.W. Holmes, J. You, and M.J. Lydy. 2005. Aquatic toxicity due to residential use of pyrethroid insecticides. Environmental Science and Technology, 39(24):9778-9784. *Sediment from 9 of 21 urban creek sites caused >90% mortality to H. azteca. Bifenthrin in the secondary tributaries reached levels 15 times greater than found in samples draining agricultural areas. Results suggest minimal transport of contaminated sediments downstream of outfalls, but "given the numerous outfalls scattered throughout the system, the result is a patchwork of highly contaminated reaches."*

Amweg, Erin L., Donald P. Weston, Jing You, and Michael J. Lydy. 2006. *Pyrethroid insecticides and sediment toxicity in urban creeks from California and Tennessee.* Environmental Science and Technology, 40(5):1700-1706. *Sampled 15 urban creeks in and around Sacramento and the East Bay and tested for toxicity to Hyalella azteca in a 10-d sediment exposure. In the Sacramento area 22 of the 33 samples were toxic and 7 of the 8 creeks had toxic samples on at least one occasion. Pyrethroid concentrations were sufficient to explain the toxicity in 21 of the 22 toxic samples.*

Giddings et al. 2000. ECT 20:660 conducted mesocosm studies of pyrethroids on invertebrates and fish. The results for cypermethrin and esfenvalerate were remarkably consistent. They revealed a trend in sensitivity from amphipods, isopods, midges, mayflies, copepods, and cladocerans (most sensitive) to fish, snails, oligochaetes, and rotifers (least sensitive). With few exceptions, populations affected by pyrethroids in the mesocosms recovered to normal levels before the end of the year of exposure; most populations recovered within weeks. Factors presumed responsible for population recovery included internal refuges (areas of low exposure), resistant life stages, rapid generation times, and egg deposition by adults from outside the treated systems. Indirect effects on fish (which have been hypothesized to occur when invertebrate food sources are reduced) were not observed.

Lawler et al. (2008) reported that survival of Daphnia and mayflies in mesocosms treated with pyrethrin and PBO in amounts used for mosquito control were not different from survival in control mesocosms.

Komjarova I., Blust J. 2008. Mixture effects of trace metals on zooplankton. Copper and lead increase each others uptake.

Tiefenthaler et al 2008 ETC 27:277 evaluated metals concentration in urban runoff in southern California. They reported mean flux at land use sites ranged from 24 to 1,238, 0.1 to 1,272, and 6 to 33,189 g/km2 for total copper, total lead, and total zinc, respectively. Storm water runoff from industrial land use sites contained higher EMCs and generated greater flux of trace metals than other land use types. For all storms sampled, the highest metal concentrations occurred during the early phases of storm water runoff, with peak concentrations usually preceding peak flow. Early season storms produced significantly higher metal flux compared with late season storms at both mass emission and land use sites.

Effects of copper have been shown on fish eggs and larvae (Adema-Hannes, R. and J. Shenker. 2008), algae growth (Stoiber et al. 2008), and leaf litter decomposition rates (Roussel et al. 2008) at concentrations found in urban runoff.

Magnitude = 2-3
Effects, if any, are likely localized.

Certainty = 2-3

Acute toxic effects on invertebrates have been shown in sediments and water column of urban creeks; mesocosm studies suggest lower level effects in receiving waters. Copper at concentrations associated with urban runoff show adverse effects on algal growth and leaf litter decomposition rates, suggesting possible effects on primary production and detritivores/shredders. How these effects translate to effects in receiving waters and beneficial effects on covered species is not known.

Although there are some uncertainties regarding the magnitude of the evaluated outcomes based on specific in-Delta studies, the sensitivity of invertebrates to pyrethroid pesticides and copper in water and the wide-spread occurrence in these compounds in urban runoff suggest that benefits to the species of concern would accrue from a reduction of contaminants flowing to the Delta in urban runoff.

Potential Negative Ecological Outcome(s)

Outcome N1: Ponded or contained stormwater could exacerbate mosquito control problems and associated human health issues.

N1a. Humans.

Magnitude = 1
Spatial extent is likely to be small.

Certainty = 3
Mosquito occurrence should be monitored, but if the stormwater management systems are well designed, they should be able to accommodate large rain events without standing water present for more than 48-72 hours

Outcome N2: Ponded or contained stormwater could transfer contaminants to groundwater by infiltration.

N2a. Humans.

Magnitude = 1
Spatial extent is likely to be small.

Certainty = 3
Enhanced infiltration of urban runoff will increase adsorption and degradation of most contaminants. The use of highly mobile and persistent contaminants should be restricted or other management actions chosen if upper levels of groundwater are used as a drinking water source.

Important Gaps in Information and/or Understanding

Data Needs

See research needs.

Research Needs

Evaluation of mixture effects of multiple contaminants on fish, invertebrates and phytoplankton.

Monitor how and when small subgroups of the covered species and their zooplankton prey use urban creeks.

Evaluate how contaminants in urban runoff translate into effects in receiving waters.

Assess Reversibility and Opportunity for Learning

Reversibility

No

Comments: Once communities invest in technologies to reduce and manage urban runoff, it might be difficult to return to the status quo if monitoring indicates they are ineffective.

Opportunity for Learning

High

Comments: Implementation of urban runoff technologies would provide the opportunity to evaluate before and after conditions, with reference to the research needs, to determine whether management objectives are met, and which technologies are most effective at reducing both the volume and contaminant load of urban runoff.

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Food Web Model?

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Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P3a	All	Increased food abundance for splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from reduced food web disruption and increased food quality and abundance for important invertebrate species.	2-3	2-3
P1	All	Reduced direct mortality of splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races) from contaminants.	3	2
P2a	Delta smelt	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)	2	2
P2i	Fall-run Chinook salmon	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)	3	3
P2d	Green Sturgeon	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)	2	2
P2b	Longfin smelt	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)	2	2
P2c	Splittail	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)	2	2

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes (contd.)				
P2h	Spring-run Chinook salmon, Sac.	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)	3	3
P2f	Steelhead	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)	3	3
P2e	White Sturgeon	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)	2	2
P2g	Winter-run Chinook salmon, Sac.	Reduced sublethal effects (behavior, tissue/organ damage, reproduction, growth, and immune) of contaminants on splittail, delta and longfin smelt, green and white sturgeon, steelhead, and Chinook salmon (all races)	3	3

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Negative Outcomes				
N1	Human health	Ponded or contained stormwater could exacerbate mosquito control problems and associated human health issues.	1	3
N2	Human health	Ponded or contained stormwater could transfer of contaminants to groundwater by infiltration	1	3

OSCM7:
Improve Dissolved Oxygen Conditions in the Stockton Deep Water Ship Channel (SDWSC)

Scientific Evaluation Worksheet

Evaluation Team: Water Quality and Invasives Workgroup

James Haas - Chair , Bruce Herbold – Coach, Chris Foe, Charles Alpers; Inge Werner, Frances Brewster, Karen Larsen, Chrisinte Joab, David Fullerton, Holly Gellerman, Ron Smith, Jan Thompson, Lori Clammurro (note taker)

Date of Last Revision: 30 January 2009

Action: Improve dissolved oxygen conditions in the Stockton Deep Water Ship Channel (SDWSC) to meet the Basin water quality objectives (6.0 mg/l in the San Joaquin River [between Turner Cut and Stockton, 1 September through 30 November] and 5.0 mg/l the remainder of the year).

Problem(s) with Action as written: The action itself can be evaluated but the approaches used to address the action need to be rewritten and the outcomes based on the revised approaches may need to be refined or clarified.

Approach: The current approaches are:

1. Fund the Port of Stockton and other cooperators to evaluate the causes of dissolved oxygen in the Stockton Deep Water Ship Channel.
2. Implement measures to solve the problem.

The approaches listed above need to be rewritten. Justification for the rewriting of the approaches and outcomes is provided below.

Approach 1: Studies to determine and evaluate the causes of the low dissolved oxygen in the Stockton Deep Water Ship Channel (DWSC) have already been done. These studies, however, did not involve funding the Port of Stockton or other cooperators (not sure what is meant by "other cooperators"). Between 1999 and 2003, CALFED funded around $3M for studies to determine the causes of low dissolved oxygen in the Stockton Deep Water Ship Channel. From these studies, three factors were identified as causing the low dissolved oxygen conditions in the Stockton DWSC (see references at the end). These three factors are:

- Geometry (cross-sectional area) of the DWSC, which is controlled and manipulated by the US Army Corps of Engineers and the Port of Stockton through deepening projects and maintenance dredging.
- Reduced flow through the DWSC, which is controlled and manipulated by the US Bureau of Reclamation, Department of Water Resources, and the Water Rights Division of the State Water Resources Control Board (SWRCB) through various projects such as the CVP and SWP pumping at Tracy, diversions and dams along the upstream tributaries that feed flow into the San Joaquin River, and various water users along the San Joaquin River and its upstream tributaries.
- Loads of oxygen depleting substances from upstream sources such as the Stockton Regional Waste Control Facility, non-point sources such as irrigated lands, and unknown sources/new sources that have a reasonable potential to impact dissolved oxygen.

In 2000, Proposition 13, Article 3 Bay-Delta Multi-Purpose Water Management Programs (Water Code Sections 79196.5[b] and [e]) was approved by California voters to allocate $40M in bond funds for the purpose of implementing the CALFED Ecosystem Restoration Program (ERP), of which the dissolved oxygen impairment in the Stockton Deep Water Ship Channel is an ERP Directed Action Proposal.

Funded by Proposition 13, one study titled *Monitoring and Investigations of the San Joaquin River and Tributaries Related to Dissolved Oxygen* was completed in June 2008 and numerous aeration studies were completed along with a Demonstration Aeration Facility constructed in 2006 at Rough & Ready Island in the Stockton Deep Water Ship Channel.

A second study titled *Characterizing the Impact of Upstream San Joaquin River Algae Loads on Dissolved Oxygen Conditions in the Stockton Deep Water Ship Channel* was approved by the Ecosystem Restoration Program Implementing Agency Managers in August 2008 and is currently making its way through the contracts process for funding through Proposition 13. This second study was to begin in early 2009 and be completed in 2011. However, the State budget crisis has pushed this project into the FY 2009/2010 funding cycle.

These two studies were designed to address the remaining issues of source and linkages to the dissolved oxygen impairment. These studies were requirements specified in the Central Valley Regional Water Board's June 2005 adopted Basin Plan Amendment (BPA) - The Control Program for Factors Contributing to the Dissolved Oxygen Impairment in the Stockton Deep Water Ship Channel. This Total Maximum Daily Load (TMDL) BPA required entities responsible for point and non-point sources of oxygen demanding substances within the TMDL source area to conduct studies that would identify and quantify three remaining unknowns:

- Identify the sources of oxygen demanding substances and their precursors in the dissolved oxygen TMDL source area;
- Growth or degradation mechanisms of these oxygen demanding substances in transit through the source area to the DWSC; and
- Impact of these oxygen demanding substances on DO concentrations in the DWSC under a range of environmental conditions considering the effects of chemical, biological, and physical mechanisms that add or remove DO from the water column in the DWSC.

If the approach listed above is to be retained, then all of the studies completed-to-date should be fully evaluated and synthesized to determine what remaining issues need to be studied, and then list the remaining unknowns as the studies to be funded. Studies that are truly lacking are control projects that could be constructed to improve dissolved oxygen, and studies to evaluate the effectiveness of certain control projects and or mitigation projects that have been or could be constructed to improve dissolved oxygen in the Stockton DWSC. One measure with the potential to improve dissolved oxygen is the use of an aeration device. Currently, there are three different types of aeration systems operating in the DWSC:

- The Demonstration Aeration Facility, which was constructed using Proposition 13 bond funds is operated and maintained by the Department of Water Resources (DWR) during its two-year demonstration phase (2009 is the last year of the demonstration phase);
- The Port of Stockton aerator, which was originally constructed by the US Army Corps of Engineers for mitigation of the prior deepening of the Stockton DWSC, and was then handed over to the Port of Stockton for their control and maintenance ; and,

- The City of Stockton, which operates 8 lateral line aerators in the DWSC east of the Turning Basin, were installed to alleviate the algae and odor issues in that section of the DWSC. The City of Stockton aerators do not have any direct affect on the DO concentration downstream in the DWSC west of the I-5 bridge.

Approach 2: The second approach listed above is too broad and nebulous. Recommended implementation measures, if known, should be specified, and should focus on the three causative factors along with the entities responsible for them. The Regional Water Board is developing Phase II of the Stockton DO TMDL, and the BDCP conservation measure and associated approaches relating to the low dissolved oxygen in the Stockton DWSC should be developed in coordination with their efforts. Implementation measures, aside from what the Regional Board has direct control, need to be directed to agencies that are responsible for the geometry of the ship channel (US Army Corps) and flow through the ship channel (US Bureau of Reclamation, DWR, and SWRCB Div. of Water Rights). Implementation measures (approaches) focused on these contributing factors will assist the Regional Water Board in developing the final TMDL, and improving the dissolved oxygen in the Stockton DWSC.

Outcome(s): Some outcomes require a minor revision or rewrite. See notes below.

Outcome P(1): Reduce impediments to upstream migration of adult San Joaquin River fall-run Chinook salmon, steelhead, and white sturgeon during summer and fall.

Since the action is focused on dissolved oxygen as an impediment to migrating fish in the Stockton DWSC, it may be better to clarify the statement to specifically identify the impediment. For example, "Reduce the dissolved oxygen impediment…".

Outcome P(2): Reduced mortality associated with low dissolved oxygen in white sturgeon, steelhead, fall-run Chinook salmon (San Joaquin populations), and splittail.

If data is available that quantifies the level of mortality directly related to low dissolved oxygen in the Stockton DWSC, then the outcome statement is fine. If data is not available to measure the success of the associated approach, then the outcome statement should be more general such as "Reduced risk of mortality associated with low dissolved oxygen…"

Outcome P(3): Reduced sublethal effects associated with low dissolved oxygen in white sturgeon, steelhead, fall-run Chinook salmon (San Joaquin populations), and splittail.

This appears to be a very logical intended outcome. Although sublethal effects may warrant a description or definition in order to clearly identify which sublethal effects the action is intended to improve.

Outcome P(4): Increase food availability nearby and downstream of the SDWC to delta and longfin smelt, green and white sturgeon, and fry and juvenile steelhead and Chinook salmon.

Although oxygen is the focus of this action and approach, there are other factors within the Stockton DWSC that can affect the lower trophic food webs. Slow moving, neutrally buoyant organisms (phytoplankton and zooplankton) can be negatively affected by depth and residence time (low flows and high flows) in the DWSC, especially if the approach taken does not address depth and flow as a method to improve dissolved oxygen.

Outcome N(1): Potential for oxygen toxicity or free radical formation to fish.

This negative outcome seems out of place considering there was no mention of aeration as an approach. If aeration is included as an approach, this negative outcome should be retained.

References for studies conducted to determine the causes of the low dissolved oxygen conditions in the Stockton Deep Water Ship Channel and studies conducted on the upstream source area for nutrients in the San Joaquin River (Most of the references listed were cited in the conceptual model for dissolved oxygen):

Brunell, M., Borglin, S., Litton, G., 2008. San Joaquin River Up-Stream DO TMDL Project ERP-02D-P63, Task 9 Final Report: Grazing Study. University of the Pacific, Stockton, CA.

Jassby, A., Nieuwenhuyse,E.E.V., 2005. Low dissolved oxygen in an estuarine channel (San Joaquin River, California): mechanisms and models based on long-term time series. San Francisco Estuary and Watershed Science 3.

Jones and Stokes, 1998. Potential solutions for achieving the San Joaquin River dissolved oxygen objectives. Prepared for the City of Stockton Department of Municipal Utilities. Jones and Stokes, Sacramento, CA.

Kendall, C., Young, M., 2008. San Joaquin River Up-Stream DO TMDL Project (ERP-02D-p63) Final Task Report, Task 7: Isotope Study. U.S. Geological Survey, Menlo Park, CA.

Kratzer, C.R., Dileanis, P.D., Zamora, C. Silva, S.R., Kendall, C., Bergamaschi, B.A., Dahlgren, R.A., 2004. Sources and Transport of Nutrients, organic Carbon, and Chlorophyll-a in the San Joaquin River Upstream of Vernalis, California, during Summer and Fall, 2000 and 2001, Report Number 2003-4127. Water Resources investigations Report. US Geological Survey Information Services, Denver, CO, p.124.

Lee, G.F., Jones-Lee, A., 2002. Synthesis of Findings on the Causes and Factors Influencing Low DO in the San Joaquin River Deep Water Ship Channel Near Stockton, CA. G. Fred Lee and Associates, El Macero, CA.

Lee, G.F., Jones-Lee, A., 2003. Managing Excessive Algae Caused Oxygen Demand in the San Joaquin River Deep Water Ship Channel. 7th IWA International Conference on Diffuse Pollution and Basin Management. International Water Association, Dublin, Ireland.

Lehman, P., 2001. The Contribution of Algal Biomass to Oxygen Demand in the San Joaquin River Deep Water Channel, Final Draft Report, San Joaquin River Dissolved Oxygen TMDL Steering Committee. California Department of Water Resources Sacramento, CA.

Lehman, P.W., Sevier, J., Giulianotti, J., Johnson, M. 2004a. Sources of Oxygen demand in the Lower San Joaquin River, California. Estuaries 27, 405-418.

Litton, G.M., 2003. Deposition Rates and Oxygen Demands in the Deep Water Ship Channel of the San Joaquin River, July-November, 2001. Department of Civil Engineering , University of the Pacific, Stockton, CA.

Litton, G.M., Brunell, M., 2004. Ammonia oxygen demands and kinetics in the DWSC. Presentation to the San Joaquin River DO TMDL Technical Work Group, November 18, Sacramento, CA.

Litton, G.M., Nikaido, J., 2001. Sediment deposition Rates and Associated Oxygen Demands in the Deep Water Ship Channel of the San Joaquin River. Stockton, California

July-November, 2000. Department of Civil Engineering, University of the Pacific, Stockton, CA.

McCarty, P.L., 1969. An Evaluation of Algal Decomposition in the San Joaquin Estuary (Research grant DI-16010DL). Federal Water Pollution Control Administration, Washington, DC.

Stringfellow, W., Borglin, S., Hanlon, J., Graham, J., Burks, R., 2008a. Scientific studies supporting the development of a dissolved oxygen TMDL. Water Practice 2, 1-10.

Stringfellow, W., Borglin,S., Hanlon, J., Graham, J., Dahlgren, R., Burkes, R., Spier, C., Letain, T., Hutchinson, K., Granadosin, A. 2008. San Joaquin River Up-Stream DO TMDL Project ERP-02D-P63 Task 4 Final Report: Monitoring Study. University of the Pacific, Stockton, CA.

Stringfellow, W.T., McGahan, J.C., Ploss, L., Brown, R., Chen, C.W., Kendall, C. Quinn, N.W.T., Litton, G., Borglin, S.E., Nader, P., Rajbhandari, H.L., Dahlgren, R., Sebasto, T., Jacobs, K., 2003. Monitoring and Investigations of the San Joaquin River and Tributaries related to Dissolved Oxygen. Environmental Engineering Research Program, University of the pacific, Stockton, CA, p.121.

Volkmar, E.C., Dahlgren, R.A., 2006. Biological oxygen demand dynamics in the lower San Joaquin River, California. Environmental Science and Technology 40, 5653-5660.

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P4	delta and longfin smelt, green and white sturgeon, and fry and juvenile steelhead and Chinook salmon.	Increase food availability nearby and downstream of the SDWC to delta and longfin smelt, green and white sturgeon, and fry and juvenile steelhead and Chinook salmon.		
P3	white sturgeon, steelhead, fall-run Chinook salmon (San Joaquin populations), and splittail.	Reduced sublethal effects associated with low dissolved oxygen in white sturgeon, steelhead, fall-run Chinook salmon (San Joaquin populations), and splittail.		
P2	white sturgeon, steelhead, fall-run Chinook salmon (San Joaquin populations), and splittail.	Reduced mortality associated with low dissolved oxygen in white sturgeon, steelhead, fall-run Chinook salmon (San Joaquin populations), and splittail.		
P1	Chinook salmon, steelhead, and white sturgeon	Reduce impediments to upstream migration of adult San Joaquin River fall-run Chinook salmon, steelhead, and white sturgeon during summer and fall.		
Negative Outcomes				
N1	All	Potential for oxygen toxicity or free radical formation to fish.		

OSCM12
Reduce Risk of Establishment of Zebra and Quagga Mussels

Scientific Evaluation Worksheet

Evaluation Team: Water Quality and Invasives Workgroup

James Haas - Chair , Bruce Herbold – Coach, Chris Foe, Charles Alpers; Inge Werner, Frances Brewster, Karen Larsen, Chrisinte Joab, David Fullerton, Holly Gellerman, Ron Smith, Jan Thompson, Lori Clammurro (note taker)

Date of Last Revision: 15 January 2009

Action: Utilize chemical treatment of isolated populations to reduce risk of establishment of zebra and quagga mussels in Delta waterways.

Problem(s) with Action as written:

This action needs to be rewritten as one specific approach. Chemical treatment cannot be used in the Delta and there is no reasonable way to isolate a specific area within the Delta.
This action should be rewritten under consultation and in cooperation with the Quagga/Zebra Mussel Task Force. Susan Ellis, who is the Aquatic Invasives Department Head for the State of CA, will be making the final decisions within this program (Task Force).

The listed approaches do not reflect the current state of science in regards to the eradication and control of zebra and quagga mussels. For example, rock barriers would not be a reasonable or functional approach in a river channel and would not have consensus (approval) from USACE and, ultimately, would not work. No current monitoring program is in place to tell us if the quagga and zebra mussels are present, and there is currently no program in place to isolate and treat a specific area. By the time these mussels are found in the system, the populations are already too well established.

Current monitoring programs include an early detection monitoring with plankton tows and PCR (DNA analysis) done on high priority waterways. If PCR analysis is positive and veligers are found (test positive), then a team goes into the system and tries to find the mussels. Currently, there is no definitive early detection program which can find non-established populations.

Outcomes: The intended outcomes are applicable for the action but they cannot implement the outcomes given the action and approach outlined.

Potential negative outcome: If chemical treatment proceeded, then you would end up killing all native clams and other mollusks.

OSCM 13:
Remove Non-Native SAV and FAV

Scientific Evaluation Worksheet

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Action: OSCM13: Remove Non-Native Submerged Aquatic Vegetation (SAV) and Floating Aquatic Vegetation (FAV)

Evaluation Team: **Water Quality & Invasives Workgroup**

James Haas - Chair , Bruce Herbold – Coach, Chris Foe, Charles Alpers; Inge Werner, Frances Brewster, Karen Larsen, Chrisinte Joab, David Fullerton, Holly Gellerman, Ron Smith, Jan Thompson, Lori Clammurro (note taker)

Date of Last Revision: March 25, 2009

Action Description and Clarifying Assumptions

Remove water hyacinth (*Eichornia crassipes*) and Brazilian waterweed (*Egeria densa*) from 1,000 water acres of ecologically important Delta waterways each year

Approach

Augment the Department of Boating and Waterways' existing vegetation control program of mechanical and chemical removal of water hyacinth and chemical removal of Brazilian waterweed.

Intended Outcomes as Stated in Conservation Measure

1. Increase food consumption by delta smelt and longfin smelt larvae and juveniles due to higher turbidity
2. Reduce predation mortality of delta smelt as a result of higher turbidity
3. Improve the extent of delta and longfin smelt rearing habitat by reducing local water temperatures
4. Reduce predation on juvenile salmon, steelhead, and splittail by reducing habitat for non-native predatory fish
5. Increase rearing habitat for juvenile salmon (all races), steelhead, and splittail
6. Increased extent of spawning habitat for delta smelt and longfin smelt
7. Increased food availability for delta and longfin smelt near removal locations by increasing light levels below vegetation. *Note: The group opted to remove this outcome from consideration. One wouldn't expect to see an increase in productivity due to more light – as Egeria dies, production is occurring in the water, so it's not likely there would be a large difference. In addition, Egeria is not a habitat delta smelt are believed to occur in.*

Conceptual Model Information Regarding Intended Outcomes

1. The Delta Smelt conceptual model (p. 5, 8) indicates that delta smelt larvae and juveniles' ability to see prey organisms in the water is enhanced by turbidity. Potential implications regarding l*ongfin smelt* are less clear.
2. The Delta Smelt conceptual model (p. 7) indicates that delta smelt may use turbidity to conceal themselves from predators.
3. The Delta Smelt and Longfin Smelt conceptual models indicate the importance of water temperatures for these species. The *Aquatic Vegatation conceptual model indicates that SAV/FAV may increase water temps by slowing water velocities, but shading of the water column due to SAV/FAVcould decrease water temperatures.*

4. *It is well-documented that juvenile Chinook experience predation by sunfish lurking in SAV.*
5. *Reduced predation due to reduced SAV/FAV could provide for more rearing habitat .*
6. There is a question as to whether delta and longfin smelt occur in the areas targeted by this action.
7. The Delta Food Web conceptual model (Durand, 2008) identifies turbidity levels in the Delta as having an inhibitory effect on primary production due to reduced photic zone depth. Removal of SAV/FAV is expected to increase photic zone depth, thereby increasing the potential for phytoplankton blooms. *Note: The group opted to remove this outcome from consideration. One wouldn't expect to see an increase in productivity due to more light – as Egeria dies, production is occurring in the water, so it's not likely there would be a large difference. In addition, Egeria is not a habitat delta smelt are believed to occur in.*

Assumptions

Provided in BDCP Conservation Measure

1. "Ecologically important Delta waterways" include Sutter and Steamboat Sloughs, Middle, Old, and San Joaquin Rivers, the mainsteam Sacramento River, Georgiana Slough, and the North and South forks of the Mokelumne River.
2. Removal would be in addition to that conducted by the Department of Boating and Waterways (projected to be 3000-5000 acres per year for 2007-2011)

Problem(s) with Action as Written:

1. There is a question of whether delta and longfin smelt actually occur in SAV/FAV areas in the Delta, and therefore whether the action would yield the expected benefits to those species. The overlap (or possible lack of overlap) between Egeria and Eichornia extent, and the presence of delta and longfin smelt should be examined.

Scale of Action:

Small – increase of 20% but just 1,000 acres Delta-wide.

Rationale:

If it is assumed that the listed waterways are the only ecologically important waterways, and these totaled 1,000 acres, then this action would be of a larger scale. It doesn't appear that the listed waterways are the only ecologically important waterways, so the group assumed this was a small action. Also, spring (April-May) is believed to be the most important period for delta and longfin smelts' food organisms to grow, but the SAV/FAV in this action experience their peak growth in summer.

Evaluation Summary Tables

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

NO

Nature of Change: Insert short sentence here.

In light of the information contained in several conceptual models and the group's understanding of how the system physically works, this action is not expected to yield substantial changes in system dynamics, possibly with some exception of very small, localized changes where the vegetation has been removed.

Potential Positive Ecological Outcome(s)

Outcome P1: Increase food consumption by delta and longfin smelt due to higher turbidity.

P1a. Delta smelt

The Delta smelt conceptual model (Nobriga and Herbold, 2008) notes the following: "Delta smelt larvae require turbidity to initiate feeding (Baskerville-Bridges et al. 2004); though the distribution of delta smelt near the end of their larval stage is not strongly influenced by turbidity (indexed as Secchi disk depths) ".

Delta smelt larvae do not feed in water that is too clear – we do not know if turbidity associated with SAV is sufficient to have this benefit to delta smelt because it is a spatial range effect.

Turbidity effects on habitat seem to manifest later in the year; earlier turbidity plays a role in initiating upmigration because higher flows of winter/spring raise turbidity.

Magnitude = 1
Inappropriate life stage and season for effect postulated; delta smelt model identifies temperature as primary larval determinate and turbidity as major juvenile/ summer distribution determinate (Bruce Herbold, pers comm.)

There is not believed to be any overlap between SAV treatment areas and delta smelt food areas (Bruce Herbold, pers comm.)

The ecological area of the waterways identified in this action represent a very small percentage of those areas thought to be important for delta smelt.

Certainty = 4
There are published local studies. There is also documentation on the distribution of smelt over many years.

P1b. Longfin smelt

Longfin smelt retain yolk sac long into larval life so that hatched larvae start feeding far downstream of their emergence site (Randy Baxter DFG, pers. comm.). The role and importance of turbidity for longfin smelt feeding efficiency is not as well-known as it is for delta smelt.

As is the case with delta smelt, we do not know if turbidity associated with SAV is sufficient to benefit longfin smelt, even if the importance of turbidity for longfin smelt is demonstrated,.

Turbidity effects on habitat seem to manifest later in the year; earlier turbidity plays a role in initiating upmigration because higher flows of winter/spring raise turbidity.
The magnitude and certainty scores below for long-fin smelt are largely based on what we know about delta smelt, but the certainty score is lower because we generally know less about long-fin smelt behavior and potential relationships to turbidity.

Magnitude = 1
Not believed to be overlap between SAV treatment areas and longfin smelt food areas (Bruce Herbold, pers comm.)

The ecological area of the waterways identified in this action represent a very small percentage of those areas thought to be important for longfin smelt.

Certainty = 3
There is documentation of the distribution of longfin smelt over many years suggesting that they do not overlap with those areas targeted by this action.

Outcome P2: Reduce predation of delta smelt as a result of reduced turbidity

P2. Delta smelt

The Delta smelt model (Nobriga and Herbold, 2008) notes that "Turbidity in the Delta is lower than it was 30-40 years ago (Jassby et al. 2002). Decreasing turbidity in the Delta has constrained the distribution of juveniles (Feyrer et al. 2007; Nobriga et al. 2008) and possibly spawning delta smelt. The most likely explanation is that delta smelt use turbidity to conceal themselves from predators. This is a hypothesis based on studies of small pelagic fishes in other river systems (e.g., Gregory and Levings 1998; Quist et al. 2004)." Thus, smelt probably avoid overly clear water and thereby reduce risk of predation, but it may be that smelt in too clear water are eaten.

As noted under Outcome P1 above, SAV/FAV treatment areas may not be important for delta smelt, as it is believed delta smelt don't occur in these areas. Any benefits of increased turbidity from the removal of SAV/FAV would depend on the spatial range of the effect.

Magnitude = 3
Predation by the visual predator, inland silversides, has been postulated as a likely mortality on emerging smelt. (Bruce Herbold, pers. comm..)

There is not believed to be any overlap between SAV treatment areas and delta smelt distribution (Bruce Herbold, pers comm.), but the predation question is different than feeding (Outcome P1). Delta smelt are concentrated in an area for part of the year, so magnitude would be slightly higher than for Outcome P1

The ecological area of the waterways identified in this action represent a very small percentage of those areas thought to be important for delta smelt.

Certainty = 2
Unclear that turbidity changes would manifest in the appropriate season to provide protection. Much studied elsewhere.

Delta smelt eggs have never been found in the field (Bruce Herbold, pers. comm.)

Outcome P3: Improve the extent of delta and longfin smelt rearing habitat by reducing local water temperatures

P3a. Delta smelt

The rationale for this outcome is that Egeria reduces flow velocities, increasing residence times and water temperatures. There is a question as to whether enhancing light penetration into more turbid water (from Egeria removal) would increase water temperatures..

It is dubious that the action and this potential outcome would overlap in time or space; i.e. reduced Egeria in spring, when fish are present, may be limited; and rearing habitat is limited in the targeted waterways. There are questions regarding the spatial extent of the potential temperature benefits from this action.

Magnitude = 1
Egeria restricts flow and therefore increases water temperatures, but delta smelt are not in these areas at the time of year that Egeria would have an effect. Spring temperatures might be an issue, when delta smelt have a small window for spawning, but it's a stretch (Bruce Herbold, pers comm)

Certainty = 2
Data / study findings not yet published.

P3b. Longfin smelt

This outcome is expected to be the same for longfin smelt as delta smelt (see discussion above).

Magnitude = 1
Egeria restricts flow and therefore increases water temperatures, but longfin smelt are not in these areas at the time of year that Egeria would have an effect. Spring temperatures might be an issue.

Certainty = 2
Data / study findings not yet published.

Outcome P4: Reduce predation on juvenile salmon, steelhead, and splittail by reducing habitat for non-native predatory fish

P4. Salmon, steelhead, and splittail

Predation on juvenile salmon, steelhead, and splittail in the migration corridor can be significant (see Nobriga and Feyrer, 2007; Brown and Michniuk, 2007; and Greenberg et al., 1995. Non-native SAV/FAV may be replaced by other plants, with similar resulting impacts to fish.

Magnitude = 2
There is likely a measurable effect, but the magnitude is small due to the small scale of the action.

Certainty = 2
Certainty is low due to the potential establishment of other non-native vegetation, which would continue to serve as habitat for non-native predators.

Outcome P5: Increase rearing habitat for juvenile salmon (all races), steelhead, and splittail

P5a. Chinook Salmon

The potential role this area plays as rearing habitat is unclear, particularly relative to total rearing habitat.

Magnitude = 3
There is likely a measurable effect; scale of action slightly larger than for other fish species due to salmonids' use of "ecologically important waterways" as defined by this action.

Certainty = 3
Certainty somewhat higher because salmonids expected to rear in areas treated for Egeria, as defined by this action.

P5b. Steelhead

The effect of this action on steelhead rearing is expected to be similar to that on Chinook salmon.

Magnitude = 3
There is likely a measurable effect; scale of action slightly larger than for other fish species due to salmonids' use of "ecologically important waterways" as defined by this action. Also, steelhead juveniles stay in the system longer than juvenile salmon.

Certainty = 3
Certainty somewhat higher because salmonids expected to rear in areas treated by Egeria, as defined by this action.

P5c. Splittail

Smaller scale action than for salmonids; splittail rear over a larger geographic area.

Magnitude = 2
There is likely a measurable effect, but the magnitude is smaller than for salmonids due to the smaller scale of the action.

Certainty = 3
Certainty somewhat high that impact on splittail rearing is less than that for salmonids, because ecological area of those waterways is a smaller portion of splittail rearing habitat.

Outcome P6: Increase extent of spawning habitat for delta smelt and longfin smelt

P6a. Delta smelt

The Delta smelt conceptual model, spawning habitat section notes that "suitable spawning microhabitats likely exist throughout the upper estuary when the overlying water is fresh enough (Hobbs et al. 2007)."

Magnitude = 2
There is no indication that the delta smelt population is affected by limitations of spawning habitat area, since they spawn throughout the Delta in different years, although larval distribution suggests smaller spawning areas in drier years (Bruce Herbold, pers. comm.)

Also, the ecological area of the waterways affected by the action is a very small percentage of the total area important for delta smelt.

Certainty = 2
Preferred spawning habitat in lab does not match habitats in delta, but larvae documented from wide areas of delta suggesting widespread successful spawning in some years (Bruce Herbold, pers. comm..)

P6b. Longfin smelt

Magnitude = 1
Longfin don't have as wide a distribution in the eastern Delta as delta smelt; mostly limited to western Delta and bays.

Certainty = 2
Longfin smelt are not believed to spawn in the geographic areas covered by this action.

Potential Negative Ecological Outcome(s)

Outcome N1: Reduction in zooplankton from effects of herbicide

N1. All covered fish species

Possible impacts from 2,4-D & Glyphosate (both w/ adjuvant Agridex) used on Hyacinth, Fluridone used for Egeria.

Magnitude = 2
Function of herbicide and transport and overt toxicity. Magnitude of the effect may be lower for species that spend only short periods in the Delta.

Certainty = 2
Significant uncertainty with regard to population-level effects of herbicides on zooplankton.

Outcome N2: Reduction in phytoplankton quantity or quality from effects of herbicide

N2. All covered fish species

There is some evidence of reduced green algae production from herbicides (Lürling and Roessink, 2006).

Studies in lakes suggest that filter feeding zooplankton remove phytoplankton while using submerged macrophytes as a refuge from predation (Stansfield et al. 1997).

Submerged macrophytes as refuges for grazing Cladocera against fish predation: observations on seasonal changes in relation to macrophyte cover and predation pressure. (Stansfield et al. 1997).

Recent work in this system using stable isotopes shows that trophic pathways within *E. densa* beds are largely distinct from those in offshore habitats, particularly for juvenile fishes (Grimaldo et al. 2004).

Magnitude = 3
Function of herbicide and transport and overt toxicity.

Certainty = 1
Significant uncertainty with regard to population-level effects of herbicides on phytoplankton, especially in light of other possible stressors (e.g. residence time). Removal of Egeria might enhance feeding success of Corbicula – possible “double-whammy” effect from toxicity of phytoplankton (from herbicides), and resultant increase in phytoplankton consumption by Corbicula who may colonize the former Egeria areas.

Outcome N3: Increase in detritus POC – temporally and spatially limited

SAV is noted in the Dissolved Oxygen (DO) conceptual model in a variety of places – as a source of DO during phytosynthesis (ranked as medium on all DLO); as a source of increased oxygen demand in the sediment (DLO was uniformly low) and as a potential source of reduced velocity and turbulence resulting in less oxygen being mixed into the water from the atmosphere.

N3. All covered fish species

Removal of SAV and FAV will result in localized collections of particulate organic carbon (POC) at the sediment surface, in the water column and as bedload material. The Dissolved Oxygen conceptual model rates the impact of POC derived from SAV/FAV as low in importance, understanding and predictability. However, the DO model does not consider the importance of recently killed plant material. The DO model also shows that an increase in POC in the water column will increase the water column oxygen demand with a rating of high importance and medium understanding and predictability. The ratings shown below are a mixture of these levels of importance and our limited knowledge about the transport or retention of recently killed plants in a treated area.

Magnitude = 2

The magnitude of the effect is likely to be localized and since the critical fish do not live in the SAV beds it seems unlikely they would be directly affected.

Certainty = 2

There is no published data that tells us how long the plant material would reside in the water column or on the bottom. If it rafts up into isolated embayments we might see localized effects that last longer than we might expect. Once the plant leaves start to decompose the plants will be harder to move and are likely to become part of the sediment.

Outcome N4: Increased blooms of microcystis due to a reduction in competition for nutrients

N4. All covered fish species

Two documented effects / possible causal mechanisms. First, microcystis is resistant to glyphosate (Lopez-Rodas et al. 2007). Second, since green algae are not resistant to glyphosate, more nutrients are available to microcystis from reduced competition with green algae (Lürling and Roessink, 2006). Rapid selection for glysophate-resistant plants increases the occurrence of microcystis.

There appears to be considerable anecdotal evidence that microcystis and SAV coexist with little mention of competition for nutrients (Lehman, pers. comm). The best reference is probably: Mazzeo, N., L. Rodriguez-Gallego, C. Kruk, M. Meerhoff, J. Gorga, G. Lacerot, F. Quintans, M. Loureiro, D. Larrea, and F. Garcia-Rodriguez. 2003. Effects of *Egeria densa* plant beds on a shallow lake without piscivourous fish. Hydrobiologia 506-509:591-602.

Magnitude = 2

Based on what we've seen so far, the geographic extent of effects is small, when comparing the area of beds as a food source relative to other food source areas. The discrete areas where Egeria would be treated, as this action is written, translates into a low magnitude score.

Response to herbicides would favor microcystis due to reduced competition for nutrients and because microcystis develops more resistance to herbicides than phytoplankton does.

Certainty = 3
Have peer-reviewed information from outside the system, plus the work of the Department of Boating and Waterways inside the system. There are two peer-reviewed papers for this system, as well.

Outcome N5: Possible toxic effects to juvenile white and green sturgeon from Fluridone and 2,4-D used at approved application rates.

N5. Green and white sturgeon

Documented greater sensitivity of white sturgeon to weed control chemicals (Little and Calfee 2008); green sturgeon included due to relationship (Dwyer et al. 2005), but the extent to which they would use these areas is unclear.

Magnitude = 2
White sturgeon don't spawn in the targeted areas, but juveniles rear in shallow, low-tidal areas (the same conditions in which Egerial colonizes). However the overall magnitude is expected to be small due to the relatively small scale of action.

Certainty = 3
Peer-reviewed studies from outside of the system; ongoing studies within the system.

Outcome N6: Possible endocrine disruption in fish by 2,4-D.

N6. All covered fish species.

LOAEC 164 ug/L (Xie et al. 2005)

Magnitude = 2
Concentrations used to treat Egeria are several orders of magnitude lower than levels of concern from toxicity tests.

Peer-reviewed study: production of vitaligennin (rainbow trout) – concentrations much lower than LC-50 concentrations.

Certainty = 2
Peer-reviewed literature from outside the system; limited range of endocrine disruption effects; also, temporal considerations.

Important Gaps in Information and/or Understanding

Data Needs

It would be helpful to define "ecologically important waterways" for this action, then see how these areas overlap with existing data on the distribution of SAV in the Delta.

Would like to know what percentage of productivity is supplied by Egeria. Two of the amphipods that live in Egeria beds are important food items for native fish. Surface area of Egeria contains algae; could be important for low-productivity system.

Research Needs

Need to research reduction in zooplankton and phytoplankton from herbicides.

When areas are treated for certain SAV, what plant species come in to replace them? Good opportunity for experimental design and monitoring.

Should have follow-up studies to document how species respond to the removal of the SAV/FAV – is the benefit really occurring, does it last, and what's the long-term ecosystem benefit?

Assess Reversibility and Opportunity for Learning

Reversibility

Yes/Easy

> ***Comments:*** If unsuccessful, funding could be de-obligated and spraying for SAV/FAV could stop at any time.

Opportunity for Learning

High

> **Comments** Would be beneficial to ascertain food web effects of aquatic weed spraying activities and of absence of the SAV/FAV communities inhabited by invertebrates, and to see whether other plant species colonize areas formerly occupied by non-native veg.

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Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P4	Chinook salmon, steelhead, and splittail- juvenile	Reduce predation on juvenile salmon, steelhead, and splittail by reducing habitat for non-native predatory fish.	2	2
P5a	Chinook salmon	Increase rearing habitat for juvenile salmon (all races), steelhead, and splittail.	3	3
P6a	Delta smelt	Increased extent of spawning habitat for delta smelt and longfin smelt.	2	2
P3a	Delta smelt	Improve the extent of delta and longfin smelt rearing habitat by reducing local water temperatures.	1	2
P2	delta smelt	Reduce predation of delta smelt as a result of reduced turbidity	3	2
P1a	Delta smelt	Increase food consumption by delta and longfin smelt due to higher turbidity	1	4
P6b	Longfin smelt	Increased extent of spawning habitat for delta smelt and longfin smelt.	1	2
P3b	Longfin smelt	Improve the extent of delta and longfin smelt rearing habitat by reducing local water temperatures.	1	2
P1b	Longfin smelt	Increase food consumption by delta and longfin smelt due to higher turbidity	1	3
P5c	Splittail	Increase rearing habitat for juvenile salmon (all races), steelhead, and splittail.	2	3
P5b	Steelhead	Increase rearing habitat for juvenile salmon (all races), steelhead, and splittail.	3	3

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Negative Outcomes				
N6	All	Possible endocrine disruption in fish by 2,4-D	2	2
N4	All	Increased blooms of microcystis due to a reduction in competition for nutrients	2	3
N3	All	Increase in detritus POC – temporally and spatially limited	2	2
N2	All	Reduction in phytoplankton quantity or quality from effects of herbicide	3	1
N1	All	Reduction in zooplankton from effects of herbicide	2	2
N5	Green & White Sturgeon	Possible toxic effects to juvenile white and green sturgeon from Fluridone and 2,4-D used at approved application rates	2	3

OSCM 14:
Increase Harvest of Non- Native Predatory Fish

Scientific Evaluation Worksheet

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Action: Increase Sport Fishing Harvest of Non-native Predatory Fish

Evaluation Team: Hatcheries and Harvest Workgroup

Brad Cavallo - Chair, Dave Zezulak – Coach/participant, Jim Smith, Jason Kindopp, Shirley Witalis, Alison Willy, Josh Israel, Larry Wise (note taker).

Date of Last Revision: February 18, 2009

Action Description and Clarifying Assumptions

Modify sport fishing regulations to reduce the abundance, size, and, therefore, reproductive capacity of black bass (largemouth, smallmouth, and spotted bass) and striped bass in the Sacramento-San Joaquin Delta (the Delta).

Approach

1. Remove all size and bag limits for sport fishing take of black bass and striped bass in the Delta.

Intended Outcomes as Stated in Conservation Measure

Note: Striped bass and black bass use habitat differently, occur in different areas, and therefore affect the covered species differently. As such, they are treated separately in this evaluation.

Striped bass

1a. Reduced predation mortality of Chinook salmon (all races) by striped bass.
1b. Reduced predation mortality of steelhead by striped bass.
1c. Reduced predation mortality of Delta smelt by striped bass.
1d. Reduced predation mortality of longfin smelt by striped bass.
1e. Reduced predation mortality of splittail by striped bass.
1f. Reduced predation mortality of green sturgeon by striped bass.
1g. Reduced predation mortality of white sturgeon by striped bass.
2. Reduced competition for food with delta and longfin smelt by juvenile striped bass.

Black bass

3a. Reduced predation mortality of Chinook salmon (all races).
3b. Reduced predation mortality of steelhead by black bass.
3c. Reduced predation mortality of Delta smelt by black bass.
3d. Reduced predation mortality of longfin smelt by black bass.
3e. Reduced predation mortality of splittail by black bass.
3f. Reduced predation mortality of green sturgeon by black bass.
3g. Reduced predation mortality of white sturgeon by black bass.

Both bass species

4. Increased knowledge about the efficacy of using sport fishing regulations to modify bass population size.

Additional outcomes:

- Increased bycatch of non-target species during fishing efforts targeted at striped and black bass.
- Release other predator populations from predation pressure currently imposed by striped and black bass.
- Release other competitor populations from predation pressure currently imposed by striped and black bass.
- Unintended changes to the striped and black bass populations. e.g., decrease abundance but increase average size.

General Conceptual Model Support for Intended Outcomes

1a. Reduced Chinook mortality (striped bass): Yes, implied in Chinook, Salmonid model pages 41 and 46, Chinook Stressors tables.
1b. Reduced steelhead mortality (striped bass): Yes, implied in Salmonid model Stressor Table for Central Valley Steelhead, predation by bass is an important stressor.
1c. Reduced Delta smelt mortality (striped bass): Yes, implied in Delta smelt model pages 12, 13, 27.
1d. Reduced longfin smelt mortality (striped bass): Yes, implied and stated in Longfin smelt model pages 8, 14, 19, 26, 34.
1e. Reduced splittail mortality (striped bass): Yes, implied in Splittail model page 8.
1f. Reduced green sturgeon mortality (striped bass): Yes, implied in Green sturgeon model p. 7.
1g. Reduced white sturgeon mortality (striped bass): No model support.
2. Reduced competition for food: Yes, implied and stated in Longfin smelt model pages 8 and 25.
3a. Reduced Chinook mortality (black bass): Yes, implied in Salmonid model on page 46 and in Stressor Tables for Chinook salmon.
3b. Reduced steelhead mortality (black bass): Yes, implied in Salmonid model Stressor Table for Central Valley Steelhead.
3c. Reduced Delta smelt mortality (black bass): No model support.
3d. Reduced longfin smelt mortality (black bass): Yes, implied in longfin smelt model Stressor table (p. 34).
3e. Reduced splittail mortality (black bass): No model support. See supporting reference in Attachment A.
3f. Reduced sturgeon mortality (black bass): No model support.
3g. Reduced white sturgeon mortality (black bass): No model support.
4. Increased knowledge: No model support. Supported by simple logic.

Assumptions

Provided in BDCP Conservation Measure
None.

Added by Evaluation Team
None

Problem(s) with Action as Written

1. The action assumes that removing size and bag limits will increase harvest and reduce population sizes of black bass and striped bass. However, the action may simply change the age structure of these populations without changing their total abundance or biomass.
2. Additionally, social pressure to establish a trophy striped bass fishery may exist and the cultural shift required to implement the action has not been evaluated.

Scale of Action

Large

Rationale:
The action has a large spatial extent, a significant duration, and represents a major reversal compared to existing conditions.

Evaluation Summary Tables

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Relation to Existing Conditions

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

The action is not expected to change any of the boundary conditions (physical background and inputs within and outside the Delta) described in the DRERIP Boundary Conditions paper.

Potential Positive Ecological Outcome(s)

Outcome P1: Reduced predation mortality by striped bass

P1a. Chinook salmon (all races)

General Observations

See Attachment A for detailed information regarding the following references:
- Salmonid model pages 41 and 46, Chinook Stressors tables
- Nobriga & Feyrer (2007) Table 1 (page 6) and page 9
- Nobriga & Feyrer (2008) Table 2
- ODFW 1998 pages 5, 14, 15

Magnitude = 2

As this predator is a generalist, predation pressure on a single prey species may not be high. Thus the magnitude of the prey species' response to reduced predator population size is difficult to predict. Predation rates may be higher than steelhead, but not enough to result in increased magnitude.

Certainty = 3

Empirical evidence for this outcome is limited to a few references.

P1b. Steelhead

General Observations

See Attachment A for detailed information regarding the following references:
- Salmonid model Stressor Table for Central Valley Steelhead
- ODFW 1998 pages 5, 14, 15

Magnitude = 2

As this predator is a generalist, predation pressure on a single prey species may not be high. Thus the magnitude of the prey species' response to reduced predator population size is difficult to predict. Steelhead are larger when moving through the delta making them less susceptible to predation than Chinook salmon.

Certainty = 2

Empirical evidence for this outcome is limited to a few references.

P1c. Delta smelt

General Observations

See Attachment A for detailed information regarding the following references:
- Delta smelt model pages 12, 13, 27
- Nobriga & Feyrer (2008) Table 2

Magnitude = 2

As this predator is a generalist, predation pressure on a single prey species may not be high. Thus the magnitude of the prey species' response to reduced predator population size is difficult to predict.

Certainty = 2

Empirical evidence for this outcome is limited to a few references.

P1d. Longfin smelt

General Observations

See Attachment A for detailed information regarding the following references:

- Longfin smelt model pages 8, 14, 19, 26, 34

Magnitude = 2

As this predator is a generalist, predation pressure on a single prey species may not be high. Thus the magnitude of the prey species' response to reduced predator population size is difficult to predict.

Certainty = 2

Empirical evidence for this outcome is limited to a few references.

P1e. Splittail

General Observations

See Attachment A for detailed information regarding the following references:

- Splittail model page 8
- Nobriga & Feyrer (2008) Table 2

Magnitude = 2

As this predator is a generalist, predation pressure on a single prey species may not be high. Thus the magnitude of the prey species' response to reduced predator population size is difficult to predict. Splittail abundances are driven more by hydrology than predation, and so predation may not be an important population driver.

Certainty = 2

Empirical evidence for this outcome is limited to a few references.

P1f. Green sturgeon

General Observations

See Attachment A for detailed information regarding the following reference:

- Green sturgeon model page 7

Magnitude = 1

As this predator is a generalist, predation pressure on a single prey species may not be high. Thus the magnitude of the prey species' response to reduced predator population size is difficult to predict. Green sturgeon are a benthic species and as such may be less susceptible to pelagic predation.

Certainty = 2

Empirical evidence for this outcome is limited to a few references.

P1g. White sturgeon

Magnitude = 1

As this predator is a generalist, predation pressure on a single prey species may not be high. Thus the magnitude of the prey species' response to reduced predator population size is difficult to predict. White sturgeon are a benthic species and as such may be less susceptible to pelagic predation.

Certainty = 2

Empirical evidence for this outcome is limited to a few references.

Outcome P2: Reduced competition for food with delta and longfin smelt by juvenile striped bass

General Observations

See Attachment A for detailed information regarding the following references:
- Longfin smelt model page 8, 25

Magnitude = 3

These species all feed on copepods at some point in their life.

Certainty = 2

Empirical evidence for this outcome is limited to a few references. Window of dietary overlap may be limited, but striped bass juvenile populations would be substantially reduced.

Outcome P3: Reduced predation mortality by black bass

P3a. Chinook salmon (all races)

General Observations

See Attachment A for detailed information regarding the following references:
- Salmonid model p. 46 and Stressor Tables for Chinook salmon
- Nobriga & Feyrer (2007) Table 1
- ODFW (1998) pages 5, 11

Magnitude = 2

As this predator is a generalist, predation pressure on a single prey species may not be high. Thus the magnitude of the prey species' response to reduced predator population size is difficult to predict.

Certainty = 3

There are a number of studies indicating predation of salmon by black bass, but magnitude of this predation is unknown.

P3b. Steelhead

General Observations

See Attachment A for detailed information regarding the following references:
- Salmonid model Stressor Table for Central Valley Steelhead
- ODFW (1998) pages 5, 11

Magnitude = 2

As this predator is a generalist, predation pressure on a single prey species may not be high. Thus the magnitude of the prey species' response to reduced predator population size is difficult to predict.

Certainty = 2

Empirical evidence for this outcome is limited to a few references. Steelhead are larger when migrating through Delta and so may not be as susceptible to predation.

P3c. Delta smelt

General Observations

See Attachment A for detailed information regarding the following reference:
- Eisermann (2006) page 33

Magnitude = 2

As this predator is a generalist, predation pressure on a single prey species may not be high. Thus the magnitude of the prey species' response to reduced predator population size is difficult to predict.

Certainty = 2

Empirical evidence for this outcome is limited to a few references.

P3d. Longfin smelt

General Observations

See Attachment A for detailed information regarding the following references:
- Longfin smelt model p. 19, stressor table (p. 34)
- Eisermann (2006) page 33

Magnitude = 2

As this predator is a generalist, predation pressure on a single prey species may not be high. Thus the magnitude of the prey species' response to reduced predator population size is difficult to predict.

Certainty = 2

Empirical evidence for this outcome is limited to a few references.

P3e. Splittail

General Observations

See Attachment A for detailed information regarding the following reference:
- Nobriga & Feyrer (2007) Table 1
- Eisermann (2006) page 33

Magnitude = 1

As this predator is a generalist, predation pressure on a single prey species may not be high. Thus the magnitude of the prey species' response to reduced predator population size is difficult to predict. Populations driven by hydrology, not predation.

Certainty = 2

Empirical evidence for this outcome is limited to a few references.

P3f. Green sturgeon

Magnitude = 1

As this predator is a generalist, predation pressure on a single prey species may not be high. Thus the magnitude of the prey species' response to reduced predator population size is difficult to predict.

Certainty = 2

Empirical evidence for this outcome is limited to a few references.

P3g. White sturgeon

Magnitude = 1

As this predator is a generalist, predation pressure on a single prey species may not be high. Thus the magnitude of the prey species' response to reduced predator population size is difficult to predict.

Certainty = 2

Empirical evidence for this outcome is limited to a few references.

Outcome P4: Increased knowledge about the efficacy of using fishing regulations to modify bass population size

Magnitude = 2

Certainty = 2

Support for this outcome is based on reasoning rather than empirical evidence.

Potential Negative Ecological Outcome(s)

Outcome N1: Increased bycatch of non-target species

General Observations

Not believed to be large risk.

Magnitude = 1

Certainty = 2

We have found no empirical evidence for this outcome.

Outcome N2: Release of other predator populations from predation pressure

General Observations

See Attachment A for detailed information regarding the following reference:
- Nobriga & Feyrer (2008) Table 2
- Swingle (1946)
- Missouri Dept. of Conservation Student Guide (2006)
- Shroyer et al. (2003)

Magnitude = 2

Largemouth bass are shown to prefer sunfish species (e.g., bluegill) over other forage fish, and often keep sunfish populations at or below carrying capacity (see Swingle 1946, Missouri Dept of Conservation 2006, Shroyer et al. 2003 – observed only a weak negative relationship between bass density and bluegill recruitment)

Certainty = 2

Empirical evidence for this outcome is limited to a few references.

Outcome N3: Release of other competitor populations from predation pressure

General Observations

See Attachment A for detailed information regarding the following references:
- Dettmers et al. (1998)
- Gleason & Bengston (1996)
- Bennett (2005) pages 49-50
- Nobriga & Feyrer (2008) Table 2
- Begon et al. (1996) pp. 325-326

Magnitude = 3

Numerous competitors to these species in Delta, who are also preyed upon by striped bass and black bass

Certainty = 3

Outcome N4: Unintended changes to the striped and black bass populations (e.g., decrease abundance but increase average size)

General Observations

See Attachment A for detailed information regarding the following references:
- Hartman (2003)
- Mayo et al. (1998)

Magnitude = 2

Might shift the population to smaller fish that are less desirable to anglers, which may consume more smelt.

Certainty = 2

Important Gaps in Information and/or Understanding

Data Needs

- Additional data are needed to address whether the action could release other delta and longfin smelt predators or competitor populations from predation pressure currently imposed by striped and black bass.
- Additional data are needed to address the potential response of target populations.
- Understanding of how fishermen would respond to changes in harvest regulations.
- Potential for other cascading effects. For example, Maezono & Miyashita (2004) found removal of bass resulted in increased crayfish populations, which then reduced macrophyte densities because they are consumed by crayfish. This type of effect could affect habitat structure.

Assess Reversibility and Opportunity for Learning

Reversibility

Yes/easy

Opportunity for Learning

High – with regard to managing predator populations through sport harvest regulations

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DRERIP Evaluation Workshop – Attachment A: References arranged by Outcome, with notes

OUTCOME P1: Reduced predation mortality by striped bass

P1a. Chinook salmon (all races)

1. Salmonid Conceptual Model
    - Striped bass consume Chinook salmon in the Delta, although the effect is likely small (pages 41 and 46).
    - Predation by bass is an important stressor (Chinook Stressors Tables).
2. Nobriga & Feyrer (2007)
    - Striped bass consume Chinook salmon in the Delta (Table 1).
    - Striped bass may be significant predators of Chinook in the Delta (page 9).
3. Nobriga & Feyrer (2008)
    - Prey items for striped bass in the Delta include Chinook salmon (Table 2).
    - However, striped bass appear to consume a wide variety of prey species and this diversity in prey items may mean that striped bass will not exert strong control over any one prey species (Table 2).
3. ODFW (1998)
    - Evidence of relief from predation via increased exploitation on non-native fishes is mixed (p. 5)
    - Periods of high striped bass abundance have correlated with periods of high coho salmon abundance, indicating that striped bass do not exert a lot of control over coho populations evaluated in Oregon. Evidence that striped bass cause declines in coho is mixed, although they are shown to eat salmonids in this region (p. 15).
    - Removal of the two bass per 24-hr period/30” limit would substantially increase harvest of smaller striped bass and cause reductions in those populations (p. 15).

P1b. Steelhead

1. Salmonid Conceptual Model
    - Predation by bass is an important stressor (Central Valley Steelhead Stressors Table).
2. ODFW (1998)
    - See information under Chinook salmon (P1a).

P1c. Delta smelt

1. Delta smelt Conceptual Model
    - Striped bass consume Delta smelt (pages 12, 13, 27).
2. Nobriga & Feyrer (2008)
    - Prey items for striped bass include Delta smelt (Table 2).
    - However, striped bass appear to consume a wide variety of prey species and this diversity in prey items may mean that striped bass will not exert strong control over any one prey species (Table 2).

P1d. Longfin smelt

1. Longfin Smelt Conceptual Model
    - Striped bass in the Delta consume longfin smelt (pages 8, 14, 19, 26, 34).

P1e. Splittail

1. Splittail Conceptual Model
    - Striped bass consume splittail in the Delta (page 8).
2. Nobriga & Feyrer (2008)
    - Prey items for striped bass in the Delta include splittail (Table 2).
    - However, striped bass appear to consume a wide variety of prey species and this diversity in prey items may mean that striped bass will not exert strong control over any one prey species (Table 2).

P1f. Green sturgeon

1. Green Sturgeon Conceptual Model
   - Anecdotally, striped bass may consume green sturgeon in the Sacramento River (page 7).

P1g. White sturgeon

OUTCOME P2: Reduced competition for food with delta and longfin smelt by juvenile striped bass

1. Longfin Smelt Conceptual Model
   - Juvenile striped bass compete for prey with longfin smelt (page 8, 25).
2. **See Stevens et al. (1985), Musick et al. (2000), & Bay-Delta Oversight Council (1995) below indicating that increased harvest would reduce striped bass populations.**

OUTCOME P3: Reduced predation mortality by black bass

P3a. Chinook salmon (all races)

1. Salmonid Conceptual Model
   - Predation by bass is an important stressor (p. 46 and Chinook Stressors Tables).
2. Nobriga & Feyrer (2007)
   - Black bass consume Chinook salmon in the Delta (Table 1).
3. ODFW (1998)
   - Evidence of relief from predation via increased exploitation on non-native fishes is mixed (p. 5)
   - The harvest rate for bass is generally low because they are difficult to catch, and catch-and-release is practiced by the most effective bass anglers (p. 11).
   - Modeling results for Tenmile Lakes in Oregon (area where largemouth bass angling is higher than in most other largemouth bass fisheries) indicate that removal of harvest regulations for largemouth would increase the harvest rate from 8-18%, reducing the bass population by 16%. Unlikely that reductions of this magnitude would have a measurable effect on native salmonid populations (p. 11).

P3b. Steelhead

1. Salmonid Conceptual Model
   - Predation by bass is an important stressor (Central Valley Steelhead Stressors Table).
2. ODFW (1998)
   - See information under Chinook salmon (P3a).

P3c. Delta smelt

1. Eisermann (2006)
   - Introduction of largemouth bass resulted in extinction of bird species (Atitlan grebe) in Guatemala because bass reduced abundance of grebe's food resources (p. 33). Removal of bass should results in increased abundance of forage fish for waterbirds.

P3d. Longfin smelt

1. Longfin Smelt Conceptual Model
   - Predation by bass is an important stressor (Stressors Table).
   - Predation is likely an important source of mortality for eggs and larvae (page 19).
2. Eisermann (2006)
   - See information under Delta smelt (P3c).

P3e. Splittail

1. Nobriga & Feyrer (2007)
   - Black bass consume splittail in the Delta (Table 1).
2. Eisermann (2006)
   - See information under Delta smelt (P3c).

P3f. Green sturgeon

P3g. White sturgeon

OUTCOME P4: Increased knowledge about the efficacy of using sport fishing regulations to modify bass population size

- No external references – this outcome is sufficiently supported by simple logic.

OUTCOME N2: Release other predator populations from predation pressure currently imposed by striped and black bass

1. Nobriga & Feyrer (2008)
   - Striped bass prey on other piscivorous Delta fishes (Table 2).
2. Swingle (1946)
   - Largemouth bass preferred bluegill over other forage fish (golden shiners, gizzard shad, *Gambusia*) stocked in experimental ponds (Abstract).
3. Missouri Department of Conservation (2006)
   - Largemouth bass prey on sunfish. Reduced bass populations could cause sunfish to exceed their carrying capacity and to consume large numbers of their prey (pp. 19, 20).
4. Shroyer et al. (2003)
   - Several authors have reported overharvest of largemouth bass leading to bluegill overpopulation and poorer fishing (see references within Shroyer et al.)
   - Shroyer et al. documented a significant increase in largemouth bass density with prohibition of bass harvest, but only a weak negative correlation between bass density and bluegill recruitment.
5. Maezono & Miyashita (2004)
   - Black bass removal from farm ponds in Japan resulted in increased populations of invasive crayfish, which reduced abundance of macrophytes. Macrophytes are important for spawning and shelter for native species.

OUTCOME N3: Release other competitor populations from predation pressure currently imposed by striped and black bass

1. Dettmers et al. (1998)
   - Striped bass can directly regulate shad populations in a closed system
2. Gleason & Bengston (1996)
   - Striped bass can directly regulate silverside populations in a closed system
3. Bennett (2005)
   - Delta smelt and inland silversides compete for prey (pages 49-50).
4. Nobriga & Feyrer (2008)
   - Striped bass prey on inland silversides in the Delta (Table 2), which compete with Delta smelt (see above).
5. Begon et al. (1996)
   - Increased predation may result in reduced competition among remaining prey for limiting resources (pp. 325-326). Thus, reduced predation would be expected to increase competition.

OUTCOME N4: Unintended changes to the striped and black bass populations (e.g., decrease abundance but increase average size)

1. Hartman (2003)
   - Management actions to change the effect of striped bass predation on prey species can be difficult due to the complexity of the interactions between populations.
2. Mayo et al. (1998)
   - Striped bass may not act as direct top-down control in open system with many predator and prey species interacting
   - Management actions to change the effect of predation on prey species can be difficult due to the complexity of the interactions between populations.

----

1. Stevens et al. (1985)

   - Removal of bag and size limits will likely decrease population and reproductive effort of basses. Twice during the last century, angling regulations were made more stringent to protect the striped bass population in the Sacramento-San Joaquin Estuary. Reductions in both the daily bag limit and the minimum total length were implemented. The striped bass population stabilized after the 1956 change in angling regulations but destabilized after 1976 (from A. Willy).

2. Musick et al. (2000)

   - Marine overfishing is a well-known phenomenon and the references are too numerous to site. See Musick 2000 for an illustrative list of citations. If angling regulations that protect both numbers and age-classes of striped bass can be used to stabilize the population, as has been done in the past, then relief from angling regulations is likely to destabilize the population (from A. Willy).

3. Bay-Delta Oversight Council (1995), Stevens et al. (1985)

   - Angling regulations implemented in 1982 (Stevens et al 1985) apparently had less of a population response than earlier regulations, even though a hatchery program was concurrently implemented (Bay-Delta Oversight Council 1995). It should be noted that, by 1995, CDFG biologists looked at striped bass declines after 1976 and stated that “other factors are to blame and existing angling regulates are appropriate.” In addition, catch of “sub-legal” striped bass has consistently exceeded legal harvest indicating that there is ongoing harvest pressure on striped bass (Bay-Delta Oversight Council 1995; from A. Willy).

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P3a	Chinook salmon	Reduced predation mortality by black bass	2	3
P1a	Chinook salmon	Reduced predation mortality by striped bass	2	3
P3c	Delta smelt	Reduced predation mortality by black bass	2	2
P1c	Delta smelt	Reduced predation mortality by striped bass	2	2
P4	Delta smelt & Longfin smelt	Increased knowledge about the efficacy of using fishing regulations to modify bass population size	2	2
P2	Delta smelt & Longfin smelt	Reduced competition for food with delta and longfin smelt by juvenile striped bass	3	2
P3f	Green Sturgeon	Reduced predation mortality by black bass	1	2
P1f	Green Sturgeon	Reduced predation mortality by striped bass	1	2

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes (contd.)				
P3d	Longfin smelt	Reduced predation mortality by black bass	2	2
P1d	Longfin smelt	Reduced predation mortality by striped bass	2	2
P3e	Splittail	Reduced predation mortality by black bass	1	2
P1e	Splittail	Reduced predation mortality by striped bass	2	2
P3b	Steelhead	Reduced predation mortality by black bass	2	2
P1b	Steelhead	Reduced predation mortality by striped bass	2	2
P3g	White Sturgeon	Reduced predation mortality by black bass	1	2
P1g	White Sturgeon	Reduced predation mortality by striped bass	1	2

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Negative Outcomes				
N4	All	Unintended changes to the striped and black bass populations (e.g., decrease abundance but increase average size)	2	2
N3	All	Release of other competitor populations from predation pressure	3	3
N2	All	Release of other predator populations from predation pressure	2	2
N1	All	Increased bycatch of non-target species	1	2

OSCM 16:
Enhance Delta Enforcement

Scientific Evaluation Worksheet

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Action: Enhance Delta Enforcement

Evaluation Team: Hatcheries and Harvest Workgroup

Brad Cavallo - Chair, Jim Smith, Jason Kindopp, Shirley Witalis, Alison Willy, Josh Israel, Dave Zezulak – Coach, Larry Wise (note taker)

Date of Last Revision: February 17, 2009

Action Description and Clarifying Assumptions

Increase enforcement of existing fishing regulations to reduce illegal harvest of catchable covered salmonids and sturgeon in the Delta and tributary rivers, including summer holding habitat for spring-run and sturgeon.

Approach

1. Fund increased enforcement of fishing regulations by the California Department of Fish and Game through the term of the BDCP.

Intended Outcomes as Stated in Conservation Measure

1. Increased population sizes of green sturgeon.
2. Increased population sizes of white sturgeon.
3. Increased population sizes of Chinook salmon (all races).
4. Increased population sizes of steelhead.

Note: This may not result in a larger population size, but will reduce mortality. Enforcement is only part of the process. Penalties should also be addressed.

NOTE: The degree of importance of this action varies inversely with the size of the population.

See Attachment A for detailed information regarding the following references:
- Bay-Delta Oversight Council (1995) p. 17
- Moyle et al. (2008) p. 69 (Fisheries section)
- Futuyma (1998) p. 304
- Begon et al. (1996) pp. 385-386

General Conceptual Model Support for Intended Outcomes

1. Green sturgeon population: yes, implied in life stage stressor matrix pp. 27,30; population section pp. 18-19, poaching is likely, but limited understanding of impact on population.
2. White sturgeon population: yes, implied on pp. 10,17,20, poaching is serious and increasing problem.
3. Chinook population: yes, implied in stressor tables for winter- fall- and spring-run Chinook, poaching during holding period for spring-run.
4. Steelhead population: no, implied in stressor table for steelhead, intentional illegal poaching is probably rare. By-catch mortality is unavoidable so long as sportfishing is legal.

Assumptions

Provided in BDCP Conservation Measure

1. Funds will support the addition of 17 field wardens and 5 supervisory and support staff as part of the Delta-Bay Enhanced Enforcement Program (DBEEP). The program currently employs 9 field wardens and 1 supervisor
2. Field wardens' efforts will focus on enforcement of regulations for covered fish species only.

Added by Evaluation Team

1. List here.

Problem(s) with Action as Written:

1. Numerous other factors affect population sizes. Therefore, this action may not result in a detectable change in populations.

Scale of Action:

Medium

Rationale:
Will substantially increase size of enforcement group, regional basis.

Evaluation Summary Tables

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Relation to Existing Conditions

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

NO. It is not affecting habitat or biological processes. This may influence population dynamics of species/runs with small adult abundances.

Potential Positive Ecological Outcome(s)

Outcome P1: Increased population sizes of green sturgeon

General Observations

See Attachment A for detailed information regarding the following references:
- Green sturgeon conceptual model life stage stressor matrix pp. 27,30; population section pp. 18-19
- Beamesderfer et al. (2007)
- CDFG (unpublished)
- Boreman (1997)
- D. Tanner, NMFS Enforcement Officer (pers. comm., 2009)
- DBEEP (2007)

Magnitude = 3

Small decrease in mortality may result in a large change in population. Don't know if adult population size is a key limiting factor for green sturgeon.

Certainty = 2

Limiting factors not well understood, production highly variable and influenced by environmental factors.

Outcome P2: Increased population sizes of white sturgeon

General Observations

See Attachment A for detailed information regarding the following references:
- White sturgeon conceptual model pp. 10,17,20
- Beamesderfer et al. (2007)
- Bay-Delta Oversight Council (1995) p. 34
- CDFG (unpublished)
- Boreman (1997)
- DFG Sturgeon Report Card (2007)
- DBEEP (2007)

Magnitude = 3

Small decrease in mortality may result in a large change in population.

Certainty = 2

Poaching well documented in bay. Effect of poaching on population size is not well understood.

Outcome P3: Increased population sizes of Chinook salmon

General Observations

DRERIP (salmon stressor tables) indicates spring run is more susceptible to poaching due to over summer holding and ease of locating them. The mark selective program will necessitate additional enforcement.

See Attachment A for detailed information regarding the following references:
- Salmonid conceptual model stressor tables for winter- fall- and spring-run Chinook
- Williams (2006) p. 248
- Bay-Delta Oversight Council (1995) p. 17

Magnitude = 2-3

Spring-run populations are more susceptible than other runs because they are found consistently in summer holding pools, where they are easy to poach (CV Salmon model).

Small populations are more vulnerable to the effects of poaching than larger populations.

Certainty = 2

Effect of poaching on population size is not well understood.

Outcome P4: Increased population sizes of steelhead

General Observations

See Attachment A for detailed information regarding the following references:
- Salmonid conceptual model stressor table for steelhead
- Moyle et al. (2008) p. 69 (Fisheries section)
- DFG Creel Survey Annual Performance Report, July 2007-June 2008
- DBEEP (2007)
- DFG Steelhead Report Card (2007)

Magnitude = 2

All hatchery steelhead are marked, so distinguishing from hatchery fish from wild fish is possible for legal fisherman. Fishery is closed to wild fish.

Magnitude score of 2 for outcome P4 is partially informed by DBEEP (2007). DBEEP (2007) briefly discusses poaching of sturgeon and striped bass as significant enforcement issues with no mention of steelhead. Although the report is limited in its discussion of poaching activities, the fact that steelhead are not mentioned demonstrates the relative lack of concern on the part of the DBEEP staff.

Certainty = 2

Steelhead biology and harvest is poorly understood. Production is highly variable depending on environmental conditions (McEwan & Jackson 1996).

Potential Negative Ecological Outcome(s)

Outcome N1: Information gap about where poaching is most important may result in effort being directed at less important areas and may shift poaching to areas with greater importance to the population

General Observations

See Attachment A for detailed information regarding the following references:
- Moeltner (2006) pp. 18-21
- Gentner (2004) pp. 8,10

Magnitude = 1

Potential for impact for this happening is small and dependent on faulty implementation.

Certainty = 2

Important Gaps in Information and/or Understanding

Data Needs

- Information gap about where poaching is most important.
- Importance of poaching on individual runs.

Research Needs

Assess Reversibility and Opportunity for Learning

Reversibility

YES

Opportunity for Learning

Low

Comments: Potential to better understand importance of poaching in population dynamics.

References Cited

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DRERIP Evaluation Workshop – Attachment A

Enhanced Delta Enforcement

OUTCOME P1: INCREASED POPULATION SIZES OF GREEN STURGEON

1. Green sturgeon conceptual model

   - "*Poaching for sturgeon seems to be a threat in the Sacramento River, and green sturgeon may be illegally harvested in these operations.* Manager's understanding for the effect of fishing-associated mortality on green sturgeon is low and the predictability of this stressor is little" (Population section, pp. 18-19).

   - Life stage stressor matrix (p. 27): Harvest causes direct mortality in the Delta and river.

   - Life stage stressor matrix including importance, understanding and predictability scores (p. 30): Harvest will have moderate impacts on coastal migrants (Delta), spawning adults (river), and mature adults (ocean/Delta/river) with an importance score of 3 for each. An importance score of 2 was assigned to spawning adults in Delta/bay habitat and post-spawners in river/Delta habitat. There is a limited understanding (score of 2) for all sturgeon except mature adults in ocean/Delta/bay habitat (score of 3). Predictability scores were 3 across the board.

2. Beamesderfer et al. (2007)

   - Models indicate that an increase in harvest of 2-3% reduces egg production levels indicating stocks are susceptible to reduced population sizes.

3. CDFG (unpublished)

   - Green sturgeon fishing mortality estimated at 0%.

4. Boreman (1997)

   - "Restricting fishing mortality may be the only tool available to managers for restoring depleted populations. At a minimum, reducing fishing pressure on long-lived species allows managers time to detect and correct the true causes of population decline."

5. NMFS Enforcement Officer Don Tanner (Personal Communication 2009)

   - "I know CDFG has a 'task force' geared towards stopping the poaching of green sturgeon for roe. They consider the cases important and large in scope due to its nexus to organized crime. . ."
   - Don also explained that poaching is considered significant because of makeshift factories where workers jar (with fake labels) the illegally harvested roe for sale and consumption—therefore it is an on-going operation.
   - NMFS Enforcement will actively partner with CDFG Enforcement on green sturgeon issues once the proposed 4(d) rule and designated critical habitat is finalized for green sturgeon, expected to occur in the Spring of 2009 (a few months).

6. DBEEP (2007)

   - Poaching of sturgeon is a significant enforcement issue.

OUTCOME P2: INCREASED POPULATION SIZES OF WHITE STURGEON

1. White sturgeon conceptual model

    - "*Poaching and the illegal commercialization of the sturgeon fishery to supply the black market with caviar and sturgeon flesh is a serious and increasing problem (Gingras, CDFG, pers. comm.), and the resultant mortality rates from this industry are unquantifiable but may be quite high. For example, the unusually low annual survival rates (~ 60-82%) during the 1990s (Schaffter and Kohlhorst 1999) may have been due in part to poaching.* In sum, the total annual mortality attributable to humans may be sufficient to limit completion of the life cycle for a significant proportion of the white sturgeon population via reduction in overall population size and size-selective harvest for large, fecund individuals" (Key limiting factors section, p. 10).

    - "Flows are diverted back to the main channel from the bypasses when water levels subside, and the bypasses dry up. *When these bypasses are closed, white sturgeon on their way to the spawning grounds are often stranded, leaving them vulnerable to poaching*, desiccation, scavenging, and death unless they are rescued (Zoltan Matica, DWR, pers. comm.)" (Poaching of fish stranded in dry bypass areas, p. 17).

    - "White sturgeon are a popular sport fish and *the object of a lucrative illegal fishery of unknown size.* The eggs alone from a ripe 72" female fish (which was legally harvestable until March 1, 2007) are reported to fetch $3,000 on the black market, therefore a *tremendous financial incentive exists for poachers to exploit this population. Indeed, several poaching rings have been exposed and prosecuted since 2000"* (Critical factors affecting the species, p. 20).

      "Harvest rates by legal anglers have been within reasonable limits (< 5%) since 1990. However, total mortality, which includes mortality due to all other unknown causes (including natural mortality and poaching) was extremely high during the 1990s. Annual mortality was between 20% and 35% for four of the five years in the 1990s for which we have data (Schaffter and Kohlhorst 1999, CDFG unpublished data). This is exceedingly high for a species with a life history like white sturgeon (e.g., slow growing, late to mature, infrequent successful reproduction, etc). *Poaching could have possibly been responsible for a significant portion of this additional mortality."*

2. Beamesderfer et al. (2007)

    - Models indicate that an increase in harvest of 2-3% reduces egg production levels indicating stocks are susceptible to reduced population sizes.

3. Bay-Delta Oversight Council (1995)

    - With more utilizing the resource, and improved catch success, illegal harvest likely increasing (p. 34).

4. CDFG (unpublished)

    - Fishing mortality during 12 more or less random years between 1968-1998 estimated at 1.4-11.5%.

5. Boreman (1997)

    - "Restricting fishing mortality may be the only tool available to managers for restoring depleted populations. At a minimum, reducing fishing pressure on long-lived species allows managers time to detect and correct the true causes of population decline."

6. DFG Sturgeon Report Card (2007)

    - White sturgeon are harvested outside of legal size limit.

- Harvest in 2007/2008 was reported as 23% (report card), which differs from creel data (48%).

7. DBEEP (2007)

   - Poaching of sturgeon is a significant enforcement issue.

OUTCOMES P3 & P4: INCREASED POPULATION SIZES OF CHINOOK SALMON & STEELHEAD

1. Chinook salmon and steelhead Conceptual Model

   - Stressor table for winter- fall- and spring-run Chinook: Importance level of 3 indicating incidental/accidental catch is likely. *"Poaching during the holding period may be important"* for spring-run.

   - Stressor table for CV steelhead: "*Intentional illegal poaching is probably rare. By-catch mortality is unavoidable so long as sportfishing is legal*." Importance level of 3 indicating incidental/accidental catch is likely.

2. Williams (2006)

   - "Inland harvest is significant and variable source of mortality that is not well-monitored. *Poaching is hard to quantify, but there are indications that it can be significant. Spring-run are particularly vulnerable while adults hold in pools through the summer"* (Inland harvest section, p. 248).

3. Bay-Delta Oversight Council (1995)

   - Estimated loss of spawning stock and smolts. Poaching/bycatch expected to increase proportionally with population size and CPUE (p. 17).

4. Moyle et al. (2008)

   - Mortality via incidental catch is likely occurring. This could be deleterious as wild fish numbers continue to decline and a greater percentage of the fish are caught and released (Fisheries section, p. 69).

5. DFG Creel Survey Annual Performance Report, July 2007-June 2008

   - Creel data shows the majority of steelhead angling effort (82.1%) takes place on the Feather and American Rivers, making illegal harvest of steelhead in the delta and bay an unlikely occurrence.

   - Creel data (DFG 2008?) indicates a 4.3% harvest rate.

6. DBEEP (2007)

   - DBEEP reports briefly discuss poaching of sturgeon and striped bass as significant enforcement issues with no mention of steelhead. Although the report is limited in its discussion of poaching activities, the fact that steelhead are not mentioned demonstrates the relative lack of concern on the part of the DBEEP staff.

7. DFG Steelhead Report Card (2007)

   - Based on volunteered reporting – 5% of wild fish are harvested in legal fishery.

*IMPORTANCE OF THIS ACTION WILL VARY INVERSELY WITH SIZE OF POPULATION.

- Bay-Delta Oversight Council (1995): Poaching/bycatch will increase with population size and CPUE (p. 17).
- Moyle et al. (2008): Greater proportion of small population affected by poaching.
- Futuyma (1998): Population bottlenecks will result in reduced genetic diversity; if population remains small, genetic drift will continue to erode genetic variation rapidly; if population grows in size, heterozygosity will be restored.
- Begon et al. (1996): Allee effects would also make this action more important for small populations (i.e., difficult to find mates when population is small, pp. 385-386).

OUTCOME N1: FISHING EFFORT SHIFTS TO OTHER SPECIES OR AREAS

1. Moeltner (2006)
   - 55-65% of respondents indicated that implementation of a catch and release rule would not affect their license purchase or trip decisions; 10-15% would compensate for the segment closures primarily with additional trips to sites not affected by catch and release rule (pp. 18-21).
2. Gentner (2004)
   - Anglers are substituting away from one fishery into another when fishing regulations are tightened (pp. 8, 10).

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P3	Chinook Salmon	Increased population sizes of Chinook salmon	2-3	2
P1	Green Sturgeon	Increased population sizes of green sturgeon	3	2
P4	Steelhead	Increased population sizes of steelhead	2	2
P2	White Sturgeon	Increased population sizes of white sturgeon	3	2
Negative Outcomes				
N1	Chinook salmon & Green & White Sturgeon	Information gap about where poaching is most important may result in effort being directed at less important areas and may shift poaching to areas with greater importance to the population	1	2

OSCM 17:
Splittail Harvest Regulations

Scientific Evaluation Worksheet

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Action: Modify Splittail Harvest Regulations

Evaluation Team: Hatcheries and Harvest Workgroup

Brad Cavallo - Chair, Jim Smith, Jason Kindopp, Shirley Witalis, Alison Willy, Josh Israel, Dave Zezulak – Coach, Larry Wise (note taker)

Date of Last Revision: February 17, 2009

Action Description and Clarifying Assumptions

Modify fishing regulations to reduce the effects of harvest on Sacramento splittail.

Approach

1. Establish regulations on size and daily bag limits for splittail enforced by the California Department of Fish and Game.

Intended Outcomes as Stated in Conservation Measure

1. Increase population abundance of splittail.

Additional Outcomes:

- Establishing as a sport fishery would eliminate commercial fishery for restaurant trade
- Improved foodweb energy transfer in wet years
- Would improve ability to gather information about species
- Increased predation on Corbula

General Conceptual Model Support for Intended Outcomes

1. Increased abundance: yes, implied on p. 16, Tables 2&3 (pp. 19-20), considerable but poorly documented fishery, may significantly reduce egg supply.

Assumptions

Provided in BDCP Conservation Measure

1. Size limit: Size at which an adult has had one year to spawn.
2. Daily Bag limit: 10 fish.

Added by Evaluation Team

No new assumptions added.

Problem(s) with Action as Written:

1. Allows take of most productive fish, consider targeting fishery on smaller, rather than larger, fish.

Scale of Action:

Large

Rationale:

Change from unregulated to regulated fishery, broad spatial extent, long-term action.

Evaluation Summary

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

YES

Nature of Change: Foodweb energy transfer.

May affect foodweb energy transfer in wet years if number of females are low already (Splittail model – pg 7).

Potential Positive Ecological Outcome(s)

Outcome P1: Increase population abundance of splittail

General Observations

See Attachment A for detailed information regarding the following references:
- Splittail conceptual model p. 16, Tables 2&3 (pp. 19-20).
- DFG Creel Data (2007, 2008) indicates that harvest is similar to salvage at TFCF (USBR 2008 TFCF website).

Magnitude = 3

See Splittail model.

Certainty = 2

Current fishery is poorly documented. Splittail populations may not be driven as much by harvest as by hydrology and floodplain inundation.

Outcome P3: Improved foodweb energy transfer in wet years

General Observations

See Attachment A for detailed information regarding the following references:
- Splittail conceptual model p. 7

Magnitude = 3

See Foodweb model (pg 128).

Certainty = 2

This transfer may be highly variable from year to year, depending on population size.

Outcome P4: Would improve ability to gather information about species

General Observations

Information on this species would be collected during routine creel census surveys if the species were regulated.

Magnitude = 2

Information on harvest poorly documented.

Certainty = 3

Info would be gathered during creel surveys.

Outcome P5: Increased predation on Corbula

General Observations

See Attachment A for detailed information regarding the following references:
- Splittail model pp. 7, 15.
- Foodweb model p. 129.

Magnitude = 2

See Splittail model pg 7, Foodweb model pg 129. Corbula represent about 6% of splittail diet. This impact may not be great.

Certainty = 2

Effect is dependent on a number of external factors unaffected by the action that may affect the populations of both splittail and *Corbula*.

Potential Negative Ecological Outcome(s)

Outcome N1: Potential for redirection of fishing effort to other sensitive species

General Observations

See Attachment A for detailed information regarding the following references:
- Gentner (2004) pp. 8,10

Magnitude = 2

Size of current fishery not well known.

Certainty = 2

Response of fishing community is unknown.

Important Gaps in Information and/or Understanding

Data Needs

- Need better information on amount of harvest currently occurring.
- Need to understand what other species might be targeted if splittail are regulated.

Research Needs

Assess Reversibility and Opportunity for Learning

Reversibility

Yes/easy

Opportunity for Learning

High

Comments: Would allow us to better understand effects of harvest on splittail populations.

References Cited

Department of Fish and Game (2007) Creel Data.

Department of Fish and Game (2008) Creel Data.

DFG (2009a) Unlawful sale, purchase, or possession of fish or amphibian. Fish and Game Code Section 7121.

Fish and Game Commission (2009) Department of Fish and Game Division 1. Fish, Amphibians and Reptiles. Chapter 2. Statewide Regulations for Fishing and Frogging in Inland Waters. Article 4. Species Regulations. 5.95. Other Species.

Gentner B (2004) Examining target species substitution in the face of changing recreational fishing policies. International Institute for Fisheries Economics and Trade (IIFET) 2004 Japan Proceedings.

USBR (2008) Managing Water in the West: Tracy Fish Facility Studies. Early life history stages and life histories of centrarchids in the Sacramento-San Joaquin Delta System, California. Volume 42. http://www.usbr.gov/pmts/tech_services/tracy_research/tracyreports/index.html

DRERIP Evaluation Workshop – Attachment A

Splittail Harvest Regulations

OUTCOME P1: INCREASED POPULATION ABUNDANCE

1. Splittail conceptual model

   - "One of the least appreciated aspects of the splittail migration is that they are subject to a *considerable but poorly documented legal fishery from November through May*. Anglers catch splittail using earthworms and cut bait. Most fish caught are kept because they are prized as food fish in Asian cuisine. Incidental data collected during creel surveys for striped bass and salmon (K. Murphy, unpublished data) suggest that *at times hundreds of adult fish may be caught on a daily basis. It is possible the fishery could significantly reduce egg supply available for spawning by reducing the number of large females.* However, most of the fish caught are relatively small (15-25 cm TL) so may be mostly males (J. Hileman, pers. comm.)" (Stressors by life history stage, p. 16).

   - Tables 2 & 3 (pp. 19-20): Harvest is moderately important stressor to juveniles and adults (pre-spawning, spawners, post-spawning adults). Low understanding of impact (score of 2).

2. DFG Creel Data (2007, 2008)

   - There is considerable information in the DFG creel (2007,2008) surveys for 2006-2008. This subsistence fishery (92-97% of catch harvested; 2006-07- est. 2,442 harvested; 2007-08- est. 11,191 harvested) is focused on the Sac River between Rio Vista and Colusa. Fishing also occurs on the lower Feather from Verona to Shanghai Bend. These fisheries occur principally from Jan-March.

3. TFCF website

   - Salvage of splittail at the TFCF was est. to be 23,200/annually between 2000-03.

OUTCOME P2: Establishing as a sport fishery would eliminate commercial fishery for restaurant trade

1. DFG (2009)

   - Fish and Game Code Section 7121: "Unlawful sale, purchase, or possession of fish or amphibian 7121. Except as otherwise provided by this code or by regulation, it is unlawful to sell or purchase any fish or amphibia taken in, or brought into, the waters of the state, or brought ashore at any point in the state. It is unlawful to buy, sell, or possess in any place of business where fish are bought, sold, or processed, any fish or amphibia taken on any boat, barge, or vessel which carries sport fishermen, except those fish may be possessed in such a place only for the purposes of canning or smoking under regulations adopted by the commission."

2. Fish and Game Commission (2009)

   - 5.95. Other Species. "Other species of fish may be taken in any number and at any time of the year by angling, except for closures and restrictions listed under district special regulations."

   - Splittail are included in the "Other Species" category.

OUTCOME P3: Improved foodweb energy transfer in wet years

1. Splittail conceptual model

   - "It is likely that splittail are responsible for large transfers of energy from upstream floodplains into Suisun Marsh and Bay areas. These large migrations, both upstream adults and downstream juveniles are probably important in the seasonal transfer of energy within the estuary's foodweb (Feyrer et al. 2007). While this is unquantified, *the sheer numbers of juvenile splittail that are found following large inundation events would indicate a significant positive impact to the downstream foodweb*" (Ecology section, p. 7).

OUTCOME P5: INCREASED PREDATION ON CORBULA

1. Splittail conceptual model

   - "In Suisun Marsh adult splittail gut contents are predominantly detritus (60-79%), however, a shift has occurred since the invasion of *Corbula amurensis* in 1986 (Feyrer et al. 2003). After the invasion and establishment of the clam, mysid shrimp (*Neomysis mercedis*) populations collapsed (Kimmerer and Orsi 1996). Mysid shrimp which originally made up to 24% (average dietary importance) of splittail gut contents was reduced to 2% in the post clam period (Feyrer et al. 2003). The amount of detritus remained similar at 70% with the difference being made up with other invertebrates and *Corbula* (6%) itself (Feyrer et al. 2003)." (p. 7)

   - Adult splittail feed on the overbite clam (*Corbula amurensis*), which accumulates and transfers Selenium at high concentrations. With the decline of native mysid shrimp in the estuary, splittail have turned more to benthic foods such as bivalves (Feyrer et al. 2003)." (p. 15)

2. Foodweb model

   - *"Corbula amurensis* has been found in the guts of white sturgeon, suggesting that demersal fish are able to utilize these clams as a prey item." (p. 129)

OUTCOME N1: POTENTIAL FOR REDIRECTION OF FISHING EFFORT TO OTHER SENSITIVE SPECIES

1. Gentner (2004)

   - Anglers are substituting away from one fishery into another when fishing regulations are tightened (pp. 8, 10) (from E. Floyd).

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P3	All	Would improve ability to gather information about species	2	3
P4	Splittail	Increased predation on Corbula	2	2
P2	Splittail	Improved foodweb energy transfer in wet years	3	2
P1	splittail	Increase population abundance of splittail	3	2
Negative Outcomes				
N1	Splittail	Potential for redirection of fishing effort to other sensitive species	2	2

OSCM 19:
Mark-Select Chinook Salmon Fishery

Scientific Evaluation Worksheet

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Existing M-S fisheries in WA and OR have met with mixed success (Lindsay et al. 2004). 4
Scale of Action: 4

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Action: Implement a Mark-Select program to reduce the harvest of wild Chinook salmon

Evaluation Team: Hatcheries & Harvest Workgroup

Brad Cavallo - Chair, Dave Zezulak – Coach/participant, Jim Smith, Jason Kindopp, Shirley Witalis, Alison Willy, Josh Israel, Larry Wise (note taker).

Date of Last Revision: February 16, 2009

Action Description and Clarifying Assumptions

Mark all Central Valley Chinook salmon produced in hatcheries with a visible mark (e.g., adipose fin clip), and limit all commercial and recreational harvest of Chinook salmon to those with visible marks.

Approach

1. Mark all Central Valley Chinook salmon produced in hatcheries with a visible mark (e.g., adipose fin clip).
2. Limit all commercial and recreational harvest of Chinook salmon to those with visible marks.

Intended Outcomes as Stated in Conservation Measure

1. Increased population size of wild Chinook salmon.
2. Increased knowledge base regarding Central Valley Chinook salmon (population sizes, harvest rates, success of restoration programs, and other key biological parameters) for improved management.

Additional Outcomes Added by Group

1. Increased harvest of hatchery fish.

General Conceptual Model Support for Intended Outcomes

1. Increased population size: yes, implied because hatchery fish may play a role in recent Chinook population declines (Salmonid CM p. 28), hatchery fish compete with wild fish, may attract predators, and divert attention from condition ("mask" the true status) of wild stocks (Salmonid CM pp. 45-46).
2. Increased knowledge base: yes, implied because hatchery fish may conceal or divert attention from the condition of wild or naturally reproducing fish. This is particularly the case when few hatchery fish are marked (Salmonid CM pp. 45-46).
3. Reduce competition and introgression: yes, hatchery fish compete with wild Chinook (Salmonid CM p. 45).
4. Improved broodstock management: Not discussed in conceptual model. See references discussed in following Positive Outcomes section.

Assumptions

Provided in BDCP Conservation Measure

1. None

Added by Evaluation Team

1. All hatchery fish intended for harvest, regardless of run, will be marked. (*note, the team already discussed the necessity of handling hatchery conservation fish differently).
2. Our evaluation assumes that the requisite changes in harvest and hatchery management and monitoring programs would be developed to support this action.
3. Assumes adequate manpower/funding to implement the program.
4. Assumes most or all hatchery fish escapement will be harvested.

Notes:

- To obtain the anticipated resource benefit, this action will require coordinated efforts across agencies and various levels of government. "Need science, management, legislation and politics to implement a successful program." (Richards and Rago 1999). Changes to hatchery and harvest management would be profound and far reaching.
- The action lacks the specific hatchery and harvest management actions that would be necessary to obtain the desired objective of reducing catch of protected species and the adverse impacts that production hatcheries can have on wild stocks.
- Action may benefit some conservation stocks more than others depending on intermixing of stocks and level of protections currently afforded some stocks (Excerpt F, Attachment A).
- A mark-select program would allow a better forecast of the potential fishery harvest. It would also allow the development of better index to the number of wild fish harvested, which is currently estimated based on harvest of hatchery fish.
- Tagging fish, in addition to Mark Select would increase the amount of knowledge obtained through monitoring. (Note: tagging is crucial for management actions leading to the recovery of listed species and providing a knowledge base for management actions.)

Problem(s) with Action as Written:

1. Effectiveness of program largely dependent on implementation and especially monitoring
2. It would be difficult, if not impossible, to limit all commercial and recreational harvest to marked fish (Excerpt F, Attachment A). Different stocks mix in the ocean, so you can't target a specific stock. These mixed stock fisheries encompass multiple watersheds and states.
3. NMFS is not convinced that this approach will address the issue of take of protected species adequately (Mohr 2009, PSC-SFEC 2003, 2005, 2008a,b).

Existing M-S fisheries in WA and OR have met with mixed success (Lindsay et al. 2004).

Scale of Action:

Large

Rationale:
Action will affect all hatcheries. Will affect both ocean and inland harvest, population, ecosystem. Action would be continuous over the long term. Action has never been implemented in California.

Evaluation Summary

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

YES

Nature of Change: Major change in ecosystem and population dynamics.

This action would cause a major change in ecosystem and population dynamics through its effects on harvest/hatchery management.

Note: There is an existing mass marking program in CA for inland steelhead, which demonstrates that such a program can be implemented. The IEP is using this mass marking program to develop and implement monitoring programs to develop scientific and management information for these stocks.

Potential Positive Ecological Outcome(s)

Outcome P1: Increased population size of Central Valley Chinook salmon (all races)

General Observations

See Attachment A for detailed information regarding the following references:

Info in Support:
- Population Modeling Papers (Cramer in press)
- Salmonid conceptual model Population trends (p. 28), Hatchery fish (p. 45-46).
- Hankin (1982) Introduction (p. 286)
- ISAB (2003) Executive summary (supplementation risks & Findings 1&2; pp. iv-vi), Modeling results (p. viii, point #5).
- Lindsay et al. (2004)
- Mohr (2009)

Info in Conflict:
- PSC-SFEC (2003, 2005, 2008a,b), Mohr (2009)

Magnitude = 4 (high)

The effects of this action would be large scale, major population level effect. A mark select fishery does not guarantee that the populations of conservations stocks would increase as other stressors may exert an overriding influence on population levels.

Certainty = 3 (medium)

Supported by ecological theory. Supported by modeling studies (Cramer et al. 2008)

See Richards and Rago 1999, Lindsay et al 2004, Wertheimer 1988, Cox-Rogers et al. 1999, Grover et al. 2002, Excerpt D (J. Kindopp)

Outcome P2: Increased knowledge base regarding Central Valley Chinook salmon (population sizes, harvest rates, success of restoration programs, and other key biological parameters) for improved management

General Observations

See Attachment A for detailed information regarding the following references:
- Salmonid conceptual model Stressors: Hatchery fish (p. 45).
- JHRC (2001) p. 12
- AFS Position Paper (2009)
- ISAB (2003) Supplementation uncertainties (p. v), Finding 4 (p. xi), Primary Recommendation 3 (p. xii).
- Hankin (1982) Abstract
- Mohr (2009)
- PSC-SFEC (2005) p. 4
- PSC-SFEC (2008a) p. vii

Magnitude = 3

Knowledge base would be increased (but knowledge would be increased even more through tagging).
Assumes monitoring component.
Would be able to obtain a High certainty for population size and harvest rate as you can distinquish wild and hatchery fish.
Much better than under existing conditions.
Medium increase in knowledge for restoration success because will not allow us to distinguish among different runs/stocks/hatcheries.

Certainty = 3

Monitoring is a key element, and history indicates there is little reliability to monitoring programs. (Note: this action cannot be evaluated without monitoring and expected outcomes would not be validated; monitoring efforts are increasing with improved methodology and creative problem-solving to meet challenges in the field).

Outcome P3: Reduce competition and introgression from hatchery fish with natural fish on spawning grounds

General Observations

These benefits would occur mainly on spawning grounds and would only result if the proportion of hatchery fish to natural fish spawning were reduced. This may require some active management of which fish are allowed to reach the spawning grounds or relies on the assumption that this would be obtained through higher harvest of returning hatchery fish downstream of the spawning grounds.

See Attachment A for detailed information regarding the following references:
- AFS Position Paper 2009
- HSRG assembled info
- Goodman (2005) Abstract & Introduction (p. 374).
- Hankin (1982) Introduction (p. 286)
- Weber & Fausch (2005) Abstract
- Araki et al. (2006) Abstract
- Flagg et al. (2000) Competition (pp. 36-40).
- Mohr (2009)

Magnitude = 4

Will affect number of hatchery fish returning to spawn (HSRG 2008, Cramer et al. 2008, Kostow 2008).

Certainty = 3

Reduction in hatchery fish variable and uncertain depending on external factors (e.g. harvest management, Cramer et al. 2008).

Outcome P4: Can improve broodstock management at hatcheries (with tagging, much improved)

General Observations

Knowing which fish are natural fish and which are hatchery fish could improve harvest efficiency and broodstock management. If implemented in coordination with sorting weirs, this could reduce competition and genetic effects relating to hatchery fish reaching the spawning grounds. It could also improve broodstock management as hatchery managers would be able to better manage the proportion of wild fish that they spawn in the hatchery. However this measure could also interfere with the data collection methods used by conservation hatcheries, requiring them to use alternative and more expensive techniques to assess their success.

See Attachment A for detailed information regarding the following references:
- AFS Postion Paper (2009)
- Araki refs (NEED SPECIFIC INFO)
- HSRG assembled info (www.lltk.org)
- ISAB (2003) Supplementation uncertainties (p. v).

Magnitude = 4

Would provide ability to control input of wild broodstock.

Certainty = 4

Would provide ability to identify wild broodstock. Would not affect ability to detect strays from other hatcheries.

Potential Negative Ecological Outcome(s)

Outcome N1: Complicates management and data acquisition for conservation hatcheries (e.g., Livingston-Stone) and associated agency sampling programs

General Observations

See Attachment A for detailed information regarding the following references:
- Excerpt A, Attachment A (J. Smith)
- Excerpt B, Attachment A (J. Smith)
- Excerpt C, Attachment A (J. Smith)
- PSC-SFEC (2003) pp. 6,7,9,10, 15, Figs 1&2
- PSC-SFEC (2005) pp. 10, 11
- PSC-SFEC (2008a) pp. 6, 22
- PSC-SFEC (2008b)
- Alexandersdottir (2007)

This outcome assumes conservation hatcheries will mark with same technique and these fish will be indistinguishable from production fish. Problem could be partially mitigated if conservation fish are marked differently from production fish.

Magnitude = 4

Conservation fish will be harvested at a different rate than non-conservation fish and thus the use of non-conservation fish as surrogates for conservation fish management objectives could be adversely affected.

Certainty = 4

This impact would occur under current monitoring program for conservation hatcheries. Marking at conservation hatcheries would need to be modified to accommodate this. These modifications could be expensive. This would not alleviate the problem of no longer being able to use production fish as surrogates for conservation hatchery fish in making management decisions.

Outcome N2: Action may lead to increased harvest of hatchery fish, which may result in higher bycatch of covered salmonids

General Observations

Outcome N2 relates to bycatch mortality. If there is increased incidence of bycatch for conservation species, this could result in higher mortality for conservation stocks. However, this is a management issue. Currently, there is no information on bycatch of conservation stocks, as fish are not marked and every fish caught is kept.

This action would allow for the clear distinction of hatchery fish from naturally produced fish, if carried out universally. This would allow more directed take of hatchery fish in the fishery. However, there would be societal pressure to maximize this take. Currently, conservation stocks are taken in the creel, so there is high mortality in the fishery. Under the M-S fishery these fish would continue to be caught, but they would be released. If maximizing the take of hatchery fish results in increased bycatch of naturally produced fish, naturally produced stocks may be impacted through increased catch and release or drop-off mortality associated with more frequent encounters with fishing gear (this mortality is estimated to range from 14 to 42 percent, depending on fishing technique). This type of effect might be avoided by implementing closures based on bycatch rates, supported by a reporting system that would facilitate such "real-time" management decisions.

See Attachment A for detailed information regarding the following references:
- Excerpt D, Attachment A (J. Kindopp)
- Excerpt E, Attachment A (B. Cavallo)
- Hankin (1982) Introduction (p. 286)
- Kostow (2008) p. 5 ("Large releases of hatchery fish" section, 2nd paragraph)

Magnitude = 2

See Excerpt D and E.

Certainty = 2

Outcome N3: Action may lead to sociological pressure for increased hatchery production

Not evaluated.

Important Gaps in Information and/or Understanding

Data Needs

- Non-catch mortality is not well-documented in the literature.
- Anecdotal information from the Feather River indicates that non-catch mortality appears significant (Jason, Brad).
- Approaches to management of conservation stocks that do not utilize surrogate production fish as an indicator of conservation fish need to be developed.

Assess Reversibility and Opportunity for Learning

Reversibility

Yes, easy.

Comments: This program would be easy to terminate once implemented.

Opportunity for Learning

Medium

Comments: This action will provide an opportunity for learning. This opportunity would be increased through a tagging program. This action may also increase the difficulty and expense of some programs to assess the success of conservation hatchery programs. Implementation of this action may require coordination among other regional marking and monitoring programs in the state of California.

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DRERIP Evaluation Workshop – Attachment A

Mark-select Program

OUTCOME P1: INCREASED POPULATION SIZE FOR WILD CHINOOK

1. Salmonid conceptual model

   - Sharp declines for fall-run in recent years. Increasing influence of hatchery fish may be involved, but particular mechanism is unknown. Recent haphazard sample of 100 fish from the party-boat fishery was 90% hatchery fish (Population trends section, p. 28).

   - Hatchery Chinook compete with naturally produced salmon in the Delta. Large numbers of hatchery fish may attract predators that reduce survival of naturally produced fish. Hatchery fish may also conceal or divert attention from the condition of wild or naturally reproducing fish. This is particularly the case when few hatchery fish are marked (Stressors: Hatchery fish, p. 45).

2. Hankin (1982)

   - Hatchery stocks may withstand higher harvest rates (due to higher egg to smolt survival and greater numbers of returning adults per spawning female). “Increasing reliance on hatchery returns may promote and sustain fishery harvest rates exceeding those that wild stocks may withstand” (Introduction, p. 286). (from A. Willy)

3. ISAB (2003)

   - Executive Summary (supplementation risks & Findings 1&2; pp. iv-vi).
   - Modeling results (p. viii, point #5):

“*Supplementation can result in decreased fitness of the target population*. Whether it does so, and to what extent, depends on the particular magnitudes of the pertinent parameters, e.g., the initial hatchery and natural spawning replacement rates, the broodstock mining rates, *the harvest selectivity*, as well as the degree of the negative correlation between natural spawning and hatchery spawning fitness.” (from E. Floyd)

4. Goodman (2005)

   - Negative effects of hatchery fish include competition, predation, overharvest of wild fish, inbreeding depression. Document potential for substantial erosion of natural spawning fitness (Abstract & Introduction, p. 374) (from E. Floyd).

5. Weber and Fausch (2005)

   - Evidence of negative effect of hatchery fish on wild fish growth (Abstract, p. 44) (from E. Floyd).

6. Flagg et al. (2000)

   - Competition (pp. 36-40), Predation (pp. 46-49), Fish Health (pp. 54-55), Migratory Behavior (p. 56) (from E. Floyd).

7. Lindsay et al. (2004)

   - Demonstrated that a selective sport fishery in the lower Willamette River, OR could be used to reduce harvest mortality on Wild Chinook Salmon while maintaining fishing opportunities for hatchery Chinook. Harvest of wild Chinook was estimated to be 12.2% (from J. Kindopp).

8. Mohr (2009)

   - Fishery mortality rates for unmarked fish may increase or decrease. This will depend on marked/unmarked rations in ocean, allowable fishing effort and marked fish mortality rates, hook and release mortality, and the number of repeat encounters.

   - Constant fractional marking (CFM) allows for estimating of percentage of strays, but does not allow for control over individuals as 100% marking would (from E. Floyd).

Info from NMFS (Watalis):

1. Arguments for Mass Marking/ Mark Selective Fisheries:

Mass marking (MM) and Mark Selective Fisheries (MSF) would allow for greater control of hatchery versus natural fish in spawning areas. In some years, MM and MSF may reduce the number of hatchery strays due to greater harvest rates, and increase the information on marked fish. There could also be a possible increase in California commercial fishery opportunity and harvest, dependent on the mark-ratio and other factors.

2. Arguments against Mass Marking/ Mark Select Fishery

MM and MSF will not restore listed Evolutionarily Significant Units (ESUs) because there will be pressure to increase harvest rates on marked-fish to maximum levels possible (subject to ESA constraints) without a net reduction in fishery impacts on listed stocks. MM and MSF will not ensure recovery of listed fish; recovery is really contingent on all Viable Salmonid Population (VSP) parameters (abundance, productivity, diversity and spatial structure) of fish populations and ESUs.

Supplemental monitoring in the form of Genetic Stock Identification would be required to determine the impact of MSF on listed stocks, and its prohibitive cost for tissue sampling and typing makes this impractical. Therefore, no data would be generated on commercial harvest impacts to listed stocks.

More research needs to be conducted on the all consequences of MSF. The current work on MM and MSF: 1) does not consider that Northern CA fisheries are largely constrained from expansion because of coho incidental impacts, and 2) incorrectly models Klamath River fall Chinook harvest allocation agreements, stock dynamics, and stock distribution.

Other considerations:

- costs and consistent implementation for all CA production programs
- change in management of listed hatchery conservation fish
- new fishery assessment, forecast and management models would need to be developed
- the CA recreational fishery harvest from Fort Bragg to Mexico would decrease
- there would be no change in season length (set by limits to coho incidental mortality)

- harvest would be reduced because of release of nonmarked fish (not popular)
- fisheries will still be closed in poor years for maximum escapement to maintain hatchery runs

OUTCOME P2: INCREASED KNOWLEDGE BASE FOR IMPROVED MANAGEMENT

1. Salmonid conceptual model

   - Hatchery fish may conceal or divert attention from the condition of wild or naturally reproducing fish. This is particularly the case when few hatchery fish are marked (Stressors: Hatchery fish section, p. 45).

2. JHRC (2001)

   - "There is no solid data base at present upon which to project the natural escapement of any race of Central Valley Chinook for the coming year (p. 12)."

   - "…the management hazards posed by the masking effect are worrisome because masking is definitely occurring, and the odds of making management mistakes because of this are high. The masking problem could be solved with constant fractional marking of all hatchery production (Hankin 1982, Hankin and Newman 1999), and careful genetic and behavioral studies of naturally-spawning fish (p. 12)."

3. AFS Position Paper (2009)

   - "In order to enhance opportunity for improved salmon management, and minimize genetic and ecological impacts of hatchery programs, the Cal-Neva Chapter of the American Fisheries Society proposes and supports 100% marking (by adipose fin clip) all fall run Chinook salmon produced at Central Valley (CV) and Klamath anadromous fish hatcheries."

4. ISAB (2003)

   - "…supplementation (with unmarked hatchery fish) can introduce uncertainty through masking the numbers of natural-origin fish, making a determination of reproductive success difficult (for both natural-origin and hatchery-origin fish)" (Supplementation uncertainties section, p. v).

   - Current monitoring and evaluation efforts are inadequate to estimate either benefit or harm from ongoing supplementation projects. The correct parameters are not being consistently measured (Finding 4, p. xi).

   - To reduce uncertainty and to contain the risk of long-term impacts, all supplementation programs should be conducted within an explicit experimental design that is accepted by all affected parties (Primary Recommendation 3, p. xii) (from E. Floyd).

5. Hankin (1982)

Accurate discrimination between river returns of wild and hatchery anadromous Pacific salmon (*Oncorhynchus* spp.) is necessary if the status of the two stocks is to be monitored and if the success of hatchery mitigation programs is to be assessed. Usual hatchery management practices, including release of large numbers of unmarked fish and variable fractional marking of releases, prevent such discrimination. Many Pacific-coast salmon hatcheries presently release some fish with an adipose fin clip and a binary-coded wire tag inserted in the nasal region (AD–CWT). If a constant fraction of remaining releases carried a distinctive identifying mark, then the proportion of hatchery fish in subsequent spawning runs could be estimated. Should the majority of hatchery fish in the spawning [illegible]

- "The variance in an estimated proportion of hatchery fish in the run depends strongly on the fraction of releases marked in excess of AD-CWT releases. The variance declines substantially as this fraction increases from 0.05 to 0.25, but marking fractions above 0.5 give little further statistical improvement" (Abstract). Indicates that marking all fish may not be necessary.

- Sample sizes needed to estimate the hatchery fish proportion decline as the number of hatchery fish marked increases (Abstract).

- Variance in escapement estimators increases when a high proportion of hatchery fish stray (should not release hatchery fish away from the hatchery rearing site to avoid this problem) (from A. Willy).

6. Mohr (2009)

   - Increased information on marked fish.

   - Greater control of hatchery vs. natural spawning interactions possible.

   - Need universal implementation for program to be effective (consistency among all CA production hatcheries). May not be possible due to economic and logistic constraints (100% CWT is expensive and physically difficult to accomplish).

   - Would be unable to assess impacts of fisheries on listed stocks (from E. Floyd).

7. SFEC (2005), SFEC (2008a)

   - Mass marking and CWT sampling programs are no longer synchronized among agencies. U.S. mass marking initiatives are in conflict with sampling programs in California, Alaska and Canada. The differences in sampling and tagging methodologies will impact efficacy of evaluation programs and management (SFEC 2005, p. 4; SFEC 2008a, p. vii) (from S. Witalis).

OUTCOME P3: REDUCE COMPETITION AND INTROGRESSION FROM HATCHERY FISH

1. AFS Position Paper (2009)

   - "Accumulating data indicate that hatchery-origin fish have lower fitness in natural environments than their wild counterparts (see Araki et al. 2008 for review) and that hatchery origin fish compete with natural origin fish for spawning habitat (Hatchery Scientific Review Group 2008)(p.1)".

2. Goodman (2005)

   - Negative effects of hatchery fish include competition, predation, overharvest of wild fish, inbreeding depression. Document potential for substantial erosion of natural spawning fitness (Abstract & Introduction, p. 374).

3. Hankin (1982)

   - Interbreeding of wild and hatchery fish might reduce genetic fitness of subsequent generations (Introduction, p. 286).

4. Weber and Fausch (2005)

   - Evidence of negative effect of hatchery fish on wild fish growth (Abstract).
   -

5. Araki et al. (2006)

   - Evidence of reduced fitness in fish from traditional hatchery breeding in river relative to wild fish (Abstract) (from E. Floyd).

8. Flagg et al. (2000)

   - Evidence that wild and hatchery fish utilize same habitat and eat same food resources in some cases (Competition section, pp. 36-40).

9. Mohr (2009)

   - Decreased number of hatchery strays in some years due to greater harvest rates.

OUTCOME P4: CAN IMPROVE BROODSTOCK MANAGEMENT PRACTICES

1. AFS Position Paper (2009)

   - "Allows biologists to manage hatchery broodstock and natural spawning escapement such that the natural environment (rather than the hatchery) drives adaptation and fitness.
     - Hatcheries could improve genetic fitness of hatchery broodstock by including known natural origin fish
     - Broodstock segregation weirs could be operated on some rivers to limit hatchery origin fish spawning naturally
     - Better genetic diversity and fitness among natural origin Chinook stocks will improve resilience to changing environments such as poor ocean conditions observed in 2005 (p. 2)."

2. ISAB (2003)

   - "…supplementation (with unmarked hatchery fish) can introduce uncertainty through masking the numbers of natural-origin fish, making a determination of reproductive success difficult (for both natural-origin and hatchery-origin fish)" (Supplementation uncertainties section, p. v).

OUTCOME N1: COMPLICATES MANAGEMENT AND DATA FOR CONSERVATION HATCHERIES

1. SFEC (2003), SFEC (2005), SFEC (2008a), SFEC (2008b), Alexandersdottir (2007)

   - Conversion to ETD (necessitated by implementation of MM and MSFs) results in numerous impacts to agency sampling programs: increased equipment costs, complexity of sampling process, need for more data collection, greater dependence on proper sampling technique, slower sampling process, physically demanding sampling process (SFEC 2003, p. 6; SFEC 2008a, p. 6).

   - Data analysts will have to understand and interpret a more complex data set; potential for misinterpretation of recovery data with implementation of MSFs (SFEC 2003, p. 7).

   - Because there are no direct methods of measuring incidental unmarked mortality, estimations must be made based on more assumptions and inference, adding uncertainty to estimates of total fishery-related mortality (SFEC 2003, p. 9). "The impact on assessments of exploitation rates of wild stocks may be more substantial" (SFEC 2003, p. 10).

   - Modeling could be used to assess negative impacts of MSFs (SFEC 2003, p. 15).

- SFEC (2003) Fig 1. Quality criteria for evaluating MSF effects on viability of the CWT system; Fig

2. Examples of proposal evaluations (from S. Witalis).

- Implementation of mass marking programs can have impacts on CWT data integrity (SFEC 2005, p.11). Under a mark-select fishery, tagged and untagged do not have same exploitation rate, and

  cannot extrapolate unmarked (wild) exploitation rate from recovery of marked fish (Alexandersdottir 2007, from E. Floyd). Must use a DIT approach, combined with ETD, for this to work, but ETD is very expensive on a large scale (SFEC 2005, p.11) (from S. Witalis).

- Mass marking will result in increased encounters with marked, untagged fish by visual sampling programs. Processing these untagged fish may impact agency sampling programs, potentially increasing the sampling effort and financial burden on these agencies, and reducing CWT recovery rates (SFEC 2005, p. 10; SFEC 2008a, p. 6) (from S. Witalis).

- Some concern over whether there is adequate DIT coverage considering the expanded mass marking of Chinook (SFEC 2008a, p. 22).

OUTCOME N2: ACTION MAY LEAD TO INCREASED HARVEST, RESULTING IN INCREASED MORTALITY OF COVERED SALMONIDS

1. Hankin (1982)

   - Hatchery stocks may withstand higher harvest rates (due to higher egg to smolt survival and greater numbers of returning adults per spawning female). “Increasing reliance on hatchery returns may promote and sustain fishery harvest rates exceeding those that wild stocks may withstand” (Introduction, p. 286).

2. Kostow (2008)

   - Large releases produced tens of thousands of adult hatchery fish that supported high harvest rates (p. 5, “Large releases of hatchery fish” section, 2nd paragraph).

Excerpt A (J. Smith)
Independent Scientific Advisory Board for the Northwest Power and Conservation Council, MEMORANDUM (ISAB 2005-4A) July 29, 2005.
ISAB Clarification on Mass Marking and Mark-Selective Fisheries.
Pages 4-5
http://www.nwcouncil.org/library/isab/2005-4/isab2005-4a.pdf

Issues Pertaining to Mass Marking and Mark-Selective Fisheries

Differential fishery impacts on natural fish and their hatchery indicators

Because marked hatchery fish and unmarked natural fish are no longer subject to the same patterns of exploitation under mark-selective fisheries, CWTs on hatchery indicator stocks can no longer serve as suitable surrogates to evaluate and monitor fishery impacts on natural stocks. In the presence of mass marking and mark-selective fisheries, impacts on natural stocks cannot be inferred from direct sampling because unmarked fish must be released. In addition, analytical results increasingly rely upon new assumptions on fishery impacts that are difficult to validate (e.g., assumed values for release and drop off mortality rates, plus mark retention and unmarked recognition error).

A concept termed Double Index Tagging (DIT) has been proposed as a means to provide data to help evaluate the impact of mark-selective fisheries on natural stocks. With DIT, two groups of fish with CWTs are released, identical in every respect except that: (a) the groups carry different CWT codes; and (b) only one of the groups is mass marked. When these fish are subjected to mark-selective fishing, fish from the unmark DIT pair are released while fish from the marked DIT pair are retained. In mark-selective fisheries, only CWTs from the marked DIT pair can be recovered while in non-mass-selective fisheries, CWTs from both marked and unmarked DIT releases could be collected.

With DIT, CWT recovery programs for fisheries and spawning escapements now must sample both marked and unmarked fish, must be provisions for recovering CWTs in both mark-selective and non-mark selective fisheries on the same stock. In theory, differences in recovery patterns between the DIT pairs would be used to assess the effect of mark-selective fishing.

DIT effectively doubles tagging costs for indicator stocks because now two groups of fish would need to be tagged. The number of fish in each group could not be reduced because of increased uncertainty surrounding recovery statistics.

Excerpt B (J. Smith)
Report of the Expert Panel on the Future of the Coded Wire Tag Recovery Program for Pacific Salmon, Pacific Salmon Commission Technical Report No. 18, Nov 2005,
Page 29.
http://www.psc.org/pubs/psctr18.pdf

Respond to Mass Marking and Mark-Selective Fisheries
Implement enhancements to the basic CWT system and introduce new analytical methods that are consistent with the anticipated scope of MSFs. Implementation of MSFs will ultimately depend on value judgments that must somehow balance many competing factors: a) the benefits of wild stock conservation as compared to enhanced fishing opportunities; b) the financial costs of selective fishery implementation as compared to the fishery benefits; c) the degree of uncertainty in natural stock assessments that proves politically acceptable for fishery management; and d) the theoretical viability and costs of alternative management strategies that might meet policy objectives. If MSFs are extensively implemented, our Panel has identified analytical methods and short-term enhancements to the current CWT system that could provide improved stock assessment capabilities for the CTC and CoTC. The enhancements considered should depend on the scope of MSF, including the species targeted, the geographic location of the fisheries, and the intensity of fishery exploitation.

Excerpt C (J. Smith)
Report of the Expert Panel on the Future of the Coded Wire Tag Recovery Program for Pacific Salmon, Pacific Salmon Commission Technical Report No. 18, Nov 2005,
Page 25.
http://www.psc.org/pubs/psctr18.pdf

Existing and Future Technologies that Might Complement or Replace the CWT System

Expert Panel members were provided with published reports, oral presentations, and email correspondence concerning currently available technologies and proposed future technologies that might somehow complement or replace the existing CWT system. Below we present our findings concerning two existing technologies and two emerging technologies that may have promise. The two existing technologies are otolith thermal marking and microsatellite-based genetic stock identification (GSI) methods. The emerging technologies are genetic - use of SNPs (single nucleotide polymorphisms) for stock or release group identification - and electronic – use of radio frequency identification (RFID) tags (electronic technology). We emphasize that even if these new technologies were introduced and supplemented or replaced the CWT system, the serious problems that we have identified for estimation of non-landed fishing mortalities, made more serious by mark-selective fisheries, would not be eliminated. These problems would remain.

Excerpt D (J. Kindopp) – Catch release mortality studies in ocean

There are many papers available on this topic but one paper did a very good job of summarizing most of the current work. The following is derived mostly from this review…A review of hooking mortality rates for marine recreational Coho and Chinook Salmon Fisheries in British Columbia (Cox-Rogers et al., 1999)

Catch and release mortality rates vary greatly depending on the type of fishery (mooching v. trolling), the type of bait/lure, hook size and type, depth of capture, aggressiveness of the fish, food availability, stage of maturity, age at capture, temperature of water and skill of the angler in playing and releasing the fish. Furthermore, study results vary greatly from Alaska to California depending upon the type study conducted. For example, in California, one study (Grover, 1995a) of recreational fishing mortality conducted from 1993-1995 estimated mortality as low as 11% for Chinook caught trolling to 73% for Chinook caught by mooching with anchovies. One NRC study (NRC 1998 in Cox-Rogers et al.) conducted in Oregon from 1996-1997 found hooking mortality for Chinook from 0 to 15%, depending upon the type of gear treatment used. These types of results are fairly typical up and down the Pacific Northwest. The huge range of results from these studies is mostly a byproduct of the different types of studies performed along with all of the aforementioned factors. In general, hooking mortality has been documented to be much higher in California than in Oregon, Washington or British Columbia, regardless of gear type used. It is unknown whether this is a real phenomenon or if the study designs are so different that it precludes a fair comparison (See Cox-Rogers, 1999 for a review of recent studies). It is clear that more work of this type needs to be done in California to determine the most accurate rates of hooking mortality.

Other work: Wertheimer, 1988 (23.5% mortality for legal and sublegal Chinook in commercial troll fishing in southeastern Alaska).
Lindsay et al. (2004) demonstrated that a selective sport fishery in the lower Willamette River, OR could be used to reduce harvest mortality on Wild Chinook Salmon while maintaining fishing opportunities for hatchery Chinook. Harvest of wild Chinook was estimated to be 12.2%.

Bendock and Alexandersdottir (1993) demonstrated that a hook-and-release fishery can effectively reduce sport fishing mortality and help achieve escapement goals in the Kenai River, Alaska.

Excerpt E (B. Cavallo) – Catch/Release and Non-Catch Mortality Review

Commercial and recreational fishing in the Pacific Ocean south of Cape Falcon, Oregon, are conducted by trolling, and a technique known as “mooching” has also become popular among recreational fishermen, by which a baited hook is slowly jigged from a drifting vessel (Boydstun 2001). Both harvest methods lead to fish being either released voluntarily, due to size regulations (catch and release), or hooked but not landed (drop-off). A portion of those fish die as a result of capture or attempted capture.

Catch-and-release mortality (CRM) rates vary between methods of capture for commercial and sport fisheries (PFMC 2008b). CRM in commercial troll fisheries is assumed to be 26% by the PFMC. Fish caught while mooching are more likely to swallow bait and hook than during trolling, and extraction of swallowed hooks results in higher CRM rates than for fish hooked in the mouth (Grover et al. 2002). PFMC’s Salmon Technical Team estimated CRM due to mooching at 42.2%, and recreational trolling at 14% (PFMC 2008b). Based on the expected proportion of fish caught using mooching versus trolling, the aggregate catch and release mortality for recreational fisheries south of Point Arena was estimated to be 16% (PFMC 2008b). As part of a retrospective analysis to examine the potential fishery benefits of mark-selective fisheries in California, Cramer (2008) further aggregated CRM for fall Chinook caught in recreational and commercial fisheries in the Pacific Ocean using a weighted average CRM of 24% (assuming 75% of harvest occurred in the commercial fisheries).

In addition to CRM mortality, fish that are hooked but not landed may incur increased mortality rates, deemed drop-off mortality. Drop-off mortality may be caused by gear remaining embedded in escaped fish, or increased predation rates due to restricted movements caused by the fishing line (Lawson and Sampson 1996). Unfortunately, it is not feasible to estimate drop-off mortality rates experimentally because the process is unobserved. However, for a given fishery it is reasonable to expect the drop-off mortality rate to be lower than, but related to, the corresponding CRM rate (Lawson and Sampson 1996). Cramer (2008) and Pacific Fishery Management Council (2008a) arbitrarily assume a drop off mortality rate of 5% for fall Chinook in the Pacific Ocean.

After initial release or drop-off, additional mortality may occur because some fish will be hooked and released more than once (Lawson and Sampson 1996; Cramer 2008). Therefore, mortality rates likely increase with repeated gear encounters. However, once hooked, a fish is possibly less likely to be hooked again. Studies with rainbow trout caught in catch and release fisheries, indicate that surviving fish learn to avoid being caught again (Askey et al. 2006). No similar experiments have been conducted with Chinook or coho salmon, but it is possible their catchability would likewise drop with each capture (Cramer 2008).

Excerpt F (S. Witalis) – Get and review NMFS BiOp for ocean harvest. How many covered fish are allowed to be harvested now?

Background

NMFS manages ocean salmon fisheries in the 3-200 mile exclusive economic zone (EEZ) off the U.S. coasts. Annual fishery management recommendations are developed by the Pacific Fisheries Management Council (PFMC) in accordance with the Pacific Coast Salmon Fisheries Management Plan (FMP) for the EEZ off the states of Washington, Oregon and California. PMFC provides its recommendations to the Secretary of Commerce, who implements the measures if found to be consistent with the Magnuson-Stevens Fishery Conservation and Management Act (MSA) and other applicable laws, including the Endangered Species Act (ESA).

In California, ESA Section 7 consultations analyze the effects of FMP and recommendations on endangered Sacramento River (SR) winter-run Chinook salmon, threatened Central Valley (CV) spring-run Chinook salmon, threatened California Coastal (CC) Chinook salmon, threatened Southern Oregon-Northern California Coastal Coho (SONCC), and endangered Central California Coastal (CCC) Coho. NMFS collaborates with affected states and PFMC to ensure ocean salmon fisheries are monitored and sampled for stock composition, including the collection of CWTs and other biological information for post season analysis of fishery impacts on listed species.

The biological opinion on the FMP for SR winter-run will be reinitiated by NMFS in 2009 in order to be in place at the start of the 2010 fishing season. NMFS will also consider if reinitiation of the other FMP biological opinions (i.e., for the other listed Chinook and Coho) at this time is warranted.

Harvest Limitations in Place

The MSA requires all Federal fisheries to be managed to prevent overfishing, which could lead to an overfished state, and to rebuild any stock determined to be overfished. Ocean salmon fisheries off California target Sacramento River fall Chinook and Klamath River fall Chinook. Because salmon stocks intermingle in the ocean and are caught together, the fishery is a mixed stock fishery and is managed to prevent overfishing on the weakest stock and to be consistent with ESA jeopardy

standards for listed salmon species affected by the fisheries. There is also prohibition on retention of California Coastal Chinook and all California coho.

Chinook: California Central Valley (CA CV) Complex

The CA CV complex in the FMP includes all fall, late-fall, winter, and spring stocks of the Sacramento and San Joaquin Rivers and their tributaries. Management of this complex is based primarily on Sacramento River fall Chinook, which includes a large hatchery component, and natural Sacramento River winter Chinook, which are listed as endangered.

Sacramento Fall-run Chinook (Not ESA listed)

The Salmon FMP sets the escapement goal for Sacramento River fall Chinook as a range from 122,000 to 180,000 adults. This stock comprises approximately 80-90 percent of the escapement of all Chinook stocks that return to Central Valley streams and hatcheries. The Central Valley Index (CVI), which provides an annual index of abundance for the combined Central Valley Chinook stocks, is the sum of ocean fishery Chinook harvests in the area south of Point Arena plus the Central Valley adult Chinook spawning escapement. The CVI harvest index is the ocean harvest landed south of Point Arena divided by the CVI. Since 1991, the Council's Salmon Technical Team (made up of scientists from NMFS, USFWS, and state fisheries agencies from OR, WA, and CA) has used a linear regression of the CVI on the previous year's Central Valley age-2 return to forecast the CVI. A new model is being developed that focuses on the Sacramento run.

Sacramento River Winter-run Chinook (ESA listed – Endangered)

PFMC is required to reduce ocean harvest sufficiently to increase the adult spawning escapement by 31% relative to a base period (1989-1993). Since 1992, the commercial troll effort off California has been largely limited to San Francisco and Monterey areas. Fishing seasons are severely restricted in areas north of Pt. Arena to allow longer seasons south of Pt. Arena and permit access to CV fall Chinook. In addition, commercial and recreational salmon fisheries between Pt. Arena and Pigeon Pt./Pigeon Pt. and Mexico border are restricted by time and fish length limits, from April/May through early October/November. Based on 1969 and 1970 cohort reconstruction of marked winter Chinook, it was ascertained that 80% of all recoveries occurred in the recreational fishery and 28% of all recoveries occurred in the February and March recreational fisheries. Over 95% of the landings occurred south of Pt. Arena, CA and 74% of all landings occurred in the recreational fish south of Pt. Arena. Analysis of CWT allows for analysis of effectiveness of current fishing regulations.

Central Valley Spring-run Chinook salmon (ESA listed – Threatened)

There are no FMP objectives in place specifically regulating the harvest of spring-run except that the FMP will manage ocean fisheries consistent with NMFS ESA consultation standards. The current FMP harvest constraints on winter-run serve as proxy for CV spring-run. Feather River Hatchery spring-run provides indices of harvest of natural spring-run. Maturing age-3 and age-4 spring Chinook are vulnerable to the early portion of the recreational and commercial season, whereas fall Chinook are exposed to an entire harvest season. Inferences drawn from coded-wire tag recoveries indicate that 44% of the spring-run are taken prior to May 1, the start of the commercial fishing season.

Northern California Coast Chinook Complex

The Northern CA Coast Chinook complex in the FMP includes all fall and spring stocks of California streams north of the entrance to San Francisco Bay. Management of this complex is based primarily on meeting spawning escapements for natural fall Chinook.

Klamath River Fall Chinook (KRFC) (Not ESA listed)

The Council's FMP conservation objective for Klamath River fall Chinook permits a natural spawner reduction rate via fisheries of no more than 0.67, with a minimum escapement of 35,000 natural spawning adults and an age-4 ocean harvest rate of 16.0 percent to meet the NMFS ESA consultation standard for protection of California coastal Chinook. NMFS uses the Klamath Ocean Harvest Model (developed from historical catch and spawning populations of KR fall Chinook) to predict the age-specific harvests rates on Klamath River fall Chinook resulting from proposed management measures. The harvest rate of age-4 KR fall Chinook is an indicator of the percentage reduction in adult (age 3, 4 and 5) spawning abundance due to harvest. The harvest rate of 0.16 is the maximum rate observed since 1996, the year in which additional ESA requirements to protect winter-run Chinook were put in place. The decrease in commercial fishing effort off northern and central California is in part due to the KR fall Chinook harvest allocation to in-river tribal fisheries (50% of fall-run escapement back to the Klamath River).

California Coastal (CC) Chinook (ESA listed – Threatened)

There are no PFMC goals or FMP objectives currently in place for CC Chinook. PFMC will manage ocean fisheries consistent with NMFS' ESA consultation standards. California coastal Chinook management relies on the indirect measure of the preseason prediction of the Klamath Ocean Harvest Model. Fishing mortality on CC Chinook is almost entirely limited to ocean harvest and is similar to ocean harvest rates on KRFC to the extent that ocean distribution of the stocks are the same. The California Fish and Game Commission has prohibited retention of Chinook salmon in all streams within the CC Chinook ESU.

Oregon Production Index Area Coho Complex

This FMP complex includes all WA, OR, and CA natural and hatchery coho stocks from streams south of Leadbetter Pt. Those found in CA are described below.

Southern Oregon/Northern California Coast (SONCC) Coho (ESA listed – Threatened) The SONCC coho ESU includes all naturally spawned populations of coho salmon in coastal streams from the Elk River, Oregon, through the Mattole River, California. It also includes three artificial propagation programs: Cole River Hatchery in the Rogue River Basin, Trinity River and Iron Gate Hatcheries in the Klamath-Trinity River Basin. Coho south of Cape Blanco have a southerly recovery pattern primarily in California (65-92% recovery). Exploitation rates on SONCC CA coho are expected to be similar to exploitation rates estimated by the PFMC for the Klamath/Rogue hatchery coho stocks (5% to 12%) to the extent of shared distribution pattern. PFMC recommendations have resulted in the prohibition of coho retention south of Cape Falcon since 1994, although coho are still impacted by hook-and-release mortality in Chinook-directed fisheries.

Protection for CA populations is the limitation on harvest rates and management of all listed stocks consistent with ESA consultation standards. Management measures developed under the FMP must be designed to achieve an ocean exploitation rate on Rogue/Klamath hatchery stocks of no greater than 13%, the lowest exploitation rates specified under Amendment 13 for OCN subaggretages.

Reinitiation of consultation is contingent on the development of monitoring programs that can permit a better assessment of population trends.

Central California Coastal (CCC) Coho (ESA listed – Endangered)

The CCC ESU consists of all coho reproducing in streams between Punta Gorda and the San Lorenzo River, including the Warm Springs Hatchery, and the Kingfisher Flat Hatchery coho stocks and associated captive broodstock at the SWFSC. Incidental exploitation rates on CCC coho are expected to be similar to exploitation rates (5 – 12%) estimated by the PFMC for the Klamath/Rogue hatchery coho stocks to the extent that ocean distributions of CCC coho and SONCC are similar. Reduced fishing effort off California and a continued prohibition on coho fisheries and coho retention in Chinook fisheries insures that incidental mortality of CCC coho remains low (encounters have been reduced by 25%); incidental take of CCC coho associated with ocean salmon fisheries authorized under the FMP cannot be assessed at this time. This also ensures that mortality rates on California coho stocks associated with the fishery do not increase until adequate assessment of parent spawner recruitment rates can be carried out.

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P1	Chinook Salmon	Increased population size of Central Valley Chinook salmon (all races)	4	3
P2	Chinook Salmon	Increased knowledge base regarding Central Valley Chinook salmon (population sizes, harvest rates, success of restoration programs, and other key biological parameters) for improved management	3	3
P3	Chinook Salmon	Reduce competition and introgression from hatchery fish with natural fish on spawning grounds	4	3
P4	Chinook Salmon	Can improve broodstock management at hatcheries (with tagging, much improved)	4	4
Negative Outcomes				
N1	Chinook Salmon	Complicates management and data acquisition for conservation hatcheries (e.g., Livingston-Stone) and associated agency sampling programs	4	4
N2	Chinook Salmon	Action may lead to increased harvest of hatchery fish, which may result in higher bycatch of covered salmonids	2	2
N3	Chinook Salmon	Action may lead to sociological pressure for increased hatchery production	?	?

OSCM 20:
Artificial Propagation of Smelt

Scientific Evaluation Worksheet

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Action: Artificial Propagation of Smelt

Evaluation Team: Hatcheries and Harvest Workgroup

Brad Cavallo - Chair, Dave Zezulak – Coach/participant, Jim Smith, Jason Kindopp, Shirley Witalis, Alison Willy, Josh Israel, Larry Wise (note taker)

Date of Last Revision: February 19, 2009

Action Description and Clarifying Assumptions

Establish artificial propagation programs for delta smelt and longfin smelt.

Approach

1. Fund a conservation hatchery program to restore Delta smelt and longfin smelt to self-sustaining levels in the wild. A new facility would:
   a. House genetically-managed refuge population sufficiently to minimize loss of genetic diversity,
   b. Provide fish stocks to augment existing populations and provide fish stocks for reintroduction where necessary.
2. Fund efforts by the UC Davis Fish Conservation and Culture Laboratory (FCCL) to expand the refugial population of Delta smelt and establish a refugial population of longfin smelt. The goal of the FCCL's refuge program is to preserve populations and genetic diversity of smelt. The laboratory also provides Delta smelt for multiple research efforts that will further our understanding of the threats to and management options for this species.

Intended Outcomes as Stated in Conservation Measure

1. Increased population sizes of Delta smelt and longfin smelt to self-sustaining levels in the wild.
2. Preserve genetic diversity of delta and longfin smelt.
3. Improved knowledge base about threats to and management of the species stemming from ability to study the effects of various stressors on these species using hatchery reared specimens.

General Conceptual Model Support for Intended Outcomes

1a. Increased population sizes of Delta smelt: Yes, implied in Delta smelt model p. 17, via prevention of Allee effects.

1b. Increased population sizes of longfin smelt: Uncertain, see Longfin smelt model pp. 7,8,29, uncertainty regarding life history, ecology (including breeding system), biogeography, and population viability. Increased research in these areas would improve ability to manage.

2a. Preserve genetic diversity of Delta smelt: Yes, implied in Delta smelt model p. 17, small population sizes can result in genetic problems (genetic drift, inbreeding).

2b. Preserve genetic diversity of longfin smelt: Uncertain, see Longfin smelt model pp. 8, 29, uncertainty regarding genetic independence of population, breeding system not well-studied.

3. Improved knowledge base: No conceptual model support. See support in Attachment

Assumptions

Provided in BDCP Conservation Measure

1. Genetic diversity and integrity necessary for wild survival of hatchery reared smelt will be maintained.
2. The action will produce fish that are able to survive and reproduce in the wild.

Added by Evaluation Team

1. Spawning cues may be related to total abundance (based on European smelt). Current population may be at or below this level.
   Note: Concept is that there need to be a threshold number of spawners to obtain good spawning success, and that natural populations may be below this level. Robert Clarke says that they are more concerned about swamping the natural population with hatchery releases.

2. Wild populations are not functionally extinct, however if the become so, the hatchery population may serve as a refugial population for future restoration.

Problem(s) with Action as Written:

1. Action does not discuss how fish would be returned to the environment, i.e., as fry or adults. Bob Clarke TBD by the Recovery Plan.
2. Action does not specify how fish would be collected for broodstock (see Excerpt B, Attachment A, J. Smith). For our evaluation, we have assumed adults would be collected. May be difficult to use juveniles, because they are so fragile and thus have high mortality when captured.
3. Assumptions provided with the action are not supported by experience with existing conservation hatcheries, which all report problems in maintaining genetic diversity (Turner et al. 2007)
4. Fish produced in hatcheries currently are maladapted to conditions in the natural environment and have reduced fitness relative to wild fish. These fish also have been shown to negatively affect wild populations through a variety of mechanisms. However, see Raney 1942 regarding alternate rearing techniques for silvery minnow.
5. Conservation hatcheries are generally experimental in nature and need to be managed adaptively to meet objectives. There is only one example of conservation hatcheries for group spawners (silvery minnow).
6. There is nothing in this action that would prevent it from destabilizing the population, through removal of broodstock, or through exacerbating Allee effects, which are already a problem for this species.
7. Goals of the hatchery need to be explicitly stated. This will govern hatchery procedures.

Scale of Action:

Medium to large

Rationale:

If the natural population becomes functionally extinct then it would contribute substantially and the effect would be large.

If it is used to supplement the natural population (e.g., 10% of natural population) then effect would be medium.

Evaluation Summary

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

NO. This will not affect ecosystem dynamics, small biomass going into system

Potential Positive Ecological Outcome(s)

Outcome P1: Increased population sizes to self-sustaining levels in the wild

P1a. Delta smelt

General Observations

See Attachment A for detailed information regarding the following references:
- Info from other conservation hatcheries
- Flagg et al. (2000) Conservation Hatchery Protocols (pp. 29-36).
- Delta smelt conceptual model p. 17
- Carolsfeld 1997, Kowalski et al 2006, Sorensen 1998, and Sveinsson and Hara 1995 (references from A. Willy)
- USFWS (2003) pp. 31-37 (History of Conservation Measures, pp. 37-42 (Strategy for Recovery and Recovery Analysis)
- USFWS (1998) p. iv (Exec. Summary), pp. 3-7 (distribution info), pp. 14-15 (conservation measures), pp. 16-19 (recovery plan), pp. 20-40 (tasks for recovery)
- Richards et al. (2004)
- Nobriga (2008), Excerpt D (Nobriga)
- Excerpt A, Attachment A (A. Willy)

Magnitude = 3

Sustained minor population effect if supplemental. Potential large effect if wild population goes functionally extinct.

Certainty = 2

Many factors control populations in the wild that would not be affected by this action. There is considerable uncertainty regarding the fitness of any hatchery produced fish to conditions in the wild.

P1b. Longfin smelt

General Observations

See Attachment A for detailed information regarding the following references:
- Info from other conservation hatcheries
- Flagg et al. (2000) Conservation Hatchery Protocols (pp. 29-36).
- Carolsfeld 1997, Kowalski et al 2006, Sorensen 1998, and Sveinsson and Hara 1995 (references from A. Willy)
- USFWS (2003) pp. 31-37 (History of Conservation Measures, pp. 37-42 (Strategy for Recovery and Recovery Analysis)
- USFWS (1998) p. iv (Exec. Summary), pp. 3-7 (distribution info), pp. 14-15 (conservation measures), pp. 16-19 (recovery plan), pp. 20-40 (tasks for recovery)
- Richards et al. (2004)
- Nobriga (2008), Excerpt D (Nobriga)

Magnitude = 3

Sustained minor population effect if supplemental. Potential large effect if wild population goes functionally extinct.

Certainty = 1

Propagation techniques have not been established for longfin smelt.

Outcome P2: Preserve genetic diversity

P2a. Delta smelt

General Observations

See Attachment A for detailed information regarding the following references:
- Hatchery management protocols for group spawners
- Carolsfeld 1997, Kowalski et al 2006, Sorensen 1998, and Sveinsson and Hara 1995 (references from A. Willy)
- Turner & Osborne (2008) CALFED Workshop presentation.
- Delta smelt conceptual model p. 17
- USFWS (2003) pp. 31-37 (History of Conservation Measures, pp. 37-42 (Strategy for Recovery and Recovery Analysis)
- USFWS (1998) p. iv (Exec. Summary), pp. 3-7 (distribution info), pp. 12-13 (genetic considerations), pp. 14-15 (conservation measures), pp. 16-19 (recovery plan), pp. 20-40 (tasks for recovery)
- Hedgecock et al. (2000) Abstract
- Hedrick et al. (1995)
- Nobriga (2008), Excerpt D (Nobriga)
- Clarke, pers comm. to A. Willy
- Turner et al. 2007. Example of determining effective population size for a group spawner.

Magnitude = 3

Controlled breeding can increase effective population size, especially with supplementation from wild stocks.

Certainty = 2

Existing conservation hatcheries generally have reduced diversity. However, Hedrick 2004 succeeded in increasing effective population size in winter-run Chinook salmon.

P2b. Longfin smelt

General Observations

See Attachment A for detailed information regarding the following references:
- Hatchery management protocols for group spawners
- Carolsfeld 1997, Kowalski et al 2006, Sorensen 1998, and Sveinsson and Hara 1995 (references from A. Willy)
- Turner & Osborne (2008) CALFED Workshop presentation.
- USFWS (2003) pp. 31-37 (History of Conservation Measures, pp. 37-42 (Strategy for Recovery and Recovery Analysis)
- USFWS (1998) p. iv (Exec. Summary), pp. 3-7 (distribution info), pp. 12-13 (genetic considerations), pp. 14-15 (conservation measures), pp. 16-19 (recovery plan), pp. 20-40 (tasks for recovery)
- Hedgecock et al. (2000) Abstract
- Hedrick et al. (1995)
- Nobriga (2008), Excerpt D (Nobriga)

- Turner et al. 2007. Example of determining effective population size for a group spawner.

Magnitude = 3

Controlled breeding can increase effective population size, especially with supplementation from wild stocks.

Certainty = 1

Existing conservation hatcheries generally have reduced diversity. However, Hedrick 2004 succeeded in increasing effective population size in winter-run Chinook salmon. Greater uncertainty for longfin smelt because propagation techniques have not been established for this species.

Outcome P3: Improved knowledge base about threats to and management of the species stemming from ability to study the effects of various stressors on these species using hatchery reared specimens

General Observations

Research is being conducted by multiple UC Davis researchers and others into Delta smelt stressors (e.g., Inge Werner's work).

Magnitude = 4

Demonstrated through studies conducted by Werner and others.

Certainty = 4

Demonstrated through studies conducted by Werner and others.

Potential Negative Ecological Outcome(s)

Outcome N1: Genetic consequences for hatchery and wild populations

N1a. Delta smelt

General Observations

See Attachment A for detailed information regarding the following references:
- Robert Clarke, pers. comm.
- Komen et al. (2006) Abstract
- Kostow (2008) Abstract & Intro
- Fraser (2008) Abstract
- Excerpt A, Attachment A (A. Willy)

Magnitude = 3

Existing conservation hatcheries for similar species have reduced diversity (Alo and Turner 2005). Fraser 2008. Meta-analysis of Captive Breeding Programs. in Evolutionary Applications.

Certainty = 2

Fraser 2008 suggests that conservation breeding programs are highly variable in their success in preserving genetic integrity and fitness.

N1b. Longfin smelt

General Observations

See Attachment A for detailed information regarding the following references:
- Robert Clarke, pers. comm.
- Komen et al. (2006) Abstract
- Kostow (2008) Abstract & Intro
- Fraser (2008) Abstract
- Excerpt A, Attachment A (A. Willy)

Magnitude = 3

Existing conservation hatcheries for similar species have reduced diversity (Alo and Turner 2005). Fraser 2008. Meta-analysis of Captive Breeding Programs. in Evolutionary Applications.

Certainty = 1

Fraser 2008 suggests that conservation breeding programs are highly variable in their success in preserving genetic integrity and fitness. Greater uncertainly for longfin smelt because propagation techniques have not been established for this species.

Outcome N2: Negative ecological interactions with wild fish (competition, displacement)

The following applies to both delta and longfin smelt.

General Observations

See Attachment A for detailed information regarding the following references:
- Robert Clarke, pers. comm.
- Kostow (2008) Abstract & Intro
- Nobriga & Feyrer (2007)
- Nobriga & Feyrer (2008)
- Nobriga et al. (2008)
- Bennett et al. (2008) p. 4 (Figure 1), Discussion (p. 24-26)
- Miller (2005) p. 1
- Excerpt A, Attachment A (A. Willy)

Magnitude = 3

Documented depression of food resources for Delta smelt in the late summer and fall (Nobriga and Feyrer 2007, 2008; Bennett et al. 2008; Miller 2005). Increasing populations would increase competition for these food resources. Less is known about longfin smelt.

Certainty = 2

Competition would certainly occur, but impact would be variable because of the effects of external factors on food production.

Outcome N3: Mining of wild population to support broodstock needs

The following applies to both delta and longfin smelt.

General Observations

Information from the Hatchery Scientific Review Group .

Magnitude = 3

Small natural populations. May be more of a problem for longfin smelt.

Certainty = 3

We have a good understanding of catch mortality (Swanson et al. 1996) and a general understanding of the population and the location of the existing population. This allows this catch to be managed appropriately to minimize impacts to wild populations. Because longfin smelt are larger, they will likely be less sensitive to handling stress and physical injury than Delta smelt.

Outcome N4: Mortality associated with catching broodstock (genetic material lost)

N4a. Delta smelt

General Observations

Currently using Lampara nets which results in low mortality; consider collecting fish from areas where they would already be lost to entrainment.

See Attachment A for detailed information regarding the following references:
- Swanson et al. (1996) - paper on Delta smelt handling effects, pp. 326-328.
- See Excerpt B, Attachment A (J. Smith) for information about type of net used.

Magnitude = 2

Existing brood stock collection program has very low mortality (Swanson et al. 1996, Bob Clarke pers. comm. to J. Smith).

Certainty = 3

Existing studies (Swanson et al. 1996) indicate that using current techniques there is relatively low mortality associated with collection of brood stock.

N4b. Longfin smelt

General Observations

Catch mortality is expected to be lower for longfin smelt than for Delta smelt. See Attachment A for catch mortality information from Swanson et al. 1996.

Magnitude = 2

Existing studies (Swanson et al. 1996) indicate that using current techniques for Delta smelt, there is relatively low mortality associated with collection of brood stock. This suggests that mortality associated with collecting longfin smelt would also be relatively low because longfin are larger and presumably less sensitive to handling stress and physical.

Certainty = 2

Although current techniques for catching broodstock for Delta smelt are associated with relatively low mortality, brood stock collection and artificial propagation have not been conducted for longfin smelt to date.

Important Gaps in Information and/or Understanding

Data Needs

- Don't know at what lifestage stock would be collected or released.
- Little is known about spawning and rearing longfin smelt under hatchery conditions.
- If numbers produced were sufficient to supplement and encourage spawning when released into the wild, then this would be beneficial. However, the number of fish needed to boost spawning is unknown. Number needed for hatchery 60,000 to 6 million per Bob Clarke.
- Information on genetics of wild populations vs. captive populations. Is fitness of hatchery fish comparable to wild fish? All conservation hatcheries, except winter run Chinook, have reduced genetic diversity (see Excerpt A, Attachment A, A. Willy). So far there has been little success in maintaining genetic diversity in hatchery programs for group spawners. The winter run hatchery has been successful, but this is not a group spawner.
- Very little is known about longfin smelt genetics and hatchery propagation.
- Adaptive characteristics of fish are unknown.

Research Needs

- Initiate research into captive breeding of longfin smelt, perhaps using specimens from other populations in Washington or elsewhere.
- Need to discover ways to capture larval and juvenile smelt so they will survive to be brought to the hatcheries.
- Look at methods to implement hatcheries using larval or juvenile smelt as a mechanism to increase genetic diversity and reduce take of adult smelt needed to support wild populations.
- Compare genetic diversity of wild larval vs. adults smelt to reduce the risk of bottlenecks and allee effects associated with adult broodstock.
- Development of adaptive management plan with an emphasis on spreading risk and continually modifying the program to maximize genetic input to the program and minimize impacts to wild populations.
- This action should be implemented as a targeted research program to determine the best way to manage the risks inherent in such a program, before being implemented at full scale.

Assess Reversibility and Opportunity for Learning

Reversibility

Yes/easy

Opportunity for Learning

High

Comments: Current research being done on factors affecting Delta smelt by UC Davis and others using hatchery produced fish.

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DRERIP Evaluation Workshop – Attachment A

Artificial Propagation of Smelt

OUTCOME P1: INCREASED POPULATION SIZES TO SELF-SUSTAINING LEVELS IN THE WILD

P1a. Delta smelt

1. Flagg et al. (2000)

    - Conservation Hatchery Protocols: Discusses potential ways in which conservation hatchery practices can enhance wild populations and gives specific examples from literature (pp. 29-36) (from E. Floyd).

2. Delta smelt conceptual model

    - “Allee effects occur when reproductive output per fish declines at low population levels (Allee 1931, Berec et al. 2006). Below a certain threshold the individuals in a population can no longer reproduce rapidly enough to replace themselves and the population spirals to extinction. For Delta smelt, possible mechanisms for Allee effects include mechanisms directly related to reproduction such as difficulty finding enough males to maximize egg fertilization during spawning (e.g., Purchase et al. 2007) or depensatory egg predation (e.g., DeBlois and Leggett 1991)” (Ecology section, p. 17). Supplementing populations via a conservation hatchery should prevent Allee effects.

3. Carolsfeld 1997, Kowalski et al 2006, Sorensen 1998, and Sveinsson and Hara 1995 (references from A. Willy)

    - As seen in other pelagic, group-spawning species, the number of males in the spawning run affects the spawning cue, milt production, and semen viability. It is unknown how many male Delta smelt are needed to cue and increase spawning when abiotic conditions are favorable for spawning.

4. USFWS (2003)

    - Provides history of conservation measures and their success and strategy for recovery used (pp. 31-42).

5. USFWS (1998)

    - Provides review of successful and unsuccessful conservation measures and methods for reintroduction and recovery (pp. iv, 3-7, 12-40).

6. Richards et al. (2004)

    - “We found that stocked and wild lake trout both contributed to restoring self-sustaining stocks in Lake Superior, which was the primary objective of all fishery management agencies involved with lake trout rehabilitation in the Great Lakes.” (from J. Smith)

7. Nobriga (2008) (from J. Isreal)

- Turner: Rio Grande Silvery Minnow

  - Trying environmentally induced communal spawning (turbidity): variable success relative to hormonally induced.
  - Will not be self-sustaining until improve river habitat.
  - AP is insurance vs. catastrophe, not a long-term solution.

- Waples:

  - Many risks are tightly inversely linked (e.g., inbreeding vs. catastrophic loss or swamping wild populations).
  - PacNW hatcheries cannot demonstrate success of ultimate goals of self-sustaining natural populations.
  - Supplemented salmonid populations not increasing relative to unsupplemented.
  - Supplementation might buffer very low abundance.

- See panel discussion (Excerpt D, Nobriga) for summary of pros and cons of artificial propagation.

P1b. Longfin smelt

*See references above for Delta smelt, excluding information from the Delta smelt conceptual model.

OUTCOME P2: PRESERVE GENETIC DIVERSITY

P2a. Delta smelt

1. Carolsfeld 1997, Kowalski et al 2006, Sorensen 1998, and Sveinsson and Hara 1995 (references from A. Willy)

   - It is unknown whether hatchery fish can be used to assist in enhancing spawning without genetically suppressing the wild population.

2. Turner and Osborne (2008)

   - Presentation discussing successful conservation hatchery practices for the Rio Grande silvery minnow, a group spawner. In-stream propagation, such as that used for Rio Grande silvery minnow captive propagation, may assist in maximizing genetic variability and studying optimal release sizes (from E. Floyd).

3. Robert Clarke, pers. comm.

   - Inbreeding depression is likely. A captive population is likely to have more of a genetic bottleneck than a wild population (from A. Willy).

4. Delta smelt conceptual model

   - Genetic problems like inbreeding and genetic drift result from small population sizes. Supplementing populations via a conservation hatchery should reduce these problems to some degree (Ecology section, p. 17).

5. USFWS (2003)

   - Provides history of conservation measures and their success and strategy for recovery used (pp. 31-42) (from J. Smith).

8. USFWS (1998)

- Provides review of successful and unsuccessful conservation measures and methods for reintroduction and recovery (pp. iv, 3-7, 12-40) (from J. Smith).

9. Hedgecock et al. (2000)

- Findings provide optimistic outlook for success of supplementation program for winter-run Chinook, suggesting that overall effective population size has not been greatly reduced. Returning spawners represented a broad sample of parents and not fish from only a few families in this study (Abstract) (from E. Floyd).

10. Hedrick et al. (1995)

- “It does not appear that the hatchery program has reduced the overall effective population size” (Abstract, from J. Smith).

11. Nobriga (2008) (from J. Isreal)

- Hedrick: Summary: small populations, inbreeding, adapt to captivity; Recommendations: large population size, minimize kin breeding, replicate populations, bring in wild genes, keep captive generations minimal, captive environment like natural environment.

- Turner: Rio Grande Silvery Minnow

    - o Low genetic diversity despite high population numbers at times, but still have significant genetic differences among populations in the river.
    - o Temporary population structure from reproductive schooling; not same groups year after year.
    - o 0.5M reproductively capable adults needed in captive broodstock, multiple facilities needed.
    - o Catching eggs and repatriating as adults is working well for maintaining genetic diversity.
    - o Augmentation increased gene diversity, but not variance in the EPS.

- Clarke: UCD and Livingston Stone, neither facility is large enough to maintain subpopulations.

- Bridges: Don’t wait; start refugial population now so do not risk loss of genetic diversity.

- Fisch: Need to know both wild fish genetics and MGD genetics to develop a good plan.

- See panel discussion notes (Excerpt D, Nobriga) for summary of pros and cons of artificial propagation.

P2b. Longfin smelt

*See references above for Delta smelt, excluding information from the Delta smelt conceptual model.

OUTCOME P3: IMPROVED KNOWLEDGE BASE ABOUT THREATS TO AND MANAGEMENT OF THE SPECIES

1. Current research being conducted by UC Davis and others into Delta smelt stressors

- e.g., Dr. Inge Werner (Aquatic Toxicology Lab, UC Davis), effects of chemical contaminants on survival, behavior.

OUTCOME N1: GENETIC CONSEQUENCES FOR WILD AND HATCHERY POPULATIONS

N1a. Delta smelt

1. Robert Clarke, pers. comm.

   - FWS policy is that reintroduction of species happens when a captive population can help support a wild population (negative genetic consequences would have to be negligible for supplementation to occur). It may be difficult to assess genetic consequences for wild fish.

   - Plan to introduce 10% of the effective breeding population size; "enough to work, but not so much as to swamp the population." Uncertainty on how many to introduce (estimate between 60,000 and 6 million fish).

   - Plan to model breeding protocols after Rio Grand silvery minnow (i.e., cultivated in channels, where flow and water quality are controlled, and many generations are kept concurrently. This will allow for group spawning.). Mating structure is not known when group spawning takes place, and this may result in increased rates of inbreeding (see Komen et al. 2006) (from E. Floyd).

2. Kostow (2008)

   - Review paper outlining potential negative effects of hatchery fish on wild populations, and ways to mitigate these impacts (Abstract & Intro provide good overview) (from J. Isreal).

3. Fraser (2008)

   - Suggests that conservation breeding programs are highly variable in their success in preserving genetic integrity and fitness (Abstract) (from J. Isreal).

N1b. Longfin smelt

*See references above for Delta smelt.

OUTCOME N2: NEGATIVE ECOLOGICAL INTERACTIONS WITH WILD FISH (COMPETITION, DISPLACEMENT)

1. Robert Clarke, pers. comm.

   - FWS policy is that reintroduction of species happens when a captive population can help support a wild population (negative ecological consequences would have to be negligible for supplementation to occur). It may be difficult to assess negative ecological consequences for wild fish.

   - Plan to introduce 10% of the effective breeding population size; "enough to work, but not so much as to swamp the population." Uncertainty on how many to introduce (estimate between 60,000 and 6 million fish).

2. Kostow (2008)

   - Review paper outlining potential negative effects of hatchery fish on wild populations, and ways to mitigate these impacts (Abstract & Intro provide good overview) (from J. Isreal).

3. Nobriga & Feyrer (2007, 2008), Nobriga et al. (2008)

   - The release of hatchery fish during the summer and fall, when food productivity and availability is low, is likely to stress wild fish that are attempting to survive with limited food resources (i.e., increased competition for food resources with release of hatchery fish, from A. Willy).

4. Bennett et al. (2008)

   - Reduced food availability late summer through fall (p. 4, Figure 1); evidence of selection for slow growing larvae and poor body condition under food limited conditions (i.e., otolith data for growth, most individuals showed signs of reduced glycogen content; Discussion, p. 24-25).

   - Results suggest selective mortality (for slow growers) and poor body condition were intensified by extreme environmental conditions (Discussion, p. 24-25).

   - Patterns are consistent with widespread decline of calanoid copepods in Delta (Discussion, p. 26) (from A. Willy).

5. Miller (2005)

   - Strong correlation between Delta smelt abundance and the availability of *Pseudodiaptomus* (i.e., low Delta smelt fall midwater trawl abundance index associated with extremely low level of prey (the zooplankton *Pseudodiaptomus forbesi*, p. 1).

OUTCOME N3: MINING OF WILD POPULATION TO SUPPORT BROODSTOCK NEEDS

*See information from Swanson et al. (1996) below (N4). Good understanding of catching associated mortality will allow catch to be managed appropriately.

OUTCOME N4: MORTALITY ASSOCIATED WITH CATCHING BROODSTOCK (GENETIC MATERIAL LOST)

N4a. Delta smelt

1. Swanson et al. (1996)

   - Delta smelt are extremely sensitive to handling. Initial attempts to collect transport and handle smelt were hampered by mortality rates over 90% (Intro, p. 326).

   - Use of polyethylene bags instead of rectangular coolers increased 4-h survival from 40.7 to 83.6%; 72-h survival increased from 6.9 to 27.9% (Results, p. 327).

   - With addition of NovAqua to transport water, 72-h survival increased to 54.4% (Results, p. 327).

   - Survival increased as season progressed (survival of fish collected in November was significantly higher than fish collected two months prior at 74.3%), likely due to seasonal changes in fish size and estuary conditions (i.e., temperature, salinity; Results & Discussion, pp. 327-328)

   - Existing brood stock collection program has very low mortality (from R. Wilder).

N4b. Longfin smelt

*See information from Swanson et al. (1996) under N4a.

Excerpt A (Willy) – Conservation hatchery information from Bob Clarke

How many adult (?) Delta smelt will be planted by hatchery? Will this number be a large or small component of likely current population? Is it enough? Age and timing of release?

The number of Delta smelt propagated in the hatchery will be dependent on the size of the facility, but the range would be between 60,000 and 6,000,000 fish. The final determination of size will probably support approximately 500,000 Delta smelt and represent about 10 percent of the wild population (Robert Clarke *pers comm.*). The hatchery is initially intended to hold a genetic refuge population. The Fish and Wildlife Service will be able to consider supplementation or reintroduction if those become recovery needs identified in a recovery plan. The point would be to "try and nurse along a wild population...[and] we need enough to work, but not so much as to swamp the population" (Robert Clarke *pers comm.*). It is unknown whether this will be enough. Age, timing, and location of release are yet to be determined.

As seen in other pelagic, group-spawning species, the number of males in the spawning run affects the spawning cue, milt production, and semen viability (Carolsfeld 1997, Kowalski et al 2006, Sorensen 1998, and Sveinsson and Hara 1995). It is unknown how many male Delta smelt are needed to cue and increase spawning when abiotic conditions are favorable for spawning. It is also unknown whether hatchery fish can be used to assist in enhancing spawning without genetically suppressing the wild population. In-stream propagation, such as that used for Rio Grande silvery minnow captive propagation, may assist in maximizing genetic variability and studying optimal release sizes.

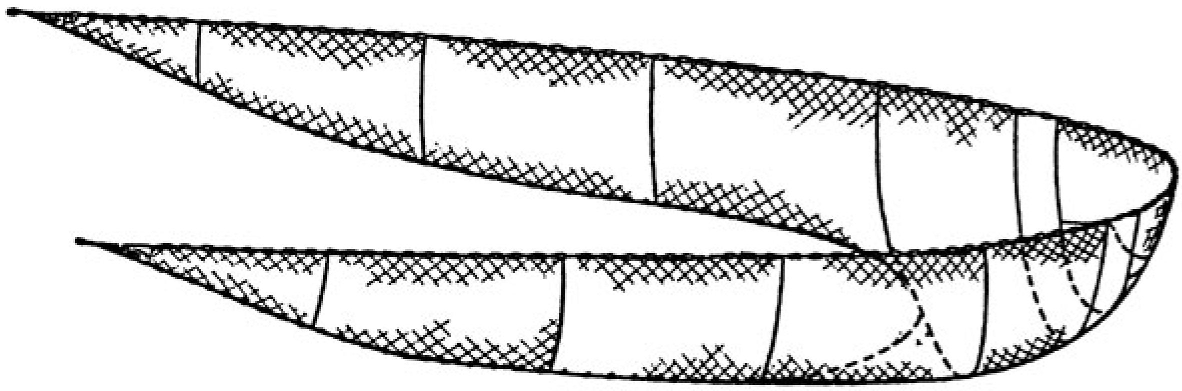
Find literature on how species similar to Delta smelt may adapt to hatchery environment such that natural fitness may be reduced. Rainbow smelt? Annual, group spawner (silvery minnow).

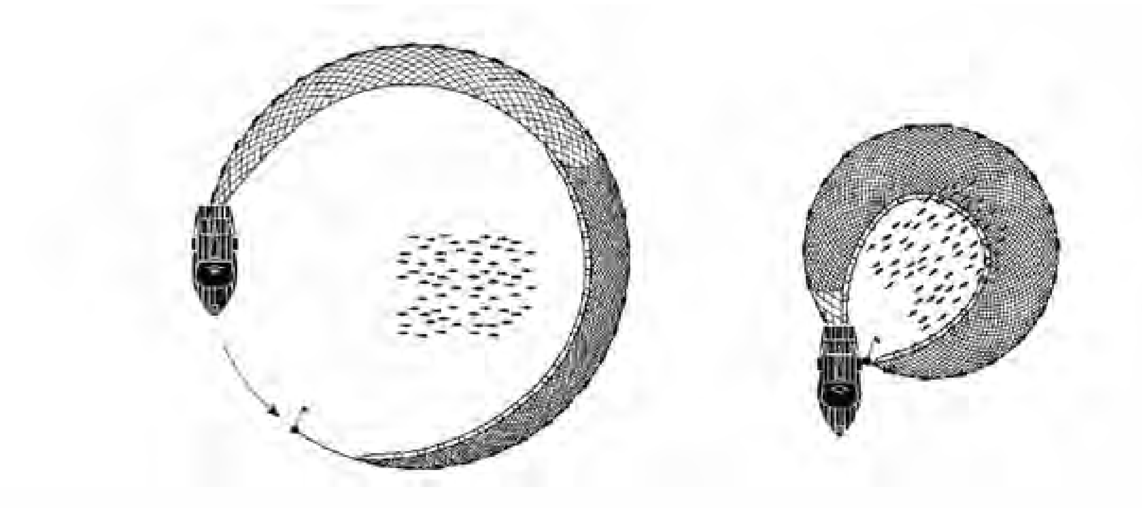
Inbreeding depression is likely. Ongoing work on the Rio Grande silvery minnow (Osborne et al 2006) may inform our future decisions. A captive population is likely to have more of a genetic bottleneck than a wild population (Robert Clarke *pers comm.*).

Excerpt B (Smith) – How will DS and LFS be collected for broodstock?

Delta smelt broodstock are collected by UC Davis Fish. Conservation and Culture Lab folks who go out with USBR. They use a lampara net (kind of like a purse seine) and collected about 70. I have not been out with them, but they tell me the boat is pretty small, so my guess is the net is handled by hand, not winches. - Bob Clarke

Lampara net
The lampara net is similar to a purse seine, but it has tapered panels to give a characteristic scoop shape rather than being flat. The lampara net is set around a school of fish and when both ends are retrieved the vessel tows the net forward, closing the bottom and then top of the net. This type of net is used to catch pilchards and anchovy in inshore waters.





Excerpt C (Smith) – Get examples of conservation hatcheries and how they've worked from Bob Clarke - FWS

List of Conservation hatcheries reviewed
Apache trout
Gila trout
Gila topminnow
Greenback trout
Barren's topminnow
Lake trout (Lake Superior)
Stripped bass - East Coast
Robust redhorse
Chinook salmon - Winter-run
Lahontan cutthroat trout
Kootenai River sturgeon
Lake Sturgeon – Menominee Res
Paddlefish
Razorback sucker
Bonytail chub Colorado pikeminnow

Gila trout

1975 – Only 4 populations remain
1989 – Stocking begins
Increased from 4 to 14 populations – 7 as a direct result of hatcheries
Natural reproduction occurring in all populations

Lake trout (Lake Superior)

1830 to 1960 – Stocks decimated
1950s – Stocking programs begin
2000 – Self-sustaining pops restored to MI waters of Superior
2007 – Natural reproduction widespread, most stocking discontinued

Chinook salmon - Winter-run

1994 – Approximately 200 fish return
1998 – Livingston Stone NFH begins operations
2006 – 17,000 fish return
Hatchery operations increased returns
Loss of genetic diversity unlikely
Little phenotypic variation

Still need to gather up reference on above programs.

Excerpt D (Nobriga) - CALFED AP Workshop 7/24/2008

Dahm:

1. Please attend Science Conference!
2. Speaker overviews
3. Discussion questions:
    a. Pros and cons
    b. Circumstances

c. When to say no
d. What kinds of fishes more or less successful
e. Alternatives?

Hedrick

1. Lower Colorado – very few large river fishes left 0-a few thousand
2. Long-term EPS; originally ca. 100,000+ effective population size
3. current census oom lower than evolutionary EPS
4. Bonytail brood stock 5-10 30 yr old fish; no successful reintro; substantial bottleneck
5. humpback range extended above Chute Falls and that worked; marked fish have been seen traversing falls now that fish are there
6. razorbacks repat'd for 20 yr or so, but need to be 350 mm to be successful; ~ 2500 repats in Havasu; but have released 100,000's; stripers are taking razorbacks even more than 350 mm
7. Genetic variation: adaptive, neutral, detrimental
8. Most adaptive variants are quickly fixed by selection; rarely polymorphic
9. Winter-run
10. Disease is a huge problem for rare spp (wolves, tasman devil, etc.)
11. exposure from common spp and new pathogens w/ inbreeding or other reduced genetic variation
12. WR MHC heteros vs homos; inbred vs. outbred; virus, bacteria, parasite Arkush etal 2002 CJFAS; if natural condition stressful; incidence higher?
13. Neutral var used for ID and genetic rate estimation; microsats, snps, mtDNA
14. Humans have estim 7m SNPs, so large pool of potential info
15. Gila/Yaqui topminnow; morpho identical, 99% mtDNA and microsats so different that diverged ~ 1m years ago; typical massive decline; genetic var all over; definitely blinking out, but ASU has captive broodstock
16. WR supplementation gain in production vs. decline in natural EPS
17. careful genetic monitoring showed returns weren't all coming from 1 parent; survival from supp parents were more or less random
18. Pallid sturgeon n= 45-136; little to no recruitment; starting captive broodstock, but releases have low survival; effective size in captivity approaching 80
19. Genetic rescue worked for mex wolves, FL panther – bringing genes from elsewhere; mex wolf has low fitness, but hunting still taking 'em out
20. Summary: small pops, inbreeding, adapt to capt
21. Recs: large pop size, minimize kin breedin', replicate pops, bring in wild genes, keep captive generations minimal, captive environ like natural one

Turner

1. Rio Grande silvery minnow is annual; pelagic eggs and larvae; then larvae go lateral
2. captive breeding, bringing wild larvae into cap, refugial pops in mg'd habitat
3. Spawning cued to flow pulses
4. Dams are passable in downstream direction, but not upstream
5. rgsms are dominant fish in their habitat and rebounded when SW drought ended in 2004-2005
6. genetic monitoring for 10 yr EPS/Pop ab.
7. low genetic diversity despite high pop #s at times; but still signif genetic diffs among little pops wi the river! Temporary pop structure from repro schooling; not same groups year after year
8. Effective pop size is on order of 100-500 fish, but 10,000s to 100,000s in census; how?

9. distance of spawning from a diversion dam; some schools get lucky; before dams were built, EPS/TPS was much higher than current; eggs drift in genetically cohesive groups; Bill's "spreading the risk" multiple cohorts; Pecos River minnows have unfrag'd habitat and higher EPS/TPS
10. Argue 0.5M repro capable adults needed in capt broodstock; multiple facilities
11. Catching eggs and repat'ing as adults is working well for maint. Genetic div.
12. Trying env induced communal spawning – turbidity; much variability compared to hormonal treatments, which ensure fish good to go
13. Hormonal communal spawn is looking like best econ and success option
14. Gene diversity was plummeting until captive broodstock repat'd fish started being added because reintroduced a lost rare haplotype
15. However, until river habitat is improved; no self-sustaining possible
16. Augmentation increased gene diversity but not variance EPS
17. AP seen as insurance against catastrophe; not long-term solution

Clarke

1. UCD + Livingston Stone; neither facility large enough esp. if subpops need to be maintained; little room for supplementation/reintro program; no ability to address other spp – FWS wants to remedy these
2. Goal; Estab a cons hatchery to help restore Delta smelt to self-sust levels in the wild
3. Model on Dexter NFH; $15-20M for smelt + 2 additional spp
4. Hatchery success list; reintros
5. work when in conjunction w/ habitat fixes

Qs for Bob

1. McEwan: will facilities have an end point? Yes – recovery plan would establish when supp would cease
2. Planning and Conservation League: when is supp appropriate (wild pop + habitat) FWS policy – recovery plan and looks at data; pro judgment; good insurance policy; annual fish forward planning
3. Kolborn Assembly parks committee: WR no genetic diversity loss – generally applicable? Didn't check; picked clearest examples to show its possible Facility cost is construction? How to pay for it? Maintenance cost? Yes; annual cost $1-2M; funding source undecided – multigroup contribution?
4. Hedrick: WR 17,000 spawners? 17,000 total return; unknown hatchery contribution; see FWS compendium report
5. Turner CFSciences: hatchery + hab restoration – what is that hab fix that is needed here? No comment but Victoria chimed in…plan will fall out of developing threats assessment
6. Maissonueve DWR: decision yes or no is part of recovery plan; now, 2 yrs from now – dunno; Do we know if wild gene pool is sufficient; Katie's talk

Bridges

1. Don't wait – risks loss of gene diversity – started a refugial pop
2. no actual supp plan for now
3. New site in Byron is where CHTR studies were done; adult system is not finished/larvae-juv is
4. > 500 broodstock incl 2 yr olds from Dec 2006
5. Livingston Stone is backup

6. Cuz facility not big enough used single pair crosses; historically did multimale; keeping fish alive as long as they are willing!
7. Age-2 massive more fecund
8. Needed min 50 SPCs to minimize inbreeding
9. Each SPC is kept alone throughout life cycle
10. 2nd clutch fecundity was same as 1st; even got 3rd and 4th time spawners (rare and lower batch fecundity) temps kept low
11. Peaks between 1st and 2nd spawns ~ 3 mos?
12. breeding plan needs to be updated – how many MFGs actually surviving? How many are needed? If only SPCs lots o' tanks! Establish a pedigree; verify parent DNA at spawning; wild supps are unlikely, so gonna go mostly on fully captive broods; hope to add a few wilds in (probably recommended); artif selection does occur
13. Refuge phase 1 nearly complete; phase 2 plan for expansion – uncertain how large they need to be – waiting on genetic data

Qs for Bradd

1. Turner: multiple spawns in the wild? DFG has found KT evidence; how many 2 yr olds? < 5%; gene variation for spawn success? Unknown but will eventually be able to tell
2. Berm PCLeague: mock release? Gonzalo's study; PIT tagging? 30% efficiency at trashrack thru salvage(not sure); also doing calcein marking and checking w/ light; adult studies in Jan-Feb
3. Waples: historic pop structure? Katie's talk
4. Hedrick: Allee effects? Katie – says not discussing

Fisch

1. Trying to develop pedigree on indiv fish to develop mating schemes
2. Pop structure, hybridization, spawning strategies (a la Turner presentation)
3. Captive fish had high allelic richness; high heterozygosity; in HW equilibrium; good markers for analysis; currently no evidence of multiple pops but input data not up to task
4. Markers can pull out individual fams from MFGs; wild fish comparatively unrelated
5. Need to know both wild fish genetics and mgd genetics to develop a good plan

Qs for Katie

1. Waples: Need power analysis to conclude HW equilibrium; so may not have pop structure evidence – or no major diffs
2. Hedrick: archives? Yes back to 40s and many from 1990s on
3. Kolborn: what's timing on additional work to develop breeding plan toward reintro? Natural genetic var part is guideline for reintro; 1 yr-ish
4. Clarke: make sure everybody knows we aren't saying FWS will supplement; only that they want to develop the tool to do it
5. Brim PCLeague: if you see differential survival; offspring do well in capt – will you favor offspring doing well? No – that's why monitored – to make sure you maintain equal representation
6. Turner: are there bad crosses that never work? Bradd – occasionally; this year more, but changed protocols (e.g. 1:1 spawn ratio)
7. Brim: question to Tom: hormonally induced multifish worked best; hormone cues so every fish rep'd
8. Hedrick: Allee effect related to mating ability? Artificial mating can exacerbate an already occurring Allee effect? Bradd: everybody crossed this year AMAP; if left to own devices likely would have been lower, so minimzing opps for worsening Allee fx

Waples:

1. Risk-Benefit; empirical results; Columbia meta-analysis; Repro success in Columbia salmon
2. Reasons not to rely on hatcheries only: long-term sustainability unproven; don't promote natural ecosystems
3. Risks and benefits eval'd on multiple levels, but science can only deal with risks/bennies to natural pops
4. Empirical evidence that sometimes AP can reduce short-term extinct risk and reseed vacate habs; uncertain can speed recovery
5. risks are genetic and ecological fx
6. Ryman-Laikre is dark side of production "success"
7. Fitness declines rapidly with every generation in the hatchery
8. Many risks are tightly inversely linked e.g., inbreeding vs. catastrophic loss or swamping wild pop; sample part of run = low contam, but low gene var vs sample whole run = contam with other runs
9. Expect the (bad) unexpected
10. It has proven impossible to stop hatchery programs once started – consider that before starting
11. PacNW hatcheries cannot demonstrate success of ultimate goals of self-sustaining natural pops
12. Supplemented salmonid pops are not increasing relative to unsupp'd pops
13. Supp might help buffer very low abundance
14. Size and spawning distribution affect repro success
15. questions answered in slide show

Qs for Robin
Berm: why diff response to ocean conditions? Slide was wild fish ocean survival; interp'd as hatchery fish compete w/ wilds in low productivity yrs, but not better yrs; hatchery fish aren't better just swamping the system

Israel
1. Biocoupling – a critter in tune w/ the modified system it gets placed in
2. Recovery opps if not relying on "nature" in a highly modified environ
3. Can AP increase survival of representing a "desired" outcome?
4. Many hatcheries doing their thing w/o considering impacts on other listed fish they aren't propagating
5. Molecular markers as tags for hatchery management: e.g., are fish adapting to the local environment?
6. Know baseline genetics and pop repro demographics before translocation to know what you're shooting for
7. Do you want the strays when trying to repat? Will keeping them promote more straying?
8. More hatchery fish proportionately = more natural selective force
9. Essential studies for repat'ing: source eval (breedng/stocking), pedigree studies, domestication studies; recognize repat is an experiment

Qs for Josh
Hedrick: origin of %'s about wild/hatchery? Based on theory in Mike Ford paper; ratio seems low? Robin said originally Ford model, maybe tweeked by someone else; many folks don't realize numbers aren't independent; nobody has eval'd as dependent

Panel Discussion

1. What are the pros and cons of AP?

Pros
- a. maintain gene pool
- b. reseed vacant habs
- c. meet some societal goals (public edu, meeting harvest goals)
- d. provide a safe-haven stave extinction; not all eggs in one broodstock
- e. captive source to undo extirpation
- f. supplement low spawner density/Allee fx? One circumstance is that Allee low equilibrium; empirical examples lacking

Cons
- a. long-term bennies not demonstrated
- b. expect reductions in fitness
- c. expect reductions in gene diversity
- d. expect unanticipated complications
- e. when are pros cons? False appearances with high hatchery production

Does AP have a role in helping fish thru 7 drivers of change?
- a. how long can fish go w/o going into a low equilibrium? If need to pull an annual thru 10 yr of drought – maybe can; long-term solution, probably not
- b. preserving gene var in AP provides template for adaptation; too much hatchery might generate a fish that's "stuck in the past"
- c. If things change, diff habs might become exploitable; AP provides fish to reseed
- d. THE role for AP; big change = big need for insurance policy; buy time until system improves for smelt, salmon

2. Under what circumstances can (might) AP be effective? Short-term stop gap

Pros
- a. high short-term extinction risk
- b. serious concern for IBD
- c. suitable hab unseeded – moving individs might be better than AP (when possible)
- d. bennies outweigh risks (demonstrated)
- e. in conjunction w/ comprehensive recovery actions; does not work w/o solutions to underlying problems – concern that Delta smelt AP will be panacea to not fixing problems

Is AP in the SJ spring strategy? Program is considering several alts incl AP, could be repast, planning risk-benefit analysis

Density-dependent situation [missed this]
Did Gila trout restoration occur from AP or translocation? Both
Some pops were more amenable to AP

3. When should AP not be used?

a. impression there aren't enough fish is undemonstrated or known not to be high extinction risk
b. natural colonization can do the job
c. logistic challenges prevent risk-averse implementation
d. when risks outweigh bennies; does this involve things w/I culture facility or greater scope?
e. Neg fx on non-target spp
f. Bullets might need to be modified in context of other societal goals

How do you assess that there's vacant habitat that can be colonized?

1. connected or historically connected waterways
2. is genetic diversity consistent with previous connections among waterways
3. historical meta-population dynamics vs. contempo short-term hybridization problems
4. When there are better or easier solutions – cui ui – blocked spawning access to Truckee – easy to fix

Cases where AP shouldn't be used because no viable habitat left (Australia)?

1. Mex wolf your last broodstock will be hunted
2. flip side – old dams will be removed in pac NW? Do you let natural repat or AP assist? Experimental benefit of understanding natural recolonization

What happened with Mt St Helens streams?
Pretty rapid recoveries
Ditto w/ receding glaciers in AK; need nearby robust pops w/ propagules

3. What spp are best suited to AP?

a. freshwater
b. anadromous w/ brief life history phase
c. spp w/ weak pop gen structure (panmictic)
d. crowding tolerant spp
e. long-lived spp like sturgeon – lots of chances to get things right
f. but more chance for catastrophe?

Which local fishes would be most amenable to AP?

a. which are most suitable to have AP for long-term recovery
b. Is Delta smelt suitable?
c. Fw vs. anadromous; sockeye/kokanee more diverged than rtrout/steelhead; kokanee transplant well, sockeye do not; more opp for local adaptation in anadromous fish; not adaptation to fw for part of year; cod showing very discreet pops with local adaptations

Are there alts to AP that should be used for endangered fish conservation?

a. abundant good qual hab
b. fxing natural systems
c. fix the causes of decline
d. fixes can take decades, so AP provides time to fix

e. translocate when possible

Natural flow regime – amount, timing, frequency?
Being implemented in highly mg'd rivers
RGSM partly due to divdam re-op toward more natural hydrograph; ESA motivated, but ecosystem fx are more broadly applicable e.g., into riparian areas
Lower Colorado – semi-nat breeding to get past predation bottleneck, so this type of supplementation is not AP and superior to it
Can supplementation help Delta smelt?
Can't find eggs
Uncertain bottlenecks

Public comment
Barbara BermPCL
CA leg bill on smelt hatcheries; full take authorization in exchange for funding for hatchery; comments? Where do existing conservation hatcheries get their funding and tie into bigger pic restoration?

No general rule; some are FWS funded; others by action agencies as mitigation; Dexter may get Congressional funding

Fed mandates eg Columbia hydropower system; usually state/tribal funded; not originally conservation-oriented; had to demonstrate net benefit to listed ESU; rough times, but substantial changes in ops due to ESA

5 key pts for legislators

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P2a	Delta smelt	Preserve genetic diversity	3	2
P1a	Delta smelt	Increased population sizes to self-sustaining levels in the wild	3	2
P3	Delta smelt & Longfin smelt	Improved knowledge base about threats to and management of the species stemming from ability to study the effects of various stressors on these species using hatchery reared specimens	4	4
P2b	Longfin smelt	Preserve genetic diversity	3	1
P1b	Longfin smelt	Increased population sizes to self-sustaining levels in the wild	3	1
Negative Outcomes				
N4a	Delta smelt	Mortality associated with catching broodstock (genetic material lost)	2	3
N1a	Delta smelt	Genetic consequences for hatchery and wild populations	3	2
N3	Delta smelt & Longfin smelt	Mining of wild population to support broodstock needs	3	3
N2	Delta smelt & Longfin smelt	Negative ecological interactions with wild fish (competition, displacement)	3	2
N4b	Longfin smelt	Mortality associated with catching broodstock (genetic material lost)	2	2
N1b	Longfin smelt	Genetic consequences for hatchery and wild populations	3	1

OSCM 21:
Non-Project Diversions

Scientific Evaluation Worksheets

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Action: Non-Project Diversions

Evaluation Team: Hatcheries and Harvest Workgroup

Brad Cavallo - Chair, Dave Zezulak – Coach/participant, Jim Smith, Jason Kindopp, Shirley Witalis, Alison Willy, Josh Israel, Larry Wise (note taker)

Date of Last Revision: February 19, 2009

Action Description and Clarifying Assumptions

Modify or eliminate non-project diversions in the Delta to reduce the entrainment of covered fish species.

Approach

For non-project diversions that are >50 cfs do one of the following:

1. Screen the diversion with a screen that is 99% efficient at screening particles,
2. Remove the diversion,
3. Relocate the diversion to a channel in which its effect would be reduced,
4. Relocate the diversion within a channel to reduce the effect on covered fish species,
5. Consolidate multiple diversions in a single location into one screened diversion, or
6. Alter timing of operation of the diversion (e.g., diel operations) to reduce the effect on covered fish species.

Intended Outcomes as Stated in Conservation Measure

1. Reduce entrainment mortality by non-project diversions of larval and juvenile delta and longfin smelt, juvenile green and white sturgeon, juvenile splittail, and fry and juvenile Chinook salmon (all races) and steelhead.
2. Increase food availability to delta and longfin smelt, green and white sturgeon, splittail, and Chinook salmon (all races) and steelhead.

General Conceptual Model Support for Intended Outcomes

1a. Reduced mortality of larval and juvenile Delta smelt: Unlikely to reduce mortality significantly; Delta smelt Conceptual Model, section 5.1.5.f, page 21

1b. Reduced mortality of larval and juvenile longfin smelt: Implied in Longfin Smelt Conceptual Model, section 5-Diversions, page 22; mortality at diversions may be significant in some years.

1c. Reduced mortality of juvenile green sturgeon: Yes, possibly; Green sturgeon Conceptual Model, section 5, page 13.

1d. Reduced mortality of juvenile white sturgeon: Yes, possibly; Green sturgeon Conceptual Model, page 21.

1e. Reduced mortality of juvenile splittail: Yes, possibly; Splittail model p. 18; power plants have ability to entrain large numbers of fish, YOY have Ucrit near velocities at large pumps and are entrained at the CVP and SWP.

1f. Reduced mortality of fry and juvenile Chinook: Yes, possibly; Salmonid Conceptual Model, page 21.

1g. Reduced mortality of fry and juvenile steelhead: Yes, possibly; Salmonid Conceptual Model, page 21.
2a. Increased food for Delta smelt: Yes, probably; Delta smelt model pp. 27, 32; water diversions constrain copepod standing stocks, could increase food availability via improved water quality management.
2b. Increased food for longfin smelt: Yes, probably; Delta smelt model pp. 27, 32: water diversions constrain copepod standing stocks, could increase food availability via improved water quality management; Longfin smelt model p. 22: water diversions may impact abundance and distribution of longfin smelt prey.
2c. Increased food for green sturgeon: Possibly; Green sturgeon model p. 9, diet of green sturgeon is unknown, but other sturgeons are known to consume drifting invertebrates.
2d. Increased food for white sturgeon: Possibly; White sturgeon model p. 8, diet of larval white may include zooplankton.
2e. Increased food for Chinook: Possibly; Salmonid model p. 47 (stressors table), indirect mortality caused by diversions.
2f. Increased food for steelhead: Possibly; Salmonid model p. 47 (stressors table), indirect mortality caused by diversions.

Assumptions

Provided in BDCP Conservation Measure

1. Willing diverters for this action will be found.
2. Priority on which diversions to focus will be based on criteria developed by DFG and USFWS.

Problem(s) with Action as Written:

1. The approach mentions using screens for particles. Shouldn't fish screens be used? Note: As the screening criteria is based upon particle size, this may increase the amount of screen clogging and require a high-maintenance cleaning regime to maintain intake flows. Farmers may advocate for more than one diversion so that they could alternate the use and cleaning of screens (one in water, one being cleaned).

   Use of screens may results in bio-clogging: "Although invasive, substrate-colonizing mussels (Zebra and Quagga mussels) have not been reported in the Delta, should they appear, it would be necessary to dry out the intakes periodically to kill off any mussel spat which have settled on the screens. To minimize bio-clogging, the intake structure should be kept out of water until needed (again, this might result in having two pumps which could alternate diversion---one drying out, one being used). Also, there is a critical velocity threshold of flow at 1.5 m/sec (Claudi & Macki 1994) that prevents the settling of spat; however, within the diversion pipe, there is a gradation of laminar flow which may still allow spat to colonize within or around the edge of the diversion." (Martha Volkoff, Staff Environmental Scientist, CDFG Invasive Species Program, Quagga-Zebra Mussel Division, pers. comm. to Shirley Witalis).

2. How was the cutoff of >50 cfs determined?

3. Relative to the >50 cfs cutoff, does this refer to the maximum capacity of the diversion? If so, this should be stated.

Scale of Action:

Medium

Rationale:

Information from CDFG indicates that there are 69 unscreened diversions with a capacity greater than 50 cfs in the Delta. Excluding Banks and Jones pumping plants, the combined capacity of these diversions exceeds 7,000 cfs

The entrainment of larvae and juveniles of covered fish species by non-project diversions >50 cfs is poorly documented. The only empirical studies of this potential impact found low rates of entrainment for listed fish (Nobriga et al. 2004, Cook and Buffaloe 1998). These studies evaluated few diversions and suffered from a lack of staffing, funding and coordination with the diverters. Most of the fish entrained were non-native fish, benthic oriented fish, observed in high numbers. These authors, however, do hypothesize that the cumulative effect of these diversions could be large. This is corroborated in a literature review by Moyle and White (2002). Impacts to any of the other covered species are likely to be even smaller than what has been estimated for Delta smelt. Results of the PTM modeling completed for the BDCP suggests that DICU entrainment is low, ranging from 3% under high flow conditions, to about 20% under low flow conditions (BDCP 2009).

Note: with a north Delta diversion these numbers increased to 20 to 50%.

Evaluation Summary

Summary tables listing magnitude and certainty scores for each outcome, by species are provided in the Outcome Summary Table Appendix at the end of this worksheet. Details regarding each of the listed scores, and the rationales for the scores are provided in the discussion of positive and negative outcomes herein.

Relation to Existing Conditions:

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

NO. The scale of this action is medium.

Potential Positive Ecological Outcome(s)

Outcome P1: Reduce entrainment mortality by non-project diversions

P1a. Larval and juvenile Delta smelt

Magnitude = 2

Empirical study (Nobriga et al. 2004) indicates low entrainment of Delta smelt by non-project Delta diversions. Low entrainment of listed species (Cook and Buffaloe 1998)

Certainty = 2

Two empirical studies (Nobriga et al. 2004, Cook and Buffaloe 1998). Nobriga et al. (2004) found that the presence of screens significantly reduced entrainment of unlisted species, even when the individual fish present in the surrounding environment were small enough to pass through the screens.

P1b. Larval and juvenile longfin smelt

Magnitude = 1

No empirical studies for this species, but given the low entrainment found for another Delta fish (Delta smelt; Nobriga et al. 2004) this outcome is likely to have little or no effect at the population level. Many of the diversions would also be located outside of the geographic range for this species.

Certainty = 1

No empirical studies for this species.

P1c. Juvenile green sturgeon

Magnitude = 1

Empirical studies do not report entrainment for this species (Nobriga et al. 2004, Cook and Buffaloe 1998). Other benthic fish (i.e. catfish, sculpin) have been observed to be entrained (Cook and Buffaloe 1998), establishing that entrainment is possible, but would be low and this outcome is likely to have little or no effect at the population level.

Certainty = 1

No empirical studies for this species.

P1d. Juvenile white sturgeon

General Observations

Magnitude = 1

Empirical studies do not report entrainment for this species (Nobriga et al. 2004, Cook and Buffaloe 1998). Other benthic fish (i.e. catfish, sculpin) have been observed to be entrained (Cook and Buffaloe 1998), establishing that entrainment is possible, but would be low and this outcome is likely to have little or no effect at the population level.

Certainty = 1

No empirical studies for this species.

P1e. Juvenile splittail

Magnitude = 1

Empirical studies report low entrainment for this species (Nobriga et al. 2004, Cook and Buffaloe 1998). Other benthic fish (i.e. catfish, sculpin) have been observed to be entrained (Cook and Buffaloe 1998), establishing that entrainment is possible, but would be low and this outcome is likely to have little or no effect at the population level.

Certainty = 1

No empirical studies for this species.

P1f. Fry and juvenile Chinook salmon (all races)

Magnitude = 1

Little empirical studies for this species, but given the low entrainment found by Cook and Buffaloe (1998) and for another Delta fish (Delta smelt; Nobriga et al. 2004) this outcome is likely to have little or no effect at the population level.

Certainty = 1

No empirical studies for this species.

P1g. Fry and juvenile steelhead

Magnitude = 1

Little empirical studies for this species, but given the low entrainment found by Cook and Buffaloe (1998) and for another Delta fish (Delta smelt; Nobriga et al. 2004) this outcome is likely to have little or no effect at the population level.

Certainty = 1

No empirical studies for this species.

Outcome P2: Increase food availability

P2a. Delta smelt

Magnitude = 1

Supported by conceptual model (Delta smelt model pp. 27, 32; water diversions constrain copepod standing stocks. No empirical studies for this species. Volume is more than 7,000 cfs. Results of the PTM modeling completed for the BDCP suggests that DICU entrainment is low, ranging from 3% under high flow conditions, to about 20% under low flow conditions (BDCP 2009).

Certainty = 1

No empirical studies for this species.

P2b. Longfin smelt

Magnitude = 1

Same as Delta smelt.

Certainty = 1

No empirical studies for this species.

P2c. Green sturgeon

Magnitude = 1

Likely little impact on food resources for this species, which is mainly a benthic feeder.

Certainty = 1

No empirical studies for this species.

P2d. White sturgeon

Magnitude = 1

Same as green sturgeon

Certainty = 1

No empirical studies for this species.

P2e. Splittail

Magnitude = 1

Mainly a benthic feeder

Certainty = 1

No empirical studies for this species.

P2f. Chinook salmon (all races)

Magnitude = 1

Possibly; Salmonid model p. 47 (stressors table), indirect mortality caused by diversions.

Certainty = 1

No empirical studies for this species.

P2g. Steelhead

Magnitude = 1

Possibly; Salmonid model p. 47 (stressors table), indirect mortality caused by diversions.

Certainty = 1

No empirical studies for this species.

Important Gaps in Information and/or Understanding

Data Needs

- Evaluation of entrainment risks due to non-project diversions in a quantitative fashion that can be linked to population levels.
- Evaluation of entrainment risks due to non-project diversions that focuses on the geography – namely, the location of diversions relative to the location of covered fish species and the timing of diversions relative to fish distributions.
- Evaluation of entrainment risks due to non-project diversions that focuses on temporal overlap between diversion pumping and proximity of covered fish species to the diversions.

Research Needs

- GIS analysis of geographical questions mentioned above.
- Investigation of the pumping schedules associated with non-project diversions in different locations and of different sizes and types.

Assess Reversibility and Opportunity for Learning

Reversibility

Yes/easy

Comments: Screened diversions could be reversed simply by removing the installed screens. Reversing the action would simply require removal of screens. The cost of this reversal would likely be much lower than the original cost of installing screens. For diversions that were eliminated or moved, the cost of reversal would likely be equivalent to the original action.

Opportunity for Learning

Low

Comments Without long-term, rigorous monitoring programs for all of the non-project diversions that receive screens, determining the impact of this action would be difficult.

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Moyle P, White D (2002) Effects of screening diversions on fish populations in the Central Valley: What do we know? A report for the Science Board, CALFED Ecosystem Restoration Program. January 2002.

Nobriga ML, Matica Z, Hymanson ZP (2004) Evaluating entrainment vulnerability to agricultural diversions: A comparison among open-water fishes. American Fisheries Society Symposium 39:281-295.

Outcome Code	Covered Spp.	Description	Magnitude	Certainty
Positive Outcomes				
P2f	Chinook Salmon	Increased Food Availability	1	1
P1f	Chinook salmon-Fry and juvenile	Reduce entrainment mortality by non-project diversions	1	1
P2a	Delta smelt	Increased Food Availability	1	1
P2c	Green Sturgeon	Increased Food Availability	1	1
P1c	Green Sturgeon-juvenile	Reduce entrainment mortality by non-project diversions	1	1
P1a	Larval and juvenile delta smelt	Reduce entrainment mortality by non-project diversions	2	2
P2b	Longfin smelt	Increased Food Availability	1	1
P1b	longfin smelt- Larval and juvenile	Reduce entrainment mortality by non-project diversions	1	1
P2e	Splittail	Increased Food Availability	1	1
P1e	Splittail- Juvenile	Reduce entrainment mortality by non-project diversions	1	1
P2g	Steelhead	Increased Food Availability	1	1
P1g	steelhead-Fry and juvenile	Reduce entrainment mortality by non-project diversions	1	1
P2d	White Sturgeon	Increased Food Availability	1	1
P1d	White Sturgeon-Juvenile	Reduce entrainment mortality by non-project diversions	1	1

Appendix G

Independent Science Advisors Reports

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Appendix G-1

Bay Delta Conservation Plan Independent Science Advisors Report

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BAY DELTA CONSERVATION PLAN

INDEPENDENT SCIENCE ADVISORS REPORT

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November 16, 2007

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EXECUTIVE SUMMARY

A group of nine scientists were convened in September 2007 to provide independent advice to the Bay Delta Conservation Plan (BDCP) Steering Committee. These scientists provided advice on the use of science in developing an effective Conservation Plan for the Sacramento-San Joaquin Delta in accordance with California's Natural Community Conservation Planning Act (NCCPA) and the BDCP Planning Agreement. Consistent with the requirements of the NCCPA, the Science Advisors' report includes a listing of principles for conservation planning, design, and management. The Report also includes a series of more specific recommendations regarding application of the existing knowledge base and the use of data and analyses for informing the BDCP. The following briefly summarizes key foundational principles and recommendations from the Report. These principles and recommendations should be considered as the overall conservation strategy and potential conservation measures are developed for the BDCP.

Principles for Conservation Planning

The Advisors developed sixteen principles that address overarching issues, fundamental aspects, of Delta ecosystem dynamics, and conservation approaches and analyses. These points should be considered during the development and implementation of the BDCP.

Overarching Principles

A. Changes in the estuarine ecosystem may be irreversible.

B. Future states of the Delta ecosystem depend on both foreseeable changes (e.g., climate change and associated sea-level rise) and unforeseen or rare events (e.g., the consequences of new species invasions).

C. The Delta is part of a larger river-estuarine system that is affected by both rivers and tides. The Delta is also influenced by long-distance connections, extending from the headwaters of the Sacramento and San Joaquin Rivers into the Pacific Ocean.

Delta Ecosystem Dynamics

D. The Delta is characterized by substantial spatial and temporal variability, including disturbances and extreme events that are fundamental characteristics of ecosystem dynamics. The Delta cannot be managed as a homogeneous system.

E. Species that use the Delta have evolved life history strategies in response to variable environmental processes. Species have limited ability to adapt to rapid changes caused by human activities.
F. Achieving desired ecosystem outcomes will require more than manipulation of Delta flow patterns alone.
G. Habitat should be defined from the perspective of a given species and is not synonymous with vegetation type, land (water) cover type, or land (water) use type.
H. Changes in water quality have important direct and indirect effects throughout the estuarine ecosystem.
I. Land use is a key determinant of the spatial distribution and temporal dynamics of flow and contaminants which, in turn, can affect habitat quality.
J. Changes in one part of the Delta may have far-reaching effects in space and time.

Conservation Approaches and Analysis

K. Prevention of undesirable ecological responses is more effective than attempting to reverse undesirable responses after they have occurred.
L. Adaptive management is essential to successful conservation.
M. Conservation measures to benefit one species may have negative effects on other species.
N. Data sources, analyses, and models should be documented and transparent so they can be understood and repeated.
O. Ecosystem responses, especially to changes in system configuration, can be predicted using a combination of statistical and process models. Statistical models document status, trends, and relationships between responses and environmental variables, whereas process-based models are useful in understanding system responses and for forecasting responses to new conditions.
P. There are many sources of uncertainty in understanding a complex system and predicting its responses to interventions and change.

Plan Scope

The Advisors agree that the BDCP Planning Agreement has correctly identified the aquatic species to be covered assuming the current list of Covered Activities. However, the extent of the available information for each species varies considerably, suggesting that each species should be evaluated individually. The Advisors specifically caution against using guilds, communities of species, or other "groupings of convenience" for planning and analysis. Rather, the Advisors recommend an approach to planning that embraces the spatial and temporal environmental gradients that occur within the Delta and the influence of these gradients on Covered Species. The Advisors developed six recommendations regarding Plan Scope:

1. Seek further advice on the appropriate geographic scope as the nature of the Covered Activities and conservation strategies becomes more defined.
2. Consider the San Joaquin fall-run Chinook salmon as a Covered Species distinct from other Central Valley fall-run Chinook salmon.
3. Revisit the inclusion of Swainson's hawk, giant garter snake, bank swallow, and other listed taxa as Covered Species once the Covered Activities, including conservation strategies, are more fully identified.
4. Use planning species such as threadfin shad, striped bass, largemouth bass, Brazilian waterweed, overbite clam, and freshwater clam to assess effects of conservation strategies on a wider range of ecosystem components and dynamics than the Covered Species represent.
5. Examine how individual species respond to gradients in environmental conditions (and changes in those gradients) to inform assessment of the effects of conservation strategies, rather than using guilds, species communities, or other groupings of convenience.
6. Assess the sensitivity of conservation outcomes to anticipated changes in environmental gradients that will likely arise from sea-level rise, subsidence, climate-change induced alteration in the timing of runoff, human activities, and other processes over the time frame of the Plan and beyond.

Delta Ecosystem Dynamics

The Delta is a highly complex system of interacting physical, geomorphic, biological, and chemical processes, all of which are influenced by human activities both inside and outside the Delta. The Advisors consider several of these interactions particularly important for anticipating the response of the Covered Species to changes in environmental conditions, the Covered Activities, and other human influences. The report includes a set of tables that identify the most important processes influencing covered species, assess the current state of knowledge regarding those processes, outline key uncertainties, and assess the ability to predict how these processes operate within the system. The Advisors developed four recommendations concerning information needs, recognizing that a wide array of studies will be needed to support successful Plan implementation:

7. Routinely collect high resolution airborne imagery over the Delta, including lidar, hyperspectral or multispectral, and thermal, to detect and quantify spatial changes in miocrotopography, surface water temperature, surface turbidity, algal blooms, aquatic wetland and riparian plant species composition, and fractional cover.
8. Maintain current monitoring programs within the Delta and institute a comprehensive, long-term, Delta-wide monitoring program to provide data on contaminants in sediments, water, and aquatic organisms, including in-Delta diversions and return flows.
9. Refine and expand existing monitoring programs as Covered Activities and conservation actions are specified, and critical data needs can be identified.
10. Develop an integrated database of monitoring data (e.g., salinity, temperature, nutrients, contaminants) and relevant spatial data layers (e.g., topography, distributions of submerged, emergent, and floating aquatic plant species).

The report discusses population dynamics and process interactions at higher trophic levels. Understanding and forecasting population dynamics requires considering influences of key environmental variables on all life stages. In the case of the Covered Activities, understanding and forecasting population dynamics may also require considering the effects of environmental conditions outside the range of conditions that the species currently experience. The Advisors developed four recommendations for incorporating understanding of population dynamics into conservation planning:

11. Consider relationships between environmental conditions and the Covered Species in a life cycle context.
12. Pursue efforts to quantify the contribution of entrainment and other factors to stage-specific mortality rates of Covered Species in order to assess the population-level benefits of offsetting such losses.
13. Identify how anticipated changes in environmental conditions, including those associated with Covered Activities and climate change, propagate through populations of Covered Species, and consider how uncertainties regarding future environmental conditions potentially influence population response to Covered Activities.
14. Examine possible bottlenecks at other life stages, including those that occur outside the planning area, rather than only those at the life stage immediately affected by Covered

Activities or within the Delta. Bottlenecks at other life stages can modulate the population response to changes in environmental conditions within the Delta.

Methods of Analysis

Detailed consideration of analytical tools was beyond the Advisors' scope of work. However, the Advisors offered twelve recommendations concerning approaches for analyzing Delta hydrodynamics and species populations. The intent is not to provide a comprehensive evaluation of all available tools and models, but to provide recommendation on how analytical tools can be used to address conservation issues.

15. When potential conservation measures have been developed, convene a group of science advisors with experience in systems analysis, ecosystem restoration, population and food web dynamics, and other relevant disciplines to identify appropriate analytical tools and assessment techniques to support conservation planning and implementation in the Delta.
16. Use a hydrodynamic model that is based on fundamental physics and that accurately reproduces tidal flows in the system for analysis of Delta transport and dispersion, particularly for predictions of proposed management scenarios on hydrodynamics.
17. Use data that span as broad a range of hydrologic and operational conditions as possible to evaluate a model's performance and increase the probability that the model will have sufficient accuracy and precision for evaluating management scenarios.
18. Use models with appropriate dimensionality for the target of the analysis:
    a. Use a two-dimensional, depth-averaged analysis to predict transport of passive dissolved substances.
    b. Use a three-dimensional hydrodynamic model to account for both tidal dispersion processes and gravitational circulation associated with salinity intrusion into the Delta, or parameterize gravitational circulation based on local density forcing.
19. To allow integration of particle or organism behavior into Delta transport models:
    a. Develop a highly resolved three-dimensional hydrodynamic model to produce accurate projections of vertical and lateral variability in channels and junctions.
    b. Conduct drifter-tracking studies, especially around channel junctions, to evaluate model ability to predict particle trajectories.
20. Apply an array of tools to improve prediction of water temperature at various spatial and temporal scales:

a. Develop a correlative analysis of atmospheric conditions and water temperatures to assess large-scale variations in temperature,
b. Analyze river inputs and tidal dispersion to predict temperature at finer spatial and temporal resolution.
c. If prediction of fine-scale temperature variation between adjacent environments is desired, pursue observational and modeling studies into the effects of shallow, vegetated environments on local temperature dynamics, including the effects of shading along perimeter water.

21. Evaluate future sediment supply to the Delta from the watershed, and document sediment resuspension characteristics in the Delta, to support the development of an integrated hydrodynamic-sediment transport model to predict sediment concentrations and their variability
22. Develop spatially-explicit models of plankton dynamics, and institute monitoring to provide necessary input to these models, to improve prediction of Covered Species response to changing environmental conditions.
23. Develop statistical models that relate a) spatial and temporal distributions of environmental factors to life history stages of the Covered Species, b) fish movement to environmental factors that cue migration, c) net and tidal flows to migration, and d) abundances of the Covered Species at different life stages to relevant environmental variables.
24. When sufficient information is available and the questions to be addressed are tractable to model, develop and apply process models for covered species that are built upon the conceptual and statistical models. These process models can be used for predicting short-term, life stage-specific responses, and for predicting long-term responses of population dynamics.
25. Use hydrodynamic models of the Delta built on fundamental processes to analyze the potential consequences of different climate change scenarios (e.g., sea-level rise, timing and amount of runoff) on net and tidal flow patterns.
26. Develop and apply statistical and process models to examine the potential effects of increasing variability in salinity and water temperatures on ecosystem processes and Covered Species in the Delta.

Adaptive Management and Monitoring

Adaptive management is a systematic process for continually improving management policies and practices by learning formally from their outcomes. The Advisors think that adaptive management is perfectly suited to the BDCP, but implementing it will require a sincere, ongoing commitment to the principle and the process, and a decision-making process specifically designed to accommodate adaptive management. The Advisors developed three recommendations concerning adaptive management and monitoring:

27. Design a conservation plan based on adaptive management.
28. Identify and implement as soon as possible an administrative mechanism for the Plan to be modified in response to rapidly evolving information, data, and analyses.
29. Convene a group of science advisors to work with consultants, PREs, and implementing agencies to develop an appropriate adaptive management and monitoring strategy to support implementation of the BDCP.

1.0 INTRODUCTION

This report presents early advice and recommendations regarding the use of science in the development of the Bay Delta Conservation Plan (BDCP or Plan). The report was prepared by a multidisciplinary group of independent science advisors[1] (Science Advisors or Advisors) convened by the BDCP Steering Committee (Steering Committee) in accordance with the state of California's Natural Community Conservation Planning Act (NCCPA) and the BDCP Planning Agreement[2] (Agreement).

The advice and recommendations provided herein are based on current knowledge of the Bay Delta ecosystem and the current state of the BDCP planning process. Both the knowledge base and the planning process are evolving rapidly. Because it is early in the BDCP planning process, many of the details regarding the specific actions that the Plan will cover are undefined, as are the potential conservation measures that may be included in the Plan. Science and scientists will be able to inform management options more directly as more details emerge regarding the overall conservation strategy, including information on potential water management and conveyance actions. Additional scientific information from ongoing studies and analyses (e.g., those under the auspices of the Interagency Ecological Program, the Pelagic Organism Decline (POD) Management Team and the CALFED Science Program) should also be incorporated into the BDCP process as it becomes available. The Advisors strongly suggest establishing a mechanism for continued scientific engagement throughout the BDCP process.

1.1 Independent Scientific Input

The BDCP Planning Agreement calls for the use of the best available scientific information, including advice from well-qualified independent scientists, in preparation of the BDCP. In accordance with NCCPA requirements, the Agreement specifically seeks independent scientific advice on:

[1] Science Advisors: Jim Anderson, Univ. Washington; Erica Fleishman, UC Santa Barbara; David Freyberg, Stanford Univ.; Wim Kimmerer, San Francisco State Univ.; Denise Reed, Univ. New Orleans; Kenneth Rose, Louisiana State Univ.; Mark Stacey, UC Berkeley; Susan Ustin, UC Davis; Inge Werner, UC Davis

[2] see http://resources.ca.gov/bdcp/docs/BDCP_Planning_Agreement_revised_9.13.2007.pdf

- Scientifically sound conservation strategies for species and natural communities proposed to be covered by the BDCP;
- Conservation actions that would address the needs of species, ecosystems, and ecological processes in the Planning Area proposed to be addressed by the BDCP;
- Management principles and conservation goals that can be used in developing a framework for the monitoring and adaptive management component of the BDCP; and
- Data gaps and uncertainties.

The Planning Agreement also notes that independent scientists may be asked to provide additional feedback, including reports, on key scientific issues during preparation of the BDCP.

A Facilitation Team was retained by the Steering Committee to assist in convening independent Science Advisors and establishing an overall process for engaging scientific input. In June 2007 the Facilitation Team developed a workplan for facilitating independent scientific input for the BDCP (Appendix A). The workplan recommends a series of topically based workshops designed to provide focused, timely advice.

In consultation with the Steering Committee, the Facilitation Team identified and convened a group of independent Science Advisors for an initial workshop focused on addressing the broad requirements of the NCCPA as reflected in the Planning Agreement (see above). The workshop was held September 12-14, 2007. The workshop was designed specifically to:

- Identify principles to inform regional conservation planning under the NCCPA;
- Assess the knowledge base available for planning (what is known and not known);
- Comment on the scope of the ecological and conservation goals and objectives of the BDCP;
- Identify critical ecological processes and scales of variability that the Plan should embrace.

To help focus the Science Advisors' input and to highlight the range of scientific issues that might be relevant to development of the BDCP, a list of topics and questions was developed with input from the Steering Committee (Appendix B). Specific questions were also submitted individually by Steering Committee members (Appendix C).

The Advisors were asked not to review or comment on the specific Conservation Strategy Options being considered by the Steering Committee at the time of the September 2007 Advisors' workshop. The Conservation Strategy Options Evaluation Report prepared by the Plan consultants was not completed until after the Science Advisors' workshop.

1.2 Report Scope and Organization

The contents of this report reflect the Advisors' review of existing information, results of the three-day Advisors' workshop, and subsequent discussions amongst the Advisors. The report addresses key requirements of the NCCPA, as noted in Section 1.1. However, due to the complexity of the scientific issues involved and the early state of the planning process, some topics are addressed in more detail than others. For example, the report provides a clear set of conservation planning principles to help guide Plan development. The report also addresses principles for adaptive management and monitoring, but at this early stage of planning it is not possible to provide detailed recommendations on these topics.

Following this introduction, the remainder of the report is organized to provide scientific input, advice, and recommendations on specific topics as follows:

- Section 2 – Principles for Conservation Planning in the Delta;
- Section 3 - Plan Scope;
- Section 4 – Delta Ecosystem Dynamics;
- Section 5 – Methods of Analyses; and
- Section 6 – Adaptive Management and Monitoring

Specific recommendations are imbedded within each of the respective report sections. To the extent possible, the Advisors provided concrete recommendations that address how specific principles and analytical approaches can be applied to conservation planning. The Advisors also comment on information needs given the scope of the Plan as currently understood.

The recommendations contained in this report are intended to apply broadly to conservation planning in the Delta, both in terms of approaches that could be employed to inform decision-making (e.g. methods of analysis) and in terms of more specific implementation actions (e.g. monitoring). In crafting these recommendations, the Advisors have not focused on legal issues related to who would be responsible for implementation. In some cases, the recommendations may go beyond the specific responsibilities of the BDCP and the Potentially Regulated Entities (PREs). For example, development of a comprehensive monitoring program for contaminants in the Delta (Recommendation R8) would involve regulatory issues and entities beyond the BDCP. Similarly, there are significant ongoing monitoring programs such as those under the purview of the Interagency Ecological Program (IEP). These will likely continue regardless of the BDCP and are beyond the direct scope of the Plan, but could be enhanced or augmented by the Plan. The Advisors do not intend to imply that all recommendations contained in the report should be pursued solely by the PREs as part of the BDCP. Instead, the recommendations represent actions that could support conservation of species and their habitats in the Delta.

The Advisors have not attempted to prioritize the recommendations contained in this report. The relative importance of various recommendations and appropriate sequencing depends on the specific goals and objectives of the Plan and nature of the Plan actions, both of which are still under development. Once the Plan objectives and proposed actions are more clearly defined and if requested by the Steering Committee, the Advisors can provide further guidance on prioritization of the recommendations.

2.0 PRINCIPLES FOR CONSERVATION PLANNING IN THE DELTA

The following principles reflect broad, fundamental concepts that the Science Advisors think are important to acknowledge and understand in developing an HCP/NCCP for the Delta. Although the principles are framed in the context of the BDCP, most if not all are relevant to any comprehensive management plan. As the overall conservation strategy and potential conservation actions are developed for the BDCP, they should be reviewed and evaluated in light of the principles outlined below. The principles are further referenced throughout the report to complement additional observations and recommendations regarding the scope of the Plan and the knowledge base for planning.

A. ***Changes in the estuarine ecosystem may be irreversible.*** Relatively permanent changes in structure or processes (e.g., species introductions, extinctions, and succession, changing climate, or human infrastructure) within the ecosystem may prevent the ecosystem from reverting to a former state when temporary influences (e.g., toxicants, diversions) are removed. Similarly, some ecosystem processes within the Delta result in progressive change and cannot be reversed. Therefore, the future state of the ecosystem is difficult, if not impossible, to predict. Accordingly, goals and objectives that target restoration to historic conditions may not be realistic. Indeed, it may not even be possible to quantify historic or baseline conditions. Because predictions of the outcome or success of management interventions are highly uncertain, a strategy of adaptive management[3] may increase the probability that conservation goals will be achieved (see Principle L).

B. ***Future states of the Delta ecosystem depend on both foreseeable changes (e.g., climate change and associated sea-level rise) and unforeseen or rare events (e.g., the consequences of new species invasions).*** Conservation strategies should take into account the probability of particular system responses to both foreseeable changes and inevitable rare and unpredictable events. Evaluation of mitigation or adaptive management strategies for Covered Species should include consideration of potential alternative future states (e.g., salinity intrusion further into the Delta or large numbers of deeply flooded islands) and incorporate management flexibility (both operational and institutional) that can account for and respond to changing conditions.

[3] For more on adaptive management see Busch, D.E. and J.C. Trexler, editors. 2003.

C. ***The Delta is part of a larger river-estuarine system that is affected by both rivers and tides. The Delta is also influenced by long-distance connections, extending from the headwaters of the Sacramento and San Joaquin Rivers into the Pacific Ocean.*** For example, high inter-annual variability in precipitation and river flows are, in part, due to climate patterns that span the entire Pacific Ocean. In addition, many animals that use the Delta do so for only part of their life cycles, spending other parts upstream in the rivers or as far away as northern Canada. Effective conservation strategies will require a system-wide approach that considers the Delta in its larger environmental context. Such strategies may consider implementing actions outside the planning area that would benefit species within the planning area.

D. ***The Delta is characterized by substantial spatial and temporal variability, including disturbances and extreme events that are fundamental characteristics of ecosystem dynamics. The Delta cannot be managed as a homogeneous system***. Gradients in salinity, temperature, and turbidity establish a range of environments with boundaries that vary seasonally and among years. Variations in channel depth, vegetation density, and water velocity interact to create additional spatial and temporal variability. Potential spatial and temporal variation in the system response should be explicitly considered in development of potential conservation measures.

E. ***Species that use the Delta have evolved life history strategies in response to variable environmental processes. Species have limited ability to adapt to rapid changes caused by human activities.*** Changes in geomorphology, tidal and freshwater flow, and chemical composition of the water may fundamentally alter the processes that maintain populations of animals and plants. Examples include cues for migration, feeding, and avoiding predation, all of which affect rates of survival. Conservation strategies that seek to reestablish or maintain conditions within known tolerances of the species and that acknowledge the inherent natural variability in these conditions will likely be more successful.

F. ***Achieving desired ecosystem outcomes will require more than manipulation of Delta flow patterns alone.*** Many important drivers of ecosystem dynamics are highly variable, unpredictable, and difficult to manipulate (for example, humans cannot convert a dry year into a wet year). Furthermore, a number of key ecosystem drivers are independent of freshwater flow patterns (e.g., species introductions). Achieving conservation goals will require that managers directly address drivers that are difficult to manipulate and not related to flow.

G. ***Habitat should be defined from the perspective of a given species and is not synonymous with vegetation type, land (water) cover type, or land (water) use type.*** The term 'habitat' refers to the space and time within which an organism lives and the abiotic and biotic resources in that space and time. Thus, habitat location and quality are dynamic in space and time. At any given time, a given species may be absent from high-quality habitat because of various external constraints that restrict its populations to locations of lower-quality habitat.

H. ***Changes in water quality have important direct and indirect effects throughout the estuarine ecosystem.*** Water quality, including salinity, temperature, turbidity and contaminants, is influenced by inputs of substances from rivers, downstream sources, and local sources, estuarine physics and geomorphology, and water operations. The distribution of salinity determines the distribution of geochemical conditions and affects all estuarine species. Temperature and turbidity influence growth and reproductive rates, and contaminants can have a variety of negative effects. Water quality may affect Covered Species directly or indirectly through water quality effects on the estuarine food web that supports the Covered Species.

I. ***Land use is a key determinant of the spatial distribution and temporal dynamics of flow and contaminants which, in turn, can affect habitat quality.*** Chemicals enter the Delta from many land-use-related sources along many pathways, including atmospheric drift, rain, river flow, storm runoff during winter, return flow from irrigation during summer and fall and from seepage year round, point sources including municipal and industrial effluents, and direct application to surface waters (e.g., control of non-native aquatic plants). These patterns in distribution and timing of contaminants can influence habitat quality for species.Other effects of land use include significant alteration of high flow behavior from flood-damage mitigation, and alteration of local water inflow volumes and timing. Consequently, conservation planning must consider the role of current and future land use within and outside the Delta.

J. ***Changes in one part of the Delta may have far-reaching effects in space and time.*** Although specific actions may affect the entire Delta, the effects are not uniform in magnitude throughout the Delta. For example, changes in the physical structure of one part of the Delta, such as a levee failure or new barriers, can alter flow patterns that may affect how organisms migrate and therefore where they are abundant in or outside the Delta. Similarly, changes in flow and sediment transport determine how chemicals are partitioned among sediments, plants, and water, and where those chemicals will accumulate.

K. ***Prevention of undesirable ecological responses is more effective than attempting to reverse undesirable responses after they have occurred***. Potential negative ecological impacts of management actions should be considered and designs should attempt to minimize these impacts before projects are implemented, rather than assuming that mitigation will be effective. For example, it is better to take actions that reduce take of fish at the pumps then to rely on salvage of entrained fish to minimize pumping effects. While habitat enhancement or restoration can theoretically benefit populations, these effects are difficult to quantify compared to direct mortality. Consequently, the measurable impact of habitat improvement on fish populations may be small, and the scale of restoration needed to achieve conservation goals through mitigation is likely very large. Moreover, the potential for success of large-scale restoration efforts is often uncertain.

L. ***Adaptive management is essential to successful conservation***. Uncertainty about the likely outcomes of conservation actions arises from a variety of causes that may be inherent in the system, due to substantial changes within the system, or related to incomplete monitoring or understanding. Therefore, conservation actions should be implemented in an adaptive management context. For the BDCP, like any other conservation plan, adaptive management involves the development of quantitative conservation objectives and quantitative triggers for changes in management. The objectives also should be achievable within a specified period of time, given the scope and constraints of the Plan.

Conservation actions should be based on well-supported hypotheses about their outcomes, given the potential irreversibility of changes to the state of the ecosystem. Information from monitoring of projects and system response must feed back to system models used to inform managers and those overseeing implementation[4].

M. Conservation measures to benefit one species may have negative effects on other species. Actions necessary to achieve objectives for different conservation targets may conflict (i.e., a given action simultaneously may benefit some species or ecological processes of conservation concern and have a negative influence on other species or processes) (Margoluis and Salafsky 1998). Conservation plans must recognize these potential conflicts, evaluate tradeoffs among conservation targets, and, to the extent possible, minimize negative effects.

N. Data sources, analyses, and models should be documented and transparent so they can be understood and repeated. Important environmental decisions may be informed by statistical analysis and modeling, both of which have multiple sources of uncertainty. Analysts can obtain different results by using different data or models. Comparison among alternative methods of analyses is an effective way to explore uncertainties. These comparisons require sufficient clarity about the differences among analyses. Clear documentation of data and analyses enables comparison of results derived from alternative methods. Documentation also helps to identify what is known and not known, and the major sources of uncertainty.

O. Ecosystem responses, especially to changes in system configuration, can be predicted using a combination of statistical and process models. Statistical models document status, trends, and relationships between responses and environmental variables, whereas process-based models are useful in understanding system responses and for forecasting responses to new conditions. Statistical models may allow us to characterize empirically how a system works. However, statistical models may not allow us to predict system responses, because they apply only within the range of conditions over which data have been collected. Process models rooted in underlying mechanisms provide a much stronger basis for predicting system responses to environmental change (i.e., extrapolating beyond

[4] For more on adaptive management see Busch, D.E. and J.C. Trexler, editors. 2003.

available data), although model calibration and validation of process models are more challenging than for statistical models.

P. ***There are many sources of uncertainty in understanding a complex system and predicting its responses to interventions and change.*** Some of these uncertainties are reducible, often through additional data collection and scientific study, which can be important components of adaptive management. Other uncertainties are not reducible because they are rooted in inherent system variability. Uncertainty is unavoidable and methods for addressing uncertainty should be incorporated explicitly into decision-making.

3.0 PLAN SCOPE

The scope of an NCCP/HCP is defined by its geographic area and time horizon, and the actions, species, and communities to be covered. This report provides some preliminary observations and advice regarding each of these items based on available information. The Advisors recommend that the Steering Committee seek additional scientific input regarding the plan scope as new information becomes available, particularly as more specifics concerning the nature of the actions to be covered by the BDCP are developed.

3.1 Geographic Area

The Advisors emphasize that the Delta is embedded within a larger environmental context and cannot be managed as an isolated system (Principle C). The current boundary, as defined in the Planning Agreement, is the Statutory Delta[5]. Species and communities in the Planning Area are affected by actions and processes outside the Planning Area (e.g., upstream water diversions, spawning habitat for anadromous fish, contaminant inputs, precipitation patterns in the Sierra Nevada, sea level rise, and other aspects of climate change). Also, depending on the selected conservation strategies, some Covered Activities may occur outside the Statutory Delta. Some Covered Activities also may affect species and communities outside the Planning Area (e.g., by changing the quality of Delta outflow or increasing salinity in Suisun Bay).

The Advisors think it is premature to make firm recommendations regarding changes to the Planning Area (Recommendation R1). However, the Advisors note that alterations to the Planning Area may be necessary as planning progresses to reduce regulatory uncertainties and undesired consequences of Covered Activities..

> ***R1. Seek further advice on the appropriate geographic scope as the nature of the Covered Activities and conservation measures becomes more defined.***

[5] As defined by section 12220 of the California Water Code.

3.2 Time Horizon

For the purposes of this report, the Advisors assumed that the duration of the permit, and the time available to plan and implement Covered Activities, would be 50 years. Some actions to be permitted under the Plan will likely take many years to implement. The distribution of species and the distribution and quality of their habitat will change during that time (e.g., due to species introductions and climate change). Therefore, the Advisors recommend building contingencies into the Plan via an adaptive management program (see Section 6.0) that anticipates and can adjust to such changes to the degree feasible (Principles A and L).

3.3 Covered Species

The Advisors agree that the Planning Agreement has correctly identified the aquatic species to be covered assuming the current list of Covered Activities[6]. These species are Central Valley steelhead (*Oncorhynchus mykiss*), Central Valley Chinook salmon *(Oncorhynchus tshawytscha)* (spring run, winter run, and fall/late-fall runs), Delta smelt *(Hypomesus transpacificus),* green sturgeon *(Acipenser medirostris),* white sturgeon (*Acipenser transmontanus),* splittail (*Pogonichthys macrolepidotus)* and longfin smelt (*Spirinchus thaleichthys)*. However, the Advisors suggest that the San Joaquin River fall-run Chinook salmon deserves consideration as a Covered Species, distinct from other Central Valley Chinook salmon, because the two taxa are exposed to significantly different environmental conditions in and upstream of the Delta (Recommendation R2).

> ***R2. Consider the San Joaquin fall-run Chinook salmon as a Covered Species distinct from other Central Valley fall-run Chinook salmon.***

The Planning Agreement also identified four additional species to consider for coverage (Recommendation R3). The Advisors agree that it is premature to make firm recommendations about coverage for these species until Covered Activities and conservation strategies, are specified. However, the Advisors offer the following preliminary thoughts about including these species.

[6] The Covered Activities are those described at the 3/23/07 BDCP Steering Committee meeting. See http://resources.ca.gov/bdcp/docs/03_23_2007__handout_Covered_Activities_List.pdf

R3. Revisit the inclusion of Swainson's hawk, giant garter snake, bank swallow, and other listed taxa as Covered Species once the Covered Activities and conservation strategies, are more fully identified.

- Swainson's hawk (*Buteo swainsonii*) – This species is listed as threatened under the California ESA. It nests within the Planning Area where large trees for nesting occur near extensive agricultural fields over which the species can forage (Woodbridge 1998). The Delta is also an important wintering area for the species (Herzog 1996). Swainson's hawk typically does not travel far to forage and is likely to nest only near foraging habitat. Nesting habitat probably will not be affected directly by the currently listed Covered Activities. However, coverage for the species should be considered more thoroughly if Covered Activities are likely to include flooding of islands or major changes in agricultural practices. Such activities could reduce the amount of foraging habitat for Swainson's hawk and result in abandonment of nesting territories within the Planning Area.
- Giant garter snake (*Thamnophis gigas*) – This aquatic snake is listed as threatened under the California and federal ESA. It is found in the northern and eastern Delta (with one recent record from the western Delta in the vicinity of Decker and Sherman Islands), associated with agricultural wetlands, irrigation canals, sloughs, ponds, low gradient streams, and other aquatic land use and land cover types with emergent vegetation (USFWS 1999); http://www.californiaherps.com/snakes/maps/tgigasmap.jpg). Covered Activities could potentially affect giant garter snakes, positively or negatively, via construction in occupied areas, changes in agricultural practices, or flooding of habitat.
- Bank swallow (*Riparia riparia*) – This species is listed as threatened under the California ESA. It is not known to nest within the Statutory Delta (Garrison 1998). It nests on vertical banks with soft soil or in cliffs, usually after flood waters recede and low water levels expose cut banks. If BDCP conveyance approaches or conservation measures cause direct or indirect changes to the structure of channel banks outside the current planning area, this species may be affected and coverage should be considered.
- Valley Elderberry longhorn beetle (*Desmocerus californicus dimorphus*) – This species has been recommended for delisting by the U.S. Fish and Wildlife Service due to positive effects of ongoing conservation actions and evidence of the existence of many more populations, over a much broader geographic range, than was known at the time of listing (USFWS 2006). Therefore, the Advisors suggest that the subspecies not be covered under the NCCP/HCP.

Given that regulatory assurance is a priority for the Potentially Regulated Entities (PREs), it is prudent to examine the potential effects of Covered Activities on the full range of species that are listed under federal and state endangered species acts, or are likely to be listed during the permit period. For example, plant and animal species associated with tidal marsh and riparian vegetation may be candidates for coverage by the Plan depending on the final array of Covered Activities.

3.4 Planning Species

In addition to species to be covered by incidental take authorizations, it may be useful for the Plan to consider other species as "planning species". Although planning species may not be listed and therefore do not require incidental take permits, considering the effects of the Plan on these species may assist in meeting ecosystem goals. Planning species might include species that have strong effects (positive or negative) on Covered Species or ecological processes. For example, a planning species might play a key role in food webs that include Covered Species. Participants in other NCCPs (e.g., San Diego Multiple Species Conservation Plan, Yuba-Sutter HCP/NCCP, and Santa Clara Valley HCP/NCCP) have identified non-listed species that they think should be considered as planning species.

The Advisors discussed whether to recommend planning species for the BDCP. In general, the Advisors do not advise designating species as planning species solely for economic, recreational, or aesthetic reasons. However, some non-listed species that may be affected by Covered Activities and conservation measures exert strong influences on the Bay-Delta ecosystem and on populations of Covered Species. Specifically, the Advisors have identified two groups of species as potentially useful planning species given the current list of Covered Activities: two non-native species of pelagic fish shown to be in decline (i.e., POD species, see Sommer et al. 2007) that are not included in the list of covered aquatic species, and four non-native invasive species that have altered the structure, composition, and function of the Delta ecosystem (Recommendation R4). These two categories are addressed further below.

POD Species

- Striped bass (*Morone saxatilis).* Striped bass is not native to the Delta, although its introduction was intentional. Its decline is of concern because it contributes to the total biomass of pelagic fishes in the ecosystem, and abundance indices for 2002-2005 included record lows for young striped bass (Sommer et al. 2007). The reason for this decline is unknown, although it is not due to low adult abundance (Sommer et al. 2007). The POD Management Team and collaborating scientists are analyzing trends and associations between abundance and environmental covariates.

- Threadfin shad (*Dorosoma petenense).* Like striped bass, threadfin shad is not native to the Delta and is of interest as a planning species primarily because of its previously high abundance (in some years it has been the most abundant fish in the Delta (Sommer et al. 2007)) and sharp drop in abundance in 2001, concurrent with the declines of other POD species.

Life histories of striped bass and threadfin shad are different from those of Delta smelt and longfin smelt (two other declining pelagic species covered by BDCP). This implies that their abundance and population dynamics may be responding to different drivers. Furthermore, adult striped bass consume other fish and may cause substantial mortality to young winter-run Chinook salmon (Lindley and Mohr 2003) and possibly other pelagic species. Considering striped bass and threadfin shad as planning species and exploring their potential response to conservation strategies may provide insight into the effect of conservation measures on diverse components of the ecosystem. Their inclusion as planning species does not imply that conservation actions should be developed to increase their abundance. Rather, considering how these species may respond to actions that are designed to benefit the Covered Species may provide information on the potential effects of plan implementation on a more diverse set of components of the Delta ecosystem.

Non-native species with ecosystem-level impacts

- Largemouth bass (*Micropterus salmoides).* Abundance of this species has increased in the Delta over the past few decades concurrently with the increase in submerged vegetation (Brown and Michniuk 2007). Largemouth bass have a much more limited distribution in the estuary than striped bass, but a higher per capita impact on small fishes in near-shore waters (Nobriga and Feyrer 2007). The effects of consumption of Covered Species by largemouth bass are unknown.
- Brazilian water weed (*Egeria densa*). This species increases water clarity by trapping fine sediments, and increases vegetation structure in littoral areas. This shifts the Delta waterways from turbid, pelagic conditions that favor native species of fish to clear, vegetated littoral conditions that favor introduced species such as largemouth bass (Brown and Michniuk 2007). Remote sensing studies from 2003 to 2006 showed that the range of Brazilian water weed has fluctuated from year to year and that previously occupied areas are

frequently recolonized, even where control methods have been applied. Submerged non-native vegetation covers about 10-12% of the waterways in the Delta. Approximately 80% of the submerged vegetation is Brazilian water weed (S. Ustin, unpublished).

- Overbite clam (*Corbula amurensis*). This species was introduced in 1986. Grazing by overbite clam is thought to have resulted in a substantial decline in phytoplankton and calanoid copepods, the primary prey of early life stages of pelagic fishes, in brackish waters of the Delta and Suisun Bay (Kimmerer 2002b).
- Freshwater clam (*Corbicula fluminea).* This species was introduced to the Delta in 1945, but understanding its effect on the ecosystem is hampered by the lack of ecological studies preceding its invasion. However, the introduction of freshwater clam has caused substantial changes to other estuarine ecosystems, including shifts from a phytoplankton base toward submerged aquatic vegetation (Phelps 1994). Freshwater clams are food limited in the Delta (Foe 1986) and they can control phytoplankton biomass in at least some locations in the Delta (Lucas et al. 2002, Jassby et al. 2002), which likely reduces the energy supply to some Covered Species.

The identification of these non-natives as planning species does not mean that conservation actions need to be developed for their benefit. Rather, because these species have caused substantial changes in ecosystem processes, assessing how the species respond to conservation actions designed to benefit the Covered Species may provide information on the potential effects of plan implementation on a more diverse set of components of the Delta ecosystem.

R4. Use planning species such as threadfin shad, striped bass, largemouth bass, Brazilian waterweed, overbite clam, and freshwater clam to assess effects of conservation measures on a wider range of ecosystem components and dynamics than the Covered Species represent.

3.5 Covered Communities

The Advisors caution against using guilds, communities of species, or other groupings of convenience for planning and analysis. Although species interact to form ecological communities, we often lack knowledge about the effects of a given species on the distribution or probability of persistence of another species. In addition, although sets of species often use some resources in common, each species has distinct resource requirements that should be accounted for individually. Although the Advisors acknowledge that the statutory language of the NCCPA focuses on communities, they do not think communities are defined clearly enough to be particularly useful for conservation planning within the Delta.

It will be more scientifically robust and effective to consider the presence of Covered Species relative to characteristic sets of ecological conditions than to correlate the presence of Covered Species with easily observed vegetation or substrate types (Recommendation R5). These sets of ecological conditions are defined by the way in which key environmental gradients interact across the Delta. Two of the most influential gradients within the Delta are (1) distance from the ocean which influences tidal exchange and salinity, and (2) elevation which influences inundation (Figure 1).

The interaction of tidal exchange and salinity produces four zones from ocean to rivers: (1) high salinity with tidal exchange, (2) fluctuating salinity with tidal exchange, (3) freshwater with tidal exchange, and (4) freshwater with no tidal exchange. The borders of these zones are dynamic and depend on Delta inflows, the range of oceanic tides (mainly spring vs. neap), and regional weather.

The elevation gradient produces four zones: (1) constantly inundated, (2) inundated and exposed on tidal time scales, (3) seasonally inundated, and (4) infrequently inundated. Although the elevations are fixed, at least on short time scales, the zones of inundation vary according to water levels, which depend on the interaction of river flows and the tide as well as atmospheric pressure and winds. Structures such as levees, barriers, and tidal gates modify gradual gradients of tidal exchange and salinity, creating abrupt shifts in environmental conditions (e.g., in elevation or salinity), and subsidence increases the degree of inundation during floods. These alterations can disrupt the transport and exchange of chemical and biological materials along these gradients.

R5. Examine how individual species respond to gradients in environmental conditions (and changes in those gradients) to inform assessment of the effects of conservation strategies, rather than using guilds, species communities, or other groupings of convenience.

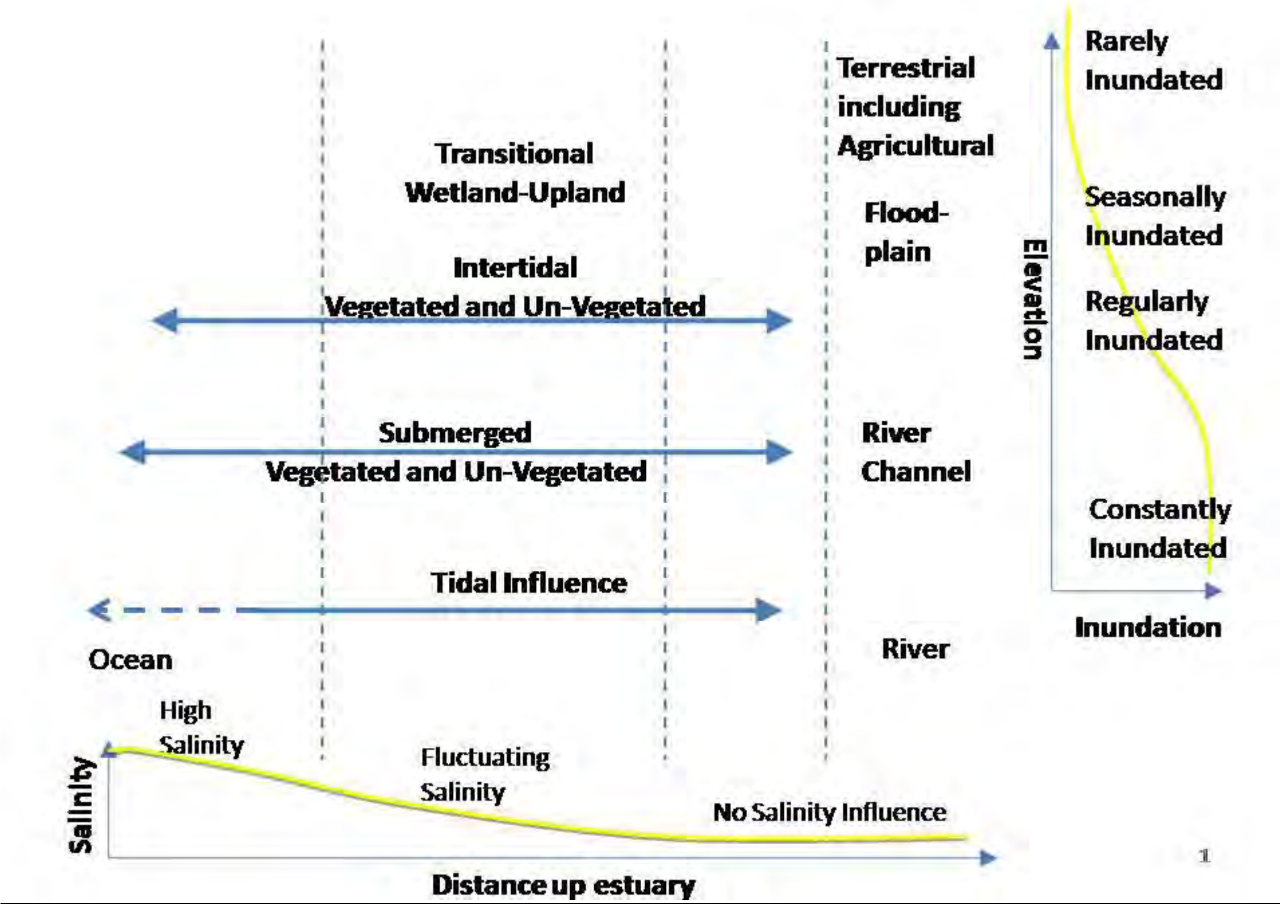

Figure 1. Horizontal and vertical gradients that control environmental conditions in the Delta.

Species disperse and are distributed across gradients of tidal exchange and salinity according to intraspecific and interspecific competition (especially in lower-stress environments) and the species' ability to exploit the range of environmental conditions (Byrd and Kelly 2006). As a result, different combinations of species occur in different areas at different times (Principle G). For example, inundation and salinity gradients affect the species richness, distributions, abundance, and biomass of tidal wetland plants (Mahall and Park 1976b, Atwater 1979).

Tidal exchange and salinity are interdependent. For example, soil salinity increases as wetland elevation increases to mean high high tide (MHHT), and then decreases further inland (Mahall and Park 1976b). Thus, spatial zonation in wetlands reflects a combination of biotic factors and physical and chemical factors, such as tidal regime, soil topographic features, and soil properties (Silvestri et. al. 2003, Belluco 2006, Mahall and Park 1976a, b, c).

Incorporating an understanding of environmental gradients in the Delta into conservation planning allows for consideration of changes to the drivers of those gradients. For example, sea-level rise will shift tidal gradients within the Delta and alter salinity penetration. Current estimates of global sea-level rise range from 9 cm[7] to more than 1 m[8] by 2100. Some scientists suggest conservation planning in the Delta should use sea-level rise estimates of 50-140 cm for the 21st century[9]. Similarly, increased temperature associated with climate change has already begun to alter runoff patterns in the system through a shift to an earlier peak in snowmelt (Knowles and Cayan 2002), which will influence environmental gradients within the estuary. Subsidence in the Delta and associated salinity penetration in the event of a levee failure have been identified as a potentially substantial influence on long-term salinity patterns (Mount and Twiss, 2005). Considering the influence of these anticipated changes on conservation measures is an essential element of planning (Recommendation R6).

Changes in the human environment should also be considered. This will likely take the form of increased urbanization around and within the Delta, and a shift in the pattern of demand for water from agriculture to municipal use. Increases in demand are expected to have at least as great an effect on water supplies globally as reductions in supply due to climate change (Vörösmarty et al. 2000). The same may be true at a regional level for water supplies in the Delta.

R6. Assess the sensitivity of conservation outcomes to anticipated changes in environmental gradients that will likely arise from sea-level rise, subsidence, climate-change induced alteration in the timing of runoff, human activities, and other processes over the time frame of the Plan and beyond.

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[7] Low range estimate from IPCC Fourth Assessment report (Low range estimate from IPCC Fourth Assessment). Note this does not include ice sheet melting and is based on the most optimistic emissions scenarios.
[8] Rahmstorf, S 2007 *A Semi-Empirical Approach to Projecting Sea-Level Rise* Science v. 315, pp. 368-370
[9] Memo from CALFED Independent Science Board to Lead Scientist, 6 September 2007. Located at http://www.calwater.ca.gov/science/isb/isb_archive_07.html August28-29, 2007 meeting.

4.0 DELTA ECOSYSTEM DYNAMICS

The Delta is a highly complex system of interacting physical, geomorphic, biological, and chemical processes, all of which are influenced by human activities both inside and outside the Delta. The Advisors consider certain of these interactions particularly important for anticipating the response of the Covered Species to future changes in environmental conditions, the Covered Activities, and other aspects of human use of the Delta. External influences (e.g., river inflows, diversions, tides) interact with the underlying physical structure of the system to influence physical, geomorphic, food web, and chemical processes. The interaction of these processes influences species population dynamics in a variety of ways (Figure 2). A process-based approach provides a basic framework for understanding system dynamics and for developing and evaluating conservation strategies (Principle O). Physical processes drive many aspects of the ecosystem both directly and indirectly (Principle F), (Figure 2).

This section is not intended to provide a detailed description of the all the physical, geomorphic, biotic, and chemical processes within the Delta. Rather, this section aims to

1. Identify the most important processes influencing Covered Species;
2. Assess the current state of knowledge regarding those processes;
3. Outline key uncertainties, and;
4. Assess the ability to predict how these processes operate within the system.

Understanding these processes, and acknowledging the limits of our understanding, is critical to the formulation of a conservation strategy. It is important to keep in mind that the system is neither static nor homogeneous (Principle D) so our understanding changes with time and new data.

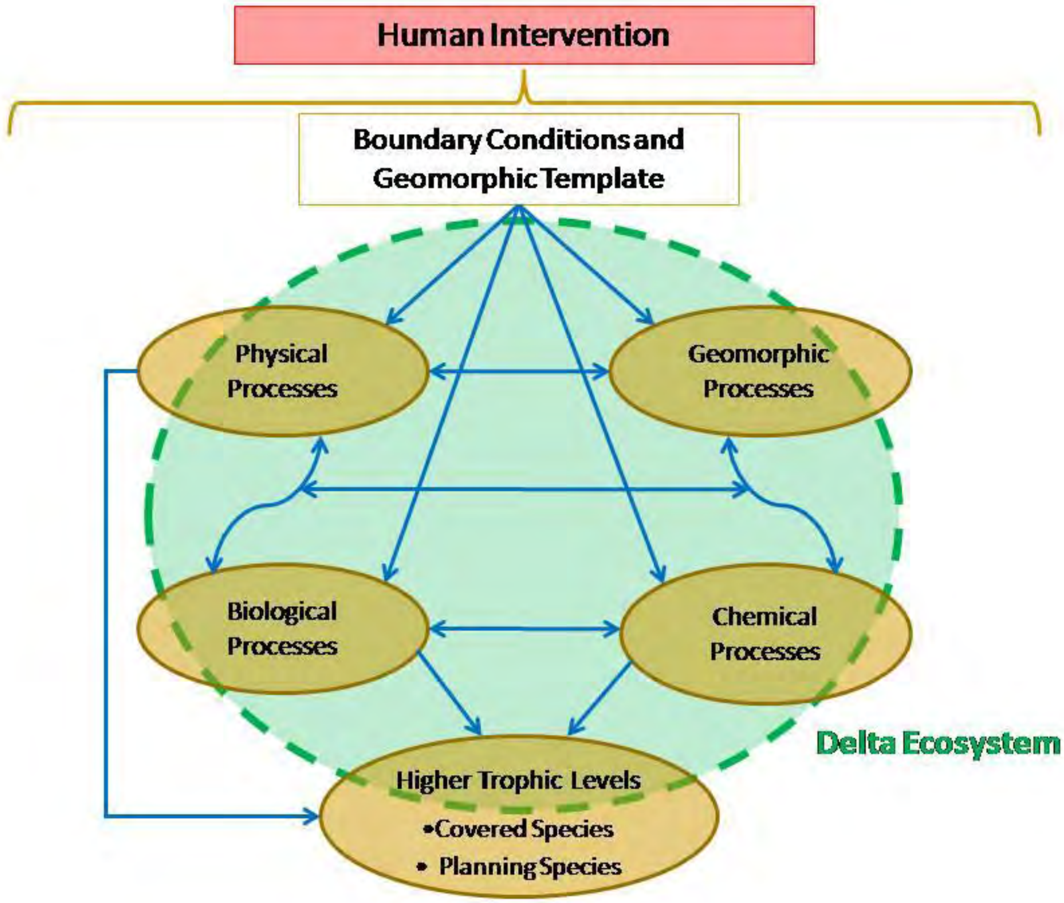

Figure 2 – Conceptual diagram of interactions among environmental processes that influence responses of higher trophic levels, including Covered Species, to changing conditions.

4.1 Process Interactions in the Delta

To understand the Delta ecosystem it is essential to consider the factors both internal and external to the Delta that drive the ecosystem (Principle C). At least 11 external processes or factors fundamentally influence the Delta ecosystem (Table 1). In addition to physical processes that are driven by external factors, some biological and chemical processes in the Delta are directly influenced from outside the Delta (e.g., harvest of salmon in the ocean, chemical applications) (Figure 2).

The Advisors have identified a number of critical processes that influence higher trophic levels, including the Covered Species (Tables 2-5). The roles of these processes in influencing different life stages of Covered Species are addressed in section 4.3 below. Interactions among these processes are frequently more important than any one process alone. Many interactions among processes are mediated by changes in dissolved constituents, (Principle H), including salts and nutrients. Inputs from upstream and from within the Delta alter the amount of these constituents, but their dynamics are often controlled by tidal dispersion (Table 5 and Principle I).

Water quality in the Delta influences higher trophic levels directly and indirectly via changing environmental conditions (Figure 1) and toxicity, and as a control on primary production and energy inputs to the food web (Table 4). Other important process interactions occur at a local scale. The Delta's aquatic food web is driven by phytoplankton and, to some extent, bacteria rather than by detrital organic matter (Table 4). However, aquatic plants, which are often the primary source of detritus, can influence turbidity through flow attenuation (Tables 1 and 2), which potentially increases phytoplankton growth. Aquatic plants may also absorb contaminants such as pyrethroid insecticides (Table 5).

Anticipating the ecosystem response to Covered Activities requires an understanding of these and other complex interactions among abiotic and biotic processes. The use of models to predict population dynamics of Covered Species is addressed in Section 4.4.3. However, forecasting changes in the process interactions described here and in Figure 2 is important for understanding the system level implications of Covered Activities. Many of these interactions are driven by physical processes. Because our ability to predict the physical dynamics of the system is effectively limited to the current system configuration (Table 2 and Section 4.4.2); predictions of how these process interactions will change in the future are highly uncertain.

4.2 Information Needs

Although monitoring programs have been implemented for some aspects of the Bay Delta system (e.g., hydrodynamics, salinity, fish densities and distribution), the ability to predict the response of any system component to the Covered Activities is limited in many instances by available data (Tables 1-5). To address the needs outlined in Tables 1-5, additional data that could be collected include detailed topography and bathymetry, wind stress and solar insolation, bed sediment character, and distribution and rates of clam grazing. This list is not intended to be comprehensive but serves to illustrate the range of data needs currently limiting conservation planning. The Advisors acknowledge efforts of groups such as CMARP (Comprehensive Monitoring and Research Program) in identifying a broader array of monitoring needs. It may be possible to monitor some parameters using recently developed techniques for the acquisition of detailed spatial data (e.g., remote sensing, towed samplers) and the Advisors encourage the evaluation and, if appropriate, implementation of these approaches (Recommendation R7). The influence of contaminants on the dynamics of plants and animals in the Delta is unclear. With the exception of mercury, which has been relatively well studied in the Delta and surrounding watersheds, and selenium, for which data are available upstream but not in the Delta, predictive ability related to effects of contaminants is fundamentally constrained by a lack of information (Recommendation R8).

Existing monitoring programs should be maintained (Recommendation R8), but as conservation options become more fully developed it is likely that additional data will need to be collected to support analysis of options; these analyses include model development and validation (Section 4.4). Development of detailed recommendations on monitoring to inform BDCP conservation actions requires more information on the nature of Covered Activities and more explicit conservation goals (Recommendation R9 and section 6.0). The effective and transparent use of existing and newly acquired data in conservation planning requires a database that can incorporate data collected over space and time (Recommendation R10). Such a database will be an important tool in Plan development. The database could inform the design of future research and monitoring activities, and assist in developing both hypotheses about relationships among ecosystem components and statistical and process models.

R7. Routinely collect high resolution airborne imagery over the Delta, including lidar, hyperspectral or multispectral, and thermal, to detect and quantify spatial changes in miocrotopography, surface water temperature, surface turbidity, algal blooms, and aquatic, wetland, and riparian plant species composition and fractional cover.

R8. Maintain current monitoring programs within the Delta and institute a comprehensive, long-term, Delta-wide monitoring program to provide data on contaminants in sediments, water, and aquatic organisms, including in-Delta diversions and return flows.

R9. Refine and expand existing monitoring programs as Covered Activities and Conservation Actions are specified and critical data needs can be identified.

R10. Develop an integrated database of monitoring data (e.g., salinity, temperature, nutrients, contaminants) and relevant spatial data layers (e.g., topography, distributions of submerged, emergent, and floating aquatic plant species).

Scientific studies will be necessary to explore the effects of Conservation Actions and other environmental changes on Covered Species. These studies will need to examine the fundamental interactions between physical, chemical, biogeomorphic and food web processes that influence the Covered Species. Targeted research can facilitate development of more successful statistical and process models, including models that support predictions of ecosystem response to changing Delta configurations and boundary conditions. More information on the Covered Activities and conservation strategies is essential before the Advisors can offer guidance on the array of scientific input that will be needed to support BDCP planning and implementation.

4.3 Population Dynamics and Process Interactions at Higher Trophic Levels

The discussion below focuses on fish because of their dominance on the list of Covered Species, but similar issues and recommendations would apply to any other covered and planning species. Organisms at higher trophic levels in the Delta are influenced by interactions among physical, chemical, biogeomorphic and food web processes (Figure 2).

Of relevance for evaluating alternative management and conservation actions is how the factors shown in Tables 1-5 affect the growth, mortality, reproduction, and movement of individual members of the Covered Species. The cumulative responses of individuals over life stages, space, and time influence the dynamics of populations. Population dynamics encompasses seasonal and interannual fluctuations in distribution and abundance, long-term trends in distribution and abundance, likelihood of persistence and recovery, and other phenomena. Understanding and forecasting population dynamics requires consideration of the dependence of all life stages on key environmental variables. Understanding and forecasting population changes due to Covered Activities may also require understanding how Covered Species respond to environmental conditions outside the range of conditions they currently experience

4.3.1 Life Cycles

To identify how environmental changes in the Delta may affect the Covered Species, first it is necessary to consider which portions of each species' life cycle occur within the Delta. For anadromous species such as salmon and steelhead the Delta serves as a migratory corridor for juveniles and adults, and a rearing area for some juveniles (Williams 2006). By contrast, one or more of the life stages of resident species of fishes occur within the Delta, Delta smelt spawn in the central and northern Delta. The juveniles move downstream into the brackish waters of the western Delta and Suisun Bay, and adults migrate back into the Delta to spawn (Bennett 2005, Moyle et al. 1992). Longfin smelt are thought to spawn in the Delta, while juveniles and sub-adults are found throughout the saline parts of the estuary, and adults may enter the near-shore areas of the ocean (Moyle 2002). Splittail spawn on floodplains in the Yolo and Sutter bypasses and along the Cosumnes River. Juvenile and adult splittail inhabit tidal freshwater and brackish water in the Delta (Moyle et al. 2004). Sturgeon, like salmon, are anadromous, but sturgeon tend to spend a greater proportion of their adult life stage throughout the estuary than do salmon (Moyle 2002). Thus, each Covered Species uses the Delta in a different way.

The Advisors suggest viewing each species' use of the Delta through a life cycle triangle that depicts the species' life cycle from birth to death as a closed migration path (Harden-Jones 1968) (Figure 3 and Recommendation R11). The path begins in the spawning habitat where adults produce offspring. The larval fish disperse to the juvenile habitat and eventually move to the adult habitat. The path is completed when the adults migrate back to the spawning habitat to reproduce. The population dynamics of a species are determined by the survival of fish over the migration path, the number of offspring produced by adults in the spawning habitat, and the number of times adults cycle between the adult and spawning habitats during their lifetime. The critical life history processes, or vital rates, include growth of individuals, mortality in each habitat, movement among habitats, and reproduction in the spawning habitat. These vital rates control the population dynamics of the species in the Delta. The set of vital rates across life stages dictates the rate at which an individual moves through its life cycle. Specific sets of vital rates, which have proven successful over evolutionary time, define the life history strategy of the species (Winemiller and Rose 1992).

R11. Consider relationships between environmental conditions and the Covered Species in a life cycle context.

4.3.2 Population Responses to Environmental Conditions

A major challenge for assessing how populations respond to environmental changes and management actions is to determine how the vital rates at different life stages may respond to the altered environmental conditions. Quantifying the effects of conservation measures on abundances at different life stages is difficult. Determining whether these effects are sufficient to offset uncertain management-induced mortality rates is even more difficult (Principle K). It is necessary to examine how hydrodynamics, salinity, temperature, food availability, contaminants, and other environmental variables directly and indirectly affect the rates of growth, reproduction, mortality, and movement. Of these processes, growth is usually the easiest to study in the field and in the laboratory. Reproduction is also generally quantifiable under current environmental conditions. Mortality is difficult to quantify and the sources and locations of mortality are notoriously difficult to identify (Recommendation R12). Even mortality at the south Delta export pumps, which are intensively monitored for fish entrainment, has some major unknowns such as mortality in the channels leading to the pumps (Kimmerer in press). Some of the unknowns related to entrainment mortality could be reduced through a program of research that might include studies of radio-tagged fish, predator removal studies, bioenergetic analysis of predators, sampling fish behind the louvers at the fish facilities, and studies of predator aggregation at release points[10]. Such a program should be built around a modeling component so results of individual studies could be compared and placed in a population context.

[10] See also the Summary of the June 22 -23, 2005 CALFED Science Program Predation Workshop at http://www.calwater.ca.gov/science/events/workshops/workshop_predation.html

R12. Pursue efforts to quantify the contribution of entrainment and other factors to stage-specific mortality rates of Covered Species to in order to assess the population-level benefits of offsetting such losses.

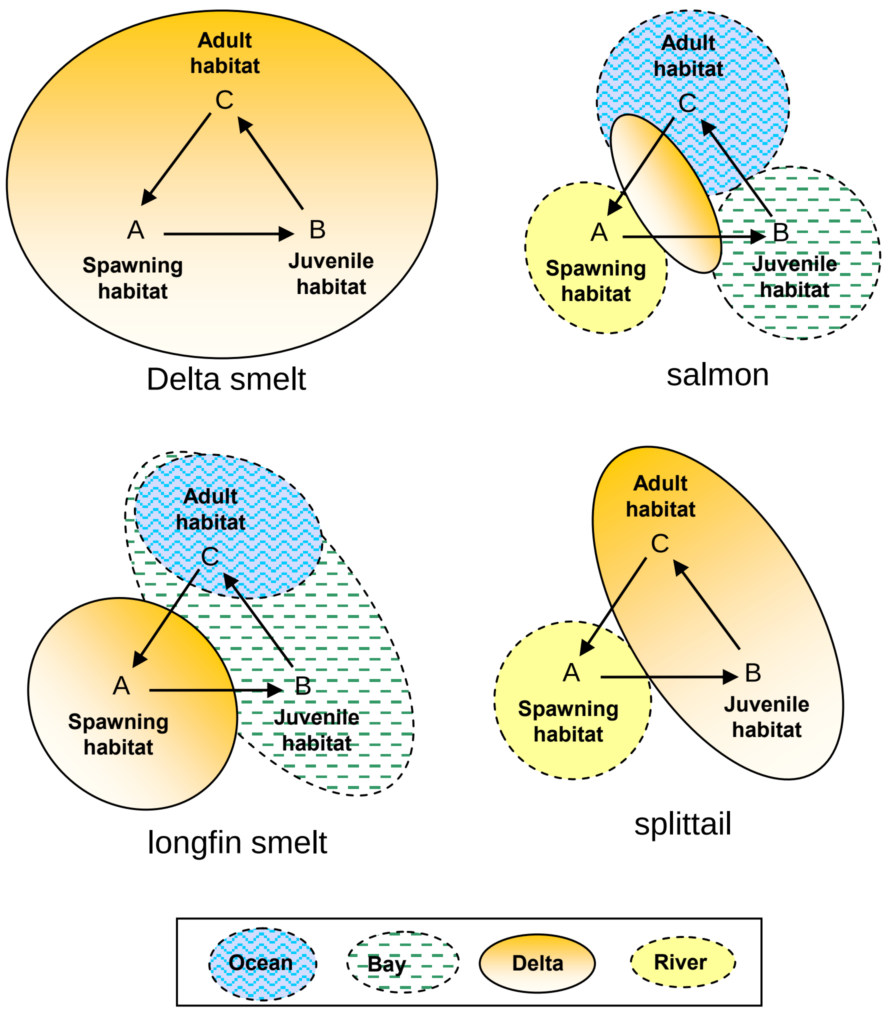

Figure 3. General pattern of use of the Delta by Covered Species over their life cycle. Arrows indicate migration among habitat types.

Determining how changes in environmental conditions may affect movement of the Covered Species is particularly important and challenging. Aquatic organisms in the Delta use various cues to move among habitats. Thus, effects of tidal and net flows on fish movement must be explicitly considered in analyses. Movement is important because vital rates, especially growth and mortality, depend on the timing and routes of movement through the Delta. For example, the central Delta is probably poorer habitat for salmon than the migration pathway along the Sacramento River (Brandes and McLain 2001). The vulnerability of many species to detrimental effects of the Delta pumps depends on their location within the Delta. Additionally, understanding how water operations and management actions affect fish exposure to salinity, temperature, and food is critical to understanding growth, movement, and mortality. Yet relatively little is known about how environmental cues affect fish behavior and movement. Even less is known about how alteration of these cues by management actions might affect movement, which, in turn, would affect the vital rates and population dynamics of species that use the Delta (Principle E).

Tables 1 through 5 describe factors that affect the vital rates at each life stage (Figure 3). These factors can influence habitat quantity and quality differently for each species by modifying the connections among habitats, pathways of movement, and the growth, survival, and reproduction of individuals as they move through their habitats.

- Table 1 describes the fundamental drivers of the Delta ecosystem, many of which can affect the vital rates of fish at different life stages, and most of which can be altered by human activities. The boundaries of the environment are defined by bathymetry, shorelines, and topography, which together determine the geographic extent of habitats for each species and the physical connections among habitats.
- Table 2 describes relevant physical processes and factors in the Delta, such as transport and mixing of water and dissolved and particulate constituents (including salts, sediments, and biota) and water temperature. These processes are particularly important because they affect both the physical transport of species and the temporal and spatial cues that the species use to navigate between specific habitats (Figure 3). For example, the hydraulic characteristics of the Delta Cross Channel determine the fraction of migrating juvenile salmon moving into the interior Delta. Throughout their life cycle, resident species rely on cues that initiate and direct their migrations. It is plausible that a species' ability to use the Delta may be the result of behavioral responses to hydraulic and chemical cues that have evolved over long time periods through natural selection. Individuals that moved in certain ways in response to specific cues had higher survival and reproductive success. For example, to avoid being flushed out of the estuary by the net river flow, many small organisms, including some larval fish, have evolved

behaviors that move them into water with higher velocities during the flood tide and lower velocities on the ebb tide. These behaviors may produce a net upstream movement to counteract losses due to the net river outflow (Bennett et al. 2002, Kimmerer et al. 2002). Changes in these cues due to management actions, or the ability to respond to such cues due to other environmental changes (e.g., contaminants - Little and Finger 1990, Sandahl et al. 2004), may alter movement patterns in ways that disrupt a how a species progresses through its life cycle (Figure 3).

- Table 3 identifies important biogeomorphic processes that determine the quality of the habitats for the different life stages of each species. For example, splittail attach their fertilized eggs to submerged aquatic vegetation on floodplains (Sommer et al. 1997). Therefore, the extent, structure, and composition of floodplain vegetation and the frequency and extent of flooding influence spawning success. Further, processes such as flow, wave energy, marsh accretion, and subsidence of Delta islands can indirectly affect spawning success through their effects on vegetation structure.
- Table 4 identifies critical processes in lower trophic levels of the food web that structure the habitat quality for fish, in particular through the effects of these processes on the growth rates of Covered Species within each of their habitat types. Growth rate, in turn, affects survival and reproduction because body size is a major determinant of the vulnerability of fish to predation and because maturity and fecundity are size-dependent (Rose et al. 2001). Critical processes that affect food web dynamics include the energy inputs in terms of primary organic material, the structuring of predator-prey communities, and the effects of non-native invasive species on the food web dynamics. For example, the western Delta and Suisun Bay, which provide habitat for juvenile to adult Delta smelt, contain invasive clams that consume Delta smelt prey and therefore can affect Delta smelt growth and survival. Food web processes can also affect the Covered Species by affecting their predators.
- Table 5 identifies contaminants that have the potential to affect the growth, survival, and reproduction of the Covered Species as they develop through their life cycle. The table considers current-use and legacy pesticides; mercury, selenium and other metals; polychlorinated biphenyls, and polyaromatic hydrocarbons. The table notes pathways by which the chemicals move through the habitats of Covered Species, their indirect effects on Covered Species via the food webs, and some direct effects on the Covered Species.

Together, Tables 1 through 5 describe the environment in which the Covered Species complete the portion of their life cycle that occurs within the Delta. Understanding how environmental factors affect the population dynamics of Covered Species is central to predicting how Covered Activities and conservation strategies may influence those species. Uncertainties regarding future changes in these environmental factors, and how cumulative uncertainties influence predictions of species response, must be considered in conservation planning (Recommendation R13).

R13. Identify how anticipated changes in environmental conditions, including those associated with Covered Activities and climate change, propagate through populations of Covered Species, and consider how uncertainties regarding future environmental conditions potentially influence population response to Covered Activities.

The complex life cycles (e.g., use of multiple habitats by different life stages) and the diversity of life history strategies (i.e., different collections of vital rates) of the Covered Species will complicate evaluation of management and conservation actions. There will likely be trade-offs among the species of concern (Principle M). The effects of management and conservation actions on population dynamics of Covered Species will be constrained by unknown bottlenecks (i.e., constraints on life stage survival and reproduction from environmental and other factors) within and outside of the Delta (Recommendation R14).

More-detailed descriptions of how to consider limiting stages or bottlenecks in a population's life history can be found in McElhany et al. (2000) and the OCAP review (Technical Review Panel 2005). These two papers addressed the concept of viable salmonid populations. The papers described four parameters that are central in evaluating population status, and ultimately, population viability: abundance, population growth rate, population spatial structure, and diversity (life history and genetic). For anadromous fish species that use the Delta as a migration corridor, improvement in water quality or other environmental conditions in the Delta may not have proportional responses at the population level. In general, anadromous fish in the San Joaquin River appear to be more sensitive to conditions in the Delta during migration than fish in the Sacramento River (Technical Review Panel 2005). Under the best passage conditions, the Delta will have limited negative impacts on survival and reproduction of anadromous fish. However, if physical and hydraulic configurations act to block migration, divert fish into the pumps, or extend migration time, then the effects of management actions in the Delta could be negative and significant. In neither case is it obvious how the populations will respond to within-Delta actions because of the potentially large effects of conditions outside of the Delta.

R14. Examine possible bottlenecks at other life stages, including those that occur outside the planning area, rather than only those at the life stage immediately affected by Covered Activities or within the Delta. Bottlenecks at other life stages can modulate the population response to changes in environmental conditions within the Delta.

Table 1 Assessment of Knowledge Base, Uncertainty and Predictive Ability for Important Drivers of the Delta Ecosystem

Critical Process/ Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability
Riverine inflows	Riverine inflows are a key driver of the hydrodynamics of flow and transport (scalar, biotic) in the Delta channel system. Characteristics include daily flows and concentrations of dissolved constituents such as organic matter, nutrients, and contaminants, as well as particulate organic matter, sediment, and biota. Time scales range from minutes (flood flows) to seasons to decades and longer. Periodic and aperiodic variability is strongly coupled to climate and weather. Trends are strongly driven by climate change and human alteration of the catchment, including systems that affect upstream water resources (e.g., dams and reservoirs, diversions, return flows, levees).	Inputs of constituents from the watershed are strongly dependent on riverine inflows at all times. Current understanding at the level of fundamental processes is high. Data are available only for a few specific locations.	Understanding of variability (including extreme events) and the influence of climate is moderate.	Variability is very high, limiting predictability. Modeling tools exist, but application at relevant scales is limited by computing capacity, and especially by limited availability of characterization data. Hydrologic models are calibrated to existing conditions, which constrains applicability under changed conditions. Confounded by non-physical elements of upstream operations, e.g., operating rules and emergency actions

Table 1 Assessment of Knowledge Base, Uncertainty and Predictive Ability for Important Drivers of the Delta Ecosystem

Critical Process/ Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability
Tides	Mixing in the Delta is largely driven by tidal flows (Burau *in press*). Net flows in western Delta channels are modest relative to tidal flows, except during flood periods (Burau *in press*).	Tides in the San Francisco Estuary have principal periods at ~12.4 and 25 hours and 2 weeks, but many other tidal periods are present, and tides are modified by non-periodic oscillations in water level in the ocean due to wind set-up and atmospheric pressure fluctuations. Existing network of tide gages at the Golden Gate and around the estuary provides high-frequency traces of water-surface elevation.		High predictive ability for the astronomical tides through tide tables. Moderate predictive ability for non-periodic modifications because the controlling processes are not predictable over time scales longer than hours to days. Tides may be modestly affected by sea level rise, which is moderately predictable.
Sea level	Mean sea level defines the base level of the seaward boundary of the estuary and thus is a critical driver for tidal processes in the estuary including the Delta. Sea level is predicted to rise over the time scales of an NCCP/HCP. Some recommend planning for a rise of 50-140 cm by 2100[9]. A rise of this magnitude will cause inundation in some low-lying areas and can alter thermal and salinity regimes, pumping heads, wave regimes.	Mechanisms leading to changes in mean sea level and non-periodic modification of the periodic tide are well understood. Substantial, long-term historic data are available at a number of locations near and within the Bay-Delta system.	Prediction of rates and extents of change.	Sea level rise is a near certainty and has been observed. The rate of sea level rise is only moderately predictable over the period of the NCCP/HCP because of inherent stochasticity in climate, incomplete data, and dependence on future human behavior and policy decisions.

Table 1 Assessment of Knowledge Base, Uncertainty and Predictive Ability for Important Drivers of the Delta Ecosystem				
Critical Process/ Factor	**Description and Importance**	**Current State of Knowledge**	**Key Uncertainties**	**Predictive Ability**
Water exports	Large volumes of water are diverted from the freshwater Delta by large state and federal pumps in the southern Delta. This water supplies farms and cities throughout central and southern California, some in the San Joaquin basin and some outside. Fish facilities associated with the pumping plants extract fish from the water and return them to the estuary, but these facilities are not very efficient, and there is considerable concern over the number of fish killed and the potential population-level consequences[11] .	Export flows are set by operators, and water is released from reservoirs in the Sacramento basin to meet export needs and salinity or other standards in the estuary. The quantity exported is well known, but the impacts to fish are only beginning to be quantified.		High for flow.
In-Delta Diversions	Substantial volumes of water are diverted from channels and ground water within the Delta. Diversions influence in-Delta flows[12] and may remove substances and organisms from the Delta.	The nature of most surface-water diversions is well-understood. The quantity and timing of diversion flows is estimated from cropping patterns and weather, which is a crude estimate. Estimates are unavailable for actual diversion volumes. Coupling between surface water and ground water is well understood, but has received relatively little attention in the specific context of the Delta.	Ground water diversions and their impacts on surface waters.	Moderate predictive ability on time scales of months, since magnitude and timing are dependent on weather, water law, population growth, land use, etc.

[11] Brown et al. 1996, Kimmerer in press.
[12] Kimmerer and Nobriga in press

Table 1 Assessment of Knowledge Base, Uncertainty and Predictive Ability for Important Drivers of the Delta Ecosystem

Critical Process/ Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability
Return flows	Some of the water extracted and used within the Delta may return to the Delta (e.g., wastewater treatment plant (WWTP) discharges, island drainage, ground water seepage to channels)	High level of understanding for the underlying physical processes, although return flows have received relatively little study. Data are available for WWTP discharges. Few data are available for return flows via ground water seepage or island pumping.	Quantity of return flows. Ground water seepage or island pumping.	Moderate predictive ability for large-scale exports and point return flows (e.g., WWTPs) due to unpredictability of future patterns of weather, climate, population growth, land-use change, etc. Moderate predictive ability for distributed return flows in a bulk, temporal sense, (e.g., as a fraction of diversions), but low for specific return flows due to variability in subsurface properties, vegetation patterns, etc.
Weather	Solar radiation, air temperature, relative humidity, wind speed and direction drive a number of important processes and conditions e.g. water temperature, precipitation, snowmelt, evaporation/transpiration, water waves and set-up, and demands for water diversion and export (especially for irrigation).	High level of understanding of basic processes at local spatial scales. Moderate for variability (including extreme events) and climate drivers, and for conditions over large spatial extents at shorter time scales. Data are limited to specific measurement locations; but improved remote sensing instruments show promise.	Connections between climate change and local weather changes.	Low to moderate predictive ability. Weather forecasting remains constrained by stochasticity (limits predictability over long time scales).

Table 1 Assessment of Knowledge Base, Uncertainty and Predictive Ability for Important Drivers of the Delta Ecosystem

Critical Process/ Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability
Land use	Land use plays a significant role in determining the magnitude, rates, and trends in many other Delta system drivers. Especially critical are land use changes that can alter the hydrologic response of catchments to precipitation, demand for water, return flows, and constituents in inflows and return flows.	Moderate level of understanding for the mechanisms connecting land use changes to changes in hydrologic response. Aggregated data sets of land use are available across a wide range of relevant scales. Substantial local land use data are available, but dispersed and inconsistent, making aggregation difficult. Remote sensing and GIS tools are increasing in use and improving in capacity and ease of use.		Low to moderate predictive ability due to dependence on population growth, policy decisions, etc.
Levees/barriers/ gates	Barriers within the Delta can significantly affect flow, transport, and mixing. Levees influence channel flow geometry, friction, and channel-island exchange. Levee failure causes a rapid change in physical configuration of the Delta and a short-term intrusion of saline water into the Delta .	Physical processes are well-understood but friction parameters are not well known. Moderate knowledge of levee geometry and local data on structures. Data on the condition of levees are limited but growing		Moderate predictive ability. Non-catastrophic performance predictable with available tools. Prediction of catastrophic performance limited by lack of detailed spatial data and dependence on the stochasticity of weather, climate, and earthquakes.

Table 1 Assessment of Knowledge Base, Uncertainty and Predictive Ability for Important Drivers of the Delta Ecosystem

Critical Process/ Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability
Bathymetry	Water depth and distribution is a fundamental influence on hydrodynamics. Complex bathymetry at channel junctions and bends is an important influence on tidal dispersion. Shallow water limits the height of wind waves and water depth determines their interaction with the bottom, which can stir up sediment.	The positions of most Delta channels are fixed but cross- sections and bed forms are dynamic. USGS recently compiled a 10 m grid of depth from 9 km inland of Mare Island and 10 km from Sacramento south to Mossdale[13]. Many surveys used to provide bathymetric data are decades old.	Detail around junctions and bends. Bed forms and their movement[14]. Inconsistent survey-to-survey accuracy limits accuracy of USGS grid. Major change possible with levee failure.	Small changes in bathymetry are influenced by sediment inflows. Bedload is a small fraction of total sediment inputs from the Sacramento River but poorly documented. Levee failure is the most significant likely future change (unless new dredging of navigation channels occurs).
Shorelines	Slope, sediment characteristics, and exposure to wave action influence colonization by plants and use by aquatic animals. Fetch, or the distance over which wind waves are produced, determines wave height for a given wind speed and thus is an important influence on erosion of shorelines.	General typology of bank forms and characteristics are well established (few natural shorelines remain). Limited studies of bank erosion by boat wakes[15].	Detailed mapping of shoreline type and characteristics	Most Delta shorelines are managed. Major changes associated with levee failure and responses.

[13] http://sfbay.wr.usgs.gov/sediment/delta/index.html
[14] Sand dunes > 3m high have been documented in Three Mile Slough (Dinehart, USGS)
[15] Bauer et al. 2002

Table 1 Assessment of Knowledge Base, Uncertainty and Predictive Ability for Important Drivers of the Delta Ecosystem

Critical Process/ Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability
Topography	Fundamental control on inundation regimes (see Section 3.5).	Recent Light Detection and Ranging (LIDAR) surveys will provide the best synoptic data. Subsidence rates of up to 4 cm/yr have been documented in peat soils[16]. Peat has been eliminated in some parts of delta; subsidence continues in the central, western and northern Delta. Peat strata are thickest in the western Delta.	Effect of alterations in land use on subsidence. Consequences of levee failure.	Low predictive ability for land use effects.

[16] Rojstaczer and Deverel 1995

Table 2 Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Physical Processes

Critical Process or Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Hydrodynamics	Hydrodynamics in the Delta are driven by tides, freshwater flows, water exports and local diversions, and atmospheric forcing.	The geometry of the Delta is highly altered from its historical structure of dendritic sloughs. Today, the Delta consists of a network of interconnected channels that extend around Delta Island, leading to circular flow paths that are distinctively different from the branching structure of the historical Delta. Hydrodynamics in the Delta are governed by a combination of tidal motions and net, river-derived flow. Net flow transports water and its dissolved and particulate constituents, and tidal exchange mixes and transports water and constituents. Tidal exchange becomes increasingly important moving from east to west, and as river flow decreases. The complex phasing of tidal flows at the intersections of channels can determine transport. A critical parameter is the ratio of tidal excursion to channel length: where this parameter is large, the flow environment will be highly dispersive and the hydrodynamics of the junctions will be control transport. Where this parameter is small, as in the eastern Delta which is more under the influence of river flow, transport is largely driven by the net flow. When salt penetrates into the western Delta, stratification and density-driven net flows (e.g., gravitational circulation) may have important effects on salt transport and mixing.	Temporal and spatial details become progressively more difficult to predict at smaller scales.	Variable predictive ability. In general, the ability to predict physical characteristics in the Delta, including hydrodynamics and transport of constituents (salinity, temperature, turbidity and particles), increases with increasing spatial and temporal scale.	Exports, reservoir releases, configuration, barriers, dredging in channels (see Table 1).

Table 2 Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Physical Processes

Critical Process or Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Transport of dissolved constituents (Eulerian transport)	The transport and dispersion of water constituents (salinity, temperature, suspended sediment and contaminants) are dominated by the interaction of tidal hydrodynamics with the complex geometry of the Delta	Much of the Delta is strongly tidally dispersive, but becomes increasingly advective towards its northern, eastern, and southern boundaries. Increases and decreases in freshwater flows and exports shift the boundaries between “advective” and “dispersive” environments. Large-scale dispersion in the Delta is largely determined by flow interactions with a number of local features. Most common of these are channel junctions, which split the flow and separate water parcels rapidly and broadly. Open tracts of water (Franks Tract, e.g.) alter the transport pathways through the Delta, and their influence may vary seasonally.	A quantitative measure of Delta-scale dispersion is not readily available. The vertical variation of flows, particularly in junctions, is not well resolved.	Dispersion in the Delta can be well modeled with a highly resolved two-dimensional model as long as the hydrodynamics are accurately represented. Most hydrodynamic models of the Delta are well-calibrated to current conditions (geometry, range of flows, etc.); their performance under scenarios of large-scale change would be uncertain.	

Table 2 Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Physical Processes

Critical Process or Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Transport of particles (Lagrangian transport)	Lagrangian transport applies to any constituent for which history is important. Examples would include the dynamics of reacting contaminants or individual-based modeling of biota.	Particle transport in the Delta is governed by the same hydrodynamics as for dissolved constituents, but the resolution required is much finer (i.e., the scale of the particle under consideration). If the velocity distribution and turbulent coefficients were known exactly, transport of particles could be easily calculated. In channels, the lateral and vertical velocity structures are reasonably well understood, with possible limitations in the cases of strong curvature or large bedforms (e.g., sand waves). Particle transport is very complex in junctions between channels of different tidal phase, depth, and density of water, and can be very difficult to resolve.	There is a severe lack of Lagrangian data in the Delta so that it is nearly impossible to even assess our ability to accurately predict transport. Some data have been collected at Sherman Lake and the DCC (both drifter studies) and Mildred Island (dye releases). The lack of detailed descriptions of transport and mixing in channel junctions is probably the most substantial limitation in the scientific understanding of transport in the Delta.	Predictability requires a highly-resolved three-dimensional model of water velocities, mixing coefficients, and particle characteristics. This is especially true for junctions where flows are particularly complex.	
Salinity	Salinity transport is largely governed by tidal dispersion and gravitational flow, which in turn occurs due to salinity variations.	Down-estuary the response of salinity to Delta outflows is well-established (X2 relationships.[17]) Within the Delta itself, the importance of tidal dispersion processes means that X2-type relationships are unlikely to hold. Movement of the salinity field into the Delta creates new dispersion mechanisms due to density forcing in the complex channel network.	Quantitative measures of tidal dispersion in the Delta are limited. In the case of a large event like a levee failure, prediction of salinity intrusion into the Delta becomes more difficult and would likely require a three-dimensional approach.	The prediction of salinity movement into the Delta is difficult because of uncertainties associated with Delta dispersion, and because density stratification and gravitational circulation are themselves difficult to predict	

[17] Jassby et al. 1995; Monismith et al. 2002

Table 2 Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Physical Processes

Critical Process or Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Temperature	Temperature variation is dominated by exchanges with the atmosphere through heating and cooling by solar insolation and surface heat fluxes. Tidal dispersion mixes oceanic temperatures and river temperatures.	Temperature in the Delta is governed locally by a heat balance between inputs from solar radiation and convection, and losses to convection and evaporation. This balance is influenced by the temperature of water flowing in from the rivers, and by exchange with the ocean. Therefore, the statistical relationships between water temperature and air temperature vary spatially throughout the Delta. Although much of the variability in water temperature in the Delta can be explained by variability in air temperature [18], the influences of flow, exchange, and temperatures in the rivers and down-estuary are also important. For example, recent analysis [19] of historical water and air temperature records indicate that at stations near temporary barriers in the South Delta, the correlation between water temperature and air temperature changes when the barriers are in place.	Local variations in forcing due to, for example, shading, sheltering from wind, and channel morphology, will create local variations in temperature. Data to drive analysis at these small scales are not available.	Predictability depends on scale, but data requirements for atmospheric forcing (e.g., insolation, convection, evaporation) could be large. A three-dimensional modeling approach may be required due to the vertical structure created by heating/cooling at the air-water interface	

[18] Kimmerer 2004
[19] Stacey and Wagner *unpublished*

Table 2 Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Physical Processes

Critical Process or Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Turbidity	Sediment dynamics are strongly governed by hydrodynamics, but complicated by the supply of sediment and the interaction of the particles with the bed through deposition and resuspension.	Sediment supply from the rivers depends strongly on river flow, but may be lower than historical values because of trapping behind dams. While in suspension, sediment is subjected to transport by the tidal currents in the same way as dissolved constituents. Particles move into or drop out of suspension depending on the bed stresses created by the tidal flows (in the channels) and wind waves (in the shallows). The size distribution and composition of the particles can also change due to flocculation in low-salinity water and the aggregation of particles due to 'sticky' biological films. The interaction of flows with the bed are strongly modulated by the presence of submerged vegetation (notably the Brazilian waterweed, see below). The reduction in turbulence due to vegetation allows particles to drop out of suspension, clarifying the water in areas of extensive vegetation.	Threshold for resuspension uncertain due to two factors: 1) Determining the hydrodynamic bed stress, and; 2) Determining threshold values of the bed stress for resuspension and deposition.	Prediction of bed stresses is difficult due to: 1) Importance of wind waves in shallows; 2) Bed forms; 3) Bed movement, and; 4) Effects of vegetation on bed stresses.	

Table 3 Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Biogeomorphic Processes

Critical Processes/Factors	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Attenuation of flow and waves by vegetation	The presence of emergent and submerged vegetation impedes flow and reduces wave energy, resulting in decreased turbidity, reduced bed stress, and sediment deposition. Tidal pumping in the Delta is influenced by extensive SAV[20].	Direct effects of vegetation on flow and waves have been studied in a few cases[21] and only recently in the Delta[22] . The drag created by submerged vegetation directs the primary flow paths over the top of the vegetation. Vertical exchange across the top of the canopy by turbulence produced in the resulting shear layer dominates the exchange between the open water and vegetated regions of the Delta. Field and laboratory studies show the importance of turbulence and drag around stems and through foliage are important[23]. Studies of wave attenuations how non-linearities associated with depth of inundation and length scale of vegetation[24].	Characterization of buoyancy and flexibility of the vegetation in response to inundation and flow. Small-scale vegetation-flow interactions and how they produce turbulence.	Application of analytical theory is limited by the lack of detailed knowledge of vegetation characteristics[25]	Control measures for Brazilian water weed limit its influence but must be repeated continually.

[20] SAV (submerged aquatic vegetation).
[21] For example, Leonard and Reed 2002; Howe et al. 2005; Chrstiansen et al. 2000; Tsihrintzis 2002.
[22] Sereno *unpublished*
[23] For summary see Tsihrintzis 2002.
[24] For example Koch et al. 2006; Mazda et al. 2006
[25] Analytical theory has been well developed by Nepf and co-workers among others (e.g., Nepf 2004) and has been field tested with relatively rigid vegetation (Lightbody and Nepf 2006). However, this has not yet been fully applied to flexible and buoyant SAV like Brazilian water weed.

Table 3 Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Biogeomorphic Processes

Critical Processes/Factors	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Marsh vertical accretion	The vertical accretion of tidal marshes in the Delta allows them to keep pace with sea-level rise.	Accretion is controlled by mineral sediment deposition and soil organic matter accumulation. Limited studies within the Delta of contemporary accretion dynamics show sediment supply is greatest close to the Sacramento River, and organic accumulation is relatively constant across the Delta[26]. The response of vegetation to salinity changes associated with sea-level rise is driven by complex interactions between soil salinity and inundation[27]. Studies in Suisun Marsh show low sediment input to high marshes and accretion dominated by organic accumulation[28].	Rates of net belowground production (production less decomposition) in tidal fresh and low-salinity brackish marshes in the Delta and its sensitivity to changes in inundation and salinity. The response of vegetation, especially in more brackish areas, to changes in timing of freshwater inflows[29].	Available models for vertical accretion[30] require local data on soil characteristics, which themselves are highly variable, so models have not yet been applied in the Delta. Most models of vegetation response to changes in salinity and inundation are empirical[31] and cannot be applied in the Delta.	Changes in salinity and nutrient inputs influence vegetative growth and organic accumulation. Influence of increased atmospheric CO_2 on plant productivity.

[26] Reed, 2002

[27] Few plant species tolerate salinities approaching 0.5 seawater strength, although even higher salinities and hypersaline conditions occur seasonally on the marsh plain due to salts in tidal waters and evapotranspiration concentrating salts in the root zone. Strong seasonal variation in salinity is important for controlling the distribution of some brackish marsh species, with low winter and early spring salinity promoting the canopy development stage and tolerance of higher salinities in late summer when annual expansive growth is complete.

[28] Culberson et a l. 2004

[29] Vegetative growth of most salt marsh species, with the exception of the hypersaline *Salicornia virginica*, generally begins with mild late winter temperatures in February and March and peaks in late spring when salinities begin to rise (Ustin et al. 1982; Pearcy and Ustin 1984).

[30] For example Rybzyck et al. 1998

[31] For example Reyes et al. 2000

Table 3 Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Biogeomorphic Processes

Critical Processes/Factors	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Subsidence reversal	High rates of subsidence on Delta islands used for agriculture are of concern due to the increasing potential for levee failure. Subsidence reversal by converting land use to permanent shallow flooding has been proposed to limit oxidation of existing peat and promote the accumulation of new organic material.	An experimental study has been underway at Twitchell Island since 1997. Unpublished results show average vertical elevation change of approximately 4cm/yr in managed tule/cattail stands. Field studies of tidal marshes show lower rates of accumulation. Preliminary findings from Twitchell Island experiment show variations in vertical change with hydrology.	'Optimal' hydrology not yet determined. Effect on wildlife of large-scale change from agriculture to tule/cattail stands.	Predictions of the effectiveness of subsidence reversal techniques will require mechanistic understanding of the processes.	Requires continued intervention.

Table 4 Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Food web Processes

Critical Process or Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Energy Inputs (unvegetated open water)	Inputs of energy (as organic matter or sunlight) provide the basis for all biological activity in an estuarine ecosystem. Declines in the production of organic matter in the Delta and Suisun Bay are likely responsible for declines in some aquatic organisms, including some covered species.	Principal source of organic matter available to Delta open-water food web is phytoplankton (microscopic algae) [32], but in brackish water the foodweb depends largely on bacteria, implying a subsidy of phytoplankton-derived organic matter from freshwater or marine water. Phytoplankton growth is limited by light, which greatly reduces the probability of eutrophication (excessive growth of phytoplankton)[33] Phytoplankton abundance and production in the Delta have declined substantially in recent decades.[34] The decline in brackish water is probably due to grazing by the overbite clam, but the cause of an earlier decline in freshwater has not been identified. Accumulation of phytoplankton depends on conditions for growth and losses to clam grazing and to transport in the water, so areas of sluggish circulation with few clams (e.g., southern Delta) have high phytoplankton biomass. Water exports remove about 18% of annual phytoplankton production in the Delta, but this loss was a relatively small component of the mass balance of phytoplankton.[35]. Studies in Suisun Bay show phytoplankton growth can be suppressed by high concentrations of ammonium at high light levels.[36] The blue-green alga *Microcystis* has formed blooms in recent years that may be causing problems in the food web.	Spatial distribution and abundance of clams. Resolution of the role of ammonium. Importance of *Microcystis* blooms in producing toxins and disrupting foraging by animals	Moderate	Human control over phytoplankton of the Delta is extremely limited. Ammonium inputs from sewage treatment plants could have some negative influence. Changes in hydrodynamics (especially residence time) could be important. These changes could be overwhelmed by the effect of clam grazing.

[32] Jassby et al. 1993; Sobczaket al. 2005; Sobczak et al. 2002.
[33] Cloern 1999; Lopez et al. 2006; Lucas et al. 1999a; Lucas et al. 1999b.
[34] Jassby et al. 2002.
[35] Ibid.
[36] Wilkerson et al. 2006.

Table 4 Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Food web Processes

Critical Process or Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Foodweb Dynamics (unvegetated open water)	Declines in estuarine fish may be linked to changes in the abundance of their prey (mostly zooplankton).	There is a fundamental difference in how planktonic and benthic (bottom-dwelling) animals respond to changes in salinity. Plankton do not experience rapid changes in salinity because they move with the water. Benthic organisms are more subject to variable salinity since they stay in place on the bottom. Zooplankton include small forms (rotifers and the larvae of copepods) and larger zooplankton, mainly cladocerans in the freshwater Delta and copepods in brackish water [37]. Mysid shrimp are less abundant than in the past – many fish species now feed more on introduced amphipods (some associated with waterweed beds) than on mysids [38]. Zooplankton feed mainly on phytoplankton in freshwater and on ciliates in brackish water; the ciliates are part of a microbial foodweb based on both phytoplankton and bacteria.[39] Species composition of zooplankton has changed especially since the invasion of the overbite clam. Plankton populations have responded to changes in abundance of major predators (e.g., decline in northern anchovy) and new invasions (e.g., *Limnoithona tetraspina* in 1993). Zooplankton, freshwater clams, and juvenile Delta smelt experience food limitation.	There is no monitoring program for ciliates, bacteria, and other microbes. Abundance of clams (especially the freshwater clam) is not adequately monitored because of their great spatial variability in abundance. Extent of consumption of zooplankton by freshwater clams is unknown. Salinity response of clams is unknown. Importance of hydrodynamic connections including losses to export pumping and local diversions, and changing hydrology and salinity distributions.	Low	There are few opportunities to manipulate or control food web dynamics. It might be possible to control clam distributions by manipulating salinity, but this must be thoroughly investigated before it is attempted in the Delta.

[37] Orsi and Mecum. 1986.
[38] Feyrer et al. 2003; Nobriga 2007
[39] Zooplankton in the freshwater Delta consume mainly phytoplankton (Müller-Solger et al. 2002). However, in brackish regions they feed mostly on single-celled ciliates (Bouley and Kimmerer 2006). Gifford et al. *in press*; Hollibaugh and Wong (1996); Sobczak et al. (2005); Sobczak et al. (2002) suggest a subsidy of phytoplankton-derived organic matter to the Low-Salinity Zone, possibly from the freshwater Delta, and a foodweb based on bacteria more than phytoplankton.

Table 4 Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Food web Processes

Critical Process or Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Foodweb Dynamics (vegetated water bodies)	The foodwebs associated with submerged vegetation (mainly Brazilian waterweed) support some species of fish, although these may be fishes that prey upon covered species.	Fishes of vegetated margins are supported by a different foodweb from fishes in the open water [40]. This little studied foodweb is based mainly on algae that live on the vegetation rather than the vegetation itself. Fishes primarily prey on amphipods (crustaceans).	Degree of interaction with open-water foodwebs. Energy balance and overall productivity	Moderate; presumably these foodwebs occur wherever there is submerged vegetation.	Removal of waterweeds would also remove the associated food webs but the impact on open-water food webs is unknown.
Species introductions	Introduced species believed to have had an important impact on the Delta ecosystem include many fish species, Brazilian waterweed and water hyacinth, and the freshwater and overbite clams. The only invasion event whose effect was observed through monitoring and analysis was that of the overbite clam.	Species introduction s can cause rapid changes in the ecosystem such as the decline in phytoplankton and some zooplankton resulting from the introduction of the overbite clam. These changes are not generally predictable because of the multiple foodweb relationships that change when a non-native species becomes established, and because only some non-native species have such profound effects on the ecosystem	Nature of future invasions.	Future introductions are likely to produce large, and largely unpredictable, changes to the estuarine ecosystem.	Changes resulting from invasions could counteract the benefits of restoration or other management actions meant to support covered species.

[40] Grimaldo 2004

Table 5 Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Chemical Processes and Contaminants

Critical Process/Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Pesticides in current use	Winter storm runoff and irrigation return water can contain fertilizer, current-use pesticides, and other chemicals. Organophosphate insecticides are gradually being replaced by pyrethroid insecticides. Large amounts of herbicides are being applied.	Insecticides, in particular organophosphates (e.g. chlorpyrifos, diazinon), have been present at acutely toxic concentrations in tributaries and the Delta[41] Pyrethroids at toxic concentrations have been found in sediment samples from water bodies draining agricultural areas in the Central Valley[42] Dissolved pyrethroid concentrations toxic to aquatic life have been found in water samples from Central Valley agricultural drains and creeks[43] Aquatic plants have been shown to absorb pyrethroids, and microbial assemblages living on the plants may enhance pyrethroid degradation[44].	Geographic and temporal distribution of contaminants within the Delta. Effects of structural changes (wetlands, floodplains) on contaminant dynamics. Contaminant effects on Delta species in the context of their habitats – direct and indirect, lethal and sub-lethal (e.g., on behavior, growth, reproduction). Effects of multiple stressors, e.g. contaminants, high temperature, food limitation, or disease[45]	Low due to lack of information on environmental concentrations and toxic effects, especially chronic effects.	Input could be controlled by changes in use and pesticide control methods. Half-lives are relatively short, so existing contaminants would degrade within months-years.

[41] Kuivila and Foe 1995; Werner et al. 2000; California Regional Water Quality Control Board Agricultural Waiver Program 2007
[42] Weston et al. 2004; California Regional Water Quality Control Board Agricultural Waiver Program 2007
[43] Bacey et al. 2005; Woudneh and Oros 2006 a, b
[44] Hand et al. 2001
[45] This uncertainty applies to all contaminant groups described in Table 5.

Table 5 Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Chemical Processes and Contaminants

Critical Process/Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Legacy pesticides	Residues of legacy pesticides, primarily organochlorine (OC) pesticides including DDTs, chlordanes, and dieldrin, remain high	In San Francisco Bay, pesticides and their breakdown products occur at concentrations high enough to contribute to advisories against the consumption of sport fish from the Bay[46] Legacy pesticides continue to enter the Bay from the Central Valley, from dredging and disposal, and other sources. DDT and other OC pesticides have been detected in agricultural irrigation ditches and drainage canals of the Delta region[47].	Geographic and temporal distribution of contaminants within the Delta. Effects of structural changes (wetlands, floodplains) on contaminant dynamics. Information on bioaccumulation of contaminants in wildlife and the extent and effects of maternal transfer to offspring. Understanding of the toxic effects of legacy pesticides, singly and in combination, on Delta species.	Low due to lack of information on environmental concentrations and toxic effects, especially chronic effects.	Legacy contaminants are persistent and difficult to remove. Other than mechanically removing contaminated sediments, human control is extremely limited. May contribute to advisories against consumption of fish due to high bioaccumulation potential.
Mercury	The Delta, and many of its tributaries, are on the State Water Quality Control Board's 303 (d) list of impaired water bodies because of mercury contamination.	Measured at potentially toxic concentrations, and associated with detrimental effects in some waterbirds in the Bay area[48] . Methylmercury is the most bioavailable and toxic form of mercury. Methylation occurs in wetlands, but rates of production vary widely, and some wetlands even appear to reduce methylmercury concentrations.[49]	Geographic and temporal distribution of mercury within the Delta. Effects of structural changes (wetlands, floodplains) on mercury dynamics. Information on bioaccumulation of mercury in wildlife and the extent and effects of maternal transfer to offspring. Understanding of the toxic effects of mercury, alone or in combination with other contaminants, on Delta species.	Possibly the best understood contaminant in the system[29]. Understanding of the effect of wetlands on biochemical fate of mercury is important for predictability.	Mercury sources are difficult to control. May contribute to advisories against consumption of fish due to high bioaccumulation potential.

[46] Connor et al. 2007
[47] California Regional Water Quality Control Board Agricultural Waiver Program 2007
[48] Conaway et al. 2007 and cited references therein
[49] Alpers et al. *in preparation*

Table 5 Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Chemical Processes and Contaminants

Critical Process/Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Selenium	Selenium is a reproductive toxicant. Selenium in agricultural drainages in the western San Joaquin Valley remains a threat because drainage problems are unresolved. Other sources are refineries (reduced after 1995) and wastewater treatment plants (minor source).	Loading through the San Luis Drain was reported to have caused massive bird deformities and local extirpation of most fish species at the Kesterson Refuge[50]. Loading of selenium to the San Joaquin River from approximately 100,000 acres of the western San Joaquin Valley was authorized in 1995.[51] Selenate, the form of selenium is most common in agricultural drainage, and can be converted to selenite in oxygen-poor environments, such as wetlands and organic-rich, stagnant waters. Selenite is bioaccumulated much more readily than selenate.[52].	Monitoring of the San Joaquin River near Vernalis is minimal and therefore effects of selenium in the Delta are extrapolated with some uncertainty. No monitoring of selenium downstream of Vernalis takes place in the Delta. Selenium inputs in drains, sloughs, and rivers are variable because of biological removal. [53] Information on bioaccumulation of contaminants in wildlife and the extent and effects of maternal transfer to offspring. Understanding of the toxic effects of Se, alone or in combination with other contaminants, on Delta species.	Low	Source control methods to reduce selenium concentration in irrigation return flows are under development.

[50] Presser and Luoma 2006
[51] Presser et al. 2007
[52] In the San Francisco Bay-Delta, Se concentrations in white sturgeon are just above the monitoring threshold of 5.9 µg/g. While these concentrations are below the current USEPA standard of 7.9 µg/g, there is substantial scientific evidence indicating that this standard is not protective enough and more stringent standards for the Bay-Delta are being considered.
[53] Presser and Piper 1998

Table 5 Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Chemical Processes and Contaminants

Critical Process/Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Other Heavy Metals	Dissolved copper concentrations are high in the low-salinity zone (copper is bound to organic molecules in higher-salinity waters, making it less available to biota) Nickel has been identified as an important water pollutant[54] Tri-butyl tin (used in antifoulant paints) is very stable and highly toxic to non-target invertebrate organisms.	Little is known about heavy metal concentration in the Delta.	Geographic and temporal distribution of contaminants within the Delta. Understanding of the effects of structural (habitat for covered species) changes (wetlands, floodplains) on contaminant dynamics. Understanding of the toxic effects of heavy metals, singly and in combination, on Delta species.	Low.	Input could be controlled in some cases (direct application, storm water runoff control).

[54] Yee et al. 2007

Table 5 Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Chemical Processes and Contaminants					
Critical Process/Factor	**Description and Importance**	**Current State of Knowledge**	**Key Uncertainties**	**Predictive Ability**	**Human Intervention/External Factors**
Polychlorinated biphenyls (PCBs)	PCBs are industrial legacy contaminants, very persistent, and bioaccumulation potential in aquatic organisms is high.	PCB concentrations in some San Francisco Bay sport fish today are more than ten times higher than the threshold of concern for human health[55]. PCB contamination is generally associated with industrial areas along shorelines and urban runoff in local watersheds. PCB concentrations in the estuary may be high enough to adversely affect wildlife.	Although reports[56] suggest that significant PCB loads enter San Francisco Bay through Delta outflow, no monitoring data are available for the Delta. Understanding of the toxic effects of PCBs, singly and in mixture, on Delta species. Information on bioaccumulation of contaminants in wildlife and the extent and effects of maternal transfer to offspring.	Low due to lack of information on environmental concentrations and toxic effects, especially chronic effects.	Legacy contaminants are persistent and difficult to remove. Other than mechanically removing contaminated sediments, human control is extremely limited. May contribute to advisories against eating fish due to high bioaccumulation potential.

[55] Davis et al. 2007 and cited references therein
[56] Davis et al. 2007

Table 5 Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Chemical Processes and Contaminants

Critical Process/Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Polycyclic aromatic hydrocarbons (PAHs)	Polycyclic aromatic hydrocarbons (PAHs) are generated by the incomplete combustion of organic matter and enter the aquatic environment through atmospheric deposition or stormwater runoff from roads, urban areas, and industrial areas. Another potential source is creosote, which has been used to impregnate wood products such as pier pilings.	Stormwater runoff from urban and industrialized areas and inflow from tributaries (including the Delta) are the major sources of PAHs in San Francisco Bay. Relatively low PAH concentrations were observed in the Sacramento/San Joaquin Rivers and the Delta during the 1993-2001 monitoring period[57].	Geographic and temporal distribution of contaminants within the Delta. Understanding of other toxic effects of these contaminants, singly and cumulative, on Delta species.	Low due to lack of information on environmental concentrations and toxic effects, especially chronic effects.	Could be controlled in part by reducing the input of stormwater runoff.

[57] Oros et al. 2007

Table 5 Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Chemical Processes and Contaminants

Critical Process/Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Emerging Pollutants	A growing number of organic compounds, including flame retardants, pesticides, plasticizers, water repellents, fragrances, pharmaceuticals, and personal care product ingredients can mimic the actions of natural hormones. Endocrine disrupting chemicals (EDCs) can interfere with the hormonal systems in humans and wildlife, and act at extremely low concentrations resulting in negative effects on reproduction and development. Exposure of fish populations to low concentrations of such compounds can have dramatic effects.	High concentrations of flame retardants (polybrominated diphenyl ethers, PBDE) have been found in freshwater clam tissue from the Sacramento and San Joaquin River[58] . Tissue concentrations of PBDE in striped bass and halibut significantly increased in 1997 and 2003. PBDE was also found in least tern (*Sternula antillarum*) and California clapper rail (*Rallus longirostris obsoletus*) eggs.	Distribution and effects of endocrine disruptors on reproduction of Delta species.	Low due to lack of information on environmental concentrations and toxic effects, especially chronic effects.	Better wastewater treatment methodology (enhanced treatment) will potentially lead to breakdown or elimination of these compounds from WWTP effluents, but some chemicals may become more toxic due to chlorination.

[58] Hoenicke et al. 2007

Table 5 Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Chemical Processes and Contaminants

Critical Process/Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Nutrients	Un-ionized ammonia (NH_3) can be toxic to fish[59]. Ammonia contributes to the depletion of oxygen in the Stockton Deep Water Ship Channel[60] and creates a barrier to fish passage.	NH_3 has reached concentrations that could be toxic to sensitive fish species such as salmon[61].	Information on sensitivity of Delta fish species to ammonia.	Moderate. Ammonia concentrations have been monitored for decades at some sites in the Delta.	Better wastewater treatment methodology (enhanced treatment) will reduce ammonia load released into Delta

[59] Note that this is a different chemical form from ammonium (the ionized form), discussed under foodweb assessment, above. The two forms are in equilibrium and the relative proportion of ammonia increases as pH and temperature increase.
[60] Jassby and Van Nieuwenhuyse 2005
[61] Vosylien et al. 2003

5.0 ANALYTICAL METHODS

Predicting the effects of Covered Activities and conservation strategies on Covered Species and communities is one of the most important tasks for most HCP/NCCPs. At a minimum, the BDCP should analyze individual and cumulative effects of the Covered Activities on populations of Covered Species. This requires assessing effects of the Covered Activities on the various physical, chemical, and biotic processes and gradients influencing population dynamics (Section 4.3). The Plan should also explicitly disclose and address uncertainties about these predictions and should address how foreseeable changes in the system (e.g., sea-level rise and other consequences of climate change, changing salinities) are likely to affect species and ecosystem processes over at least the 50-year permit duration. The scale of the area influencing the Delta (Principle C), the inherent variability in ecosystem processes (Principle D), and the need to address both conservation measures and other foreseen changes in the system (Principle B) means that analyses in support of BDCP planning and implementation must embrace a wide range of processes and uncertainties (Tables 1-5).

Detailed consideration of uncertainties requires more information on Covered Activities and conservation strategies than is currently available. In addition, detailed consideration of analytical tools was beyond the scope this group of advisors was convened to address. In this section, the Advisors offer some initial recommendations concerning appropriate approaches to analyze Delta hydrodynamics and population dynamics of Covered Species. The intent here is not to provide a comprehensive evaluation of all available tools and models. The Advisors recognize the urgent need for in-depth consideration of analytical tools and assessment techniques, beyond that provided here, to support BDCP planning and implementation (Recommendation R15).

R15. When potential Covered Activities and conservation strategies have been developed, convene a group of science advisors with experience in systems analysis, ecosystem restoration, modeling, population and food web dynamics, and other relevant disciplines to identify appropriate analytical tools and assessment techniques to support conservation planning and implementation in the Delta.

5.1 Hydrodynamic Analyses

The Sacramento-San Joaquin Delta is an unusual hydrodynamic environment due to strong tidally driven flows in a channel network. The interaction of tidal flows with this geometry creates a highly dispersive environment, in which the phasing of flows in intersecting channels strongly determines dispersion throughout the system. While the net flows affect transport over large spatial and temporal scales, the dispersion of salt, temperature, phytoplankton, and other constituents is much more strongly influenced by tidal-timescale flows. As a result, any hydrodynamic model that is used to predict transport and dispersion in the Delta must accurately predict the tidal flows, including the phasing of flows in intersecting channels (Recommendation R16). Transport models may be based on fundamental physics, or may use empirically determined dispersion coefficients. Because these coefficients are not based on fundamental processes, they will have limited utility in forecasting future conditions, especially changes involving large-scale alterations in the configuration of the Delta (Recommendation R17).

R16. Use a hydrodynamic model that is based on fundamental physics and that accurately reproduces tidal flows in the system for analysis of Delta transport and dispersion, and particularly for prediction of the effects of proposed management scenarios on hydrodynamics.

R17. Use data that span as broad a range of hydrologic and operational conditions as possible to evaluate a model's performance and increase the probability that the model will have sufficient accuracy and precision for evaluating management scenarios.

The appropriate dimensionality of a model will depend on the target of the analysis. For many dissolved substances, a depth-averaged (two-dimensional) tidal model that can accurately reproduce the tidal flows, including the phasing in junctions, is likely to be sufficiently accurate (Recommendation R18). This is because much of the Delta is relatively shallow and unstratified, resulting in limited vertical variability in the concentrations of dissolved substances. To examine the distribution of dissolved substances, it is not critical to resolve the vertical structure of the flows. Instead, computational effort would be better focused on quantifying temporal variability on the tidal time scale and the horizontal variability of flows in intersecting channels and junctions.

Resolving vertical structure of flows is more relevant for constituents that produce density stratification (salinity and temperature), settle through the water column (sediment), or have their own behavior (fish). In each of these cases, a higher dimensional model may be required. For example, one would expect the initial dispersion of salt into the Delta from Suisun Bay resulting from a levee failure to be dominated by tidal dispersion processes (the phasing and interaction of tidal flows). This aspect of the salt intrusion would be well represented by a depth-averaged tidal model. Once the salt field enters the Delta, however, the density gradients that are created lead to further intrusion. The resulting gravitational circulation brings saline waters upstream in the deep portions of the Delta (e.g., San Joaquin and Sacramento channels) and moves relatively fresh water downstream at the surface. This exchange flow will not be well represented in a depth-averaged model (Recommendation R18). One alternative is simply to pursue a three-dimensional model, which would require significant computational effort. Another alternative is to parameterize the effects of exchange flow through a supplemental along-channel dispersion coefficient (Chatwin 1976) that includes a threshold based on the local salinity gradient (Stacey et al. 2001).

R18. Use models with appropriate dimensionality for the target of the analysis:

- ***a. Use a two-dimensional, depth-averaged analysis to predict transport of passive dissolved substances.***
- ***b. Use a three-dimensional hydrodynamic model to account for both tidal dispersion processes and gravitational circulation associated with salinity intrusion into the Delta, or parameterize gravitational circulation based on local density forcing.***

The integration of particle (or organism) behavior into transport analysis requires refinement of hydrodynamic models of the Delta. As with the other transport analyses, the tidally driven flows, including the phasing of flows in intersecting channels and the resulting flow structures that arise in channel junctions, must be accurately predicted. At the same time, many species have limited ability to swim relative to tidal currents, but they are capable of vertical and lateral migrations that allow them to selectively sample tidal streamlines (see Section 4.3). As a result, a hydrodynamic model must accurately resolve the vertical and lateral structure of both the mean flows and the turbulent motions (Recommendation R19). Developing such a model will require additional data collection and hydrodynamic analysis to establish the lateral and vertical structure of flows in channel junctions. Lagrangian particle trajectories should also be studied in the field (Recommendation R19) and used to evaluate the model's ability to project particle paths, particularly flow paths through junctions.

R19 . To allow integration of particle or organism behavior into Delta transport models

a. Develop a highly resolved three-dimensional hydrodynamic model to produce accurate projections of vertical and lateral variability in channels and junctions.

b. Conduct drifter-tracking studies, especially around channel junctions, to evaluate model ability to predict particle trajectories.

Water temperature affects all vital rates of aquatic organisms, and in some cases (Delta smelt, salmon) adverse effects of high temperature have been demonstrated (Bennett, 2005; Brandies and McLean, 2001). Nevertheless, there is no model of temperature in the Delta that could be used to analyze the effects on biota. Whereas salinity in the Delta is a result of intrusion from the Bay, temperature variation in the Delta is largely forced at a local level by atmospheric heating and cooling (Kimmerer 2004). The influence local atmospheric forcing, however, varies across the Delta because of river inflows and mixing with the lower estuary. The mixing of these adjacent waters alters the correlation between atmospheric conditions and Delta water temperatures. Depending on the spatial and temporal scales of interest, a correlative analysis of atmospheric conditions and water temperatures may be sufficient for predictions of water temperature. However, refining the spatial and temporal details of water temperatures within the Delta requires inclusion of tidal dispersion processes in the analysis (Recommendation R20). At a smaller scale, temperature gradients will develop between Delta channels and shallow environments and between open and vegetated regions. Current understanding of these finer scale variations is limited by uncertainties in how shallow vegetated environments affect temperature and the exchange between shallow vegetated locations and adjacent regions. If the analysis requires data on fine-scale temperature variation between adjacent environments, observational and modeling studies of the effects of shallow, vegetated environments on the local temperature dynamics, including the effects of shading along perimeter waters, will be needed (Recommendations R9 and R20).

R20. Apply an array of tools to improve prediction of water temperature at various spatial and temporal scales:

a. Develop a correlative analysis of atmospheric conditions and water temperatures to assess large-scale variations in temperature.

b. Analyze river inputs and tidal dispersion to predict temperature at finer spatial and temporal resolution.

c. If prediction of fine-scale temperature variation between adjacent environments is desired, pursue observational and modeling studies into the effects of shallow, vegetated environments on local temperature dynamics, including the effects of shading along perimeter water.

Suspended sediments have a variety of important effects on biota, and concentrations of sediments are changing (Table 2). Sediment movement must be modeled at the tidal time scale because particles are deposited and resuspended at short time scales. Tidal dispersion redistributes sediments that enter the estuary from the watershed. To predict future concentrations of suspended sediments, future sediment supply must first be evaluated through an analysis of land use in the watersheds, hydrologic forcing, and reservoir operations. Additionally, short time-scale bed stresses (due to tidal flows and wind waves) and the effects of these bed stresses on sediment resuspension define the key uncertainties in predictive modeling of dynamics of suspended sediment (Recommendation R21). Studies of sediment particle characteristics in the Delta and associated resuspension characteristics are needed to reduce these uncertainties. Once such studies are complete, an integrated hydrodynamic-sediment transport model of the Delta can be developed to predict sediment concentrations and their variability.

R21. Evaluate future sediment supply to the Delta from the watershed, and document sediment resuspension characteristics in the Delta, to support the development of an integrated hydrodynamic-sediment transport model to predict sediment concentrations and their variability

5.2 Approaches to Assessing Population-Level Responses

It is challenging to describe the dynamics of species throughout their life cycles with sufficient accuracy and precision to allow for predictions of the effects of alternative managements actions on population dynamics. We recommend that analyses be performed on a population level for pragmatic reasons (e.g., data availability, tractability) but viewed in an ecosystem context (i.e., analyze populations but think ecosystem). The analysis of effects of environmental changes in the Delta on Covered Species depends on the development and application of a variety of predictive models. These models depend on accurate and somewhat mechanistic descriptions of environmental influences (Figure 2). Hydrodynamics strongly affects biological interactions and the distribution of salinity, temperature, turbidity, and vegetative cover that influence Covered

Species both directly and indirectly (Section 5.1). For example, turbidity (Table 2) has a direct influence on at least some of the Covered Species. Delta smelt will not feed in clear water (J. Lindberg, UC Davis, pers. comm.), and the abundances of Delta smelt, threadfin shad, and young striped bass in autumn increase as turbidity increases (Feyrer et al. 2007). Presumably these species can forage more efficiently where turbid water provides some protection from predators. Turbidity also has a direct negative influence on phytoplankton production, so these energy inputs to the food web (Table 4) may increase as the water becomes clearer.

During their juvenile life stages in the Delta, the Covered Species feed mainly on zooplankton, epibenthic crustaceans (e.g., mysids and amphipods), and insects. Analyses of Covered Species currently treat their food sources as a static input. However, the abundance of zooplankton and epibenthic crustaceans is highly dynamic. Models and analyses of Covered Species could be improved, and the range of applicability of the models and analyses increased, by including some dynamic aspects of their food supplies (Recommendation R22).

R22. Develop spatially-explicit models of plankton dynamics, and institute monitoring to provide necessary input to these models, to improve prediction of Covered Species responses to changing environmental and food web conditions.

The Advisors suggest that the evaluation of the potential effects of Covered Activities on populations use a step-wise approach involving both qualitative and quantitative models. While the analyses should be at the population level, the analyses must be set in an ecosystem context. The qualitative models (conceptual models, such as those being developed by POD and DRERIP) provide a common framework for discussion, for evaluating expert opinion, and for general planning and research on Delta processes. Quantitative models, including both statistical (e.g., regression) and process (population dynamics) models, are valuable for exploring the possible effects of current and future management actions.

The Advisors suggest using a stepwise approach based on the life cycles of the Covered Species (Recommendation R11). Evaluations might begin with analyses of how potential changes in environmental conditions caused by management actions (e.g., flow, salinity, temperature, turbidity, vegetation) would affect each of the vital rates of the life stage(s) known or thought to be *directly* affected by those actions. The next step would examine if and how the environmental changes could directly affect the vital rates of *other life stages*. In addition, analyses should examine how direct effects of Covered Activities on one life stage may indirectly affect other life stages. By examining effects of management actions on the vital rates of each life stage of the species of interest, and then iterating through all of the life stages, one obtains information not only on responses of key life stages but also on responses at the population level. Availability of data varies among the Covered Species; for some species, such as winter run Chinook salmon and Delta smelt, data are likely sufficient to estimate population level responses. For the less well studied species, analyses may be limited to the response of the directly affected life stage.

Together, qualitative and quantitative models provide a framework for clearly stating assumptions of analyses and allowing others to easily understand and evaluate the analyses (Principle N). Qualitative (e.g., conceptual) models describe important process-response relationships but do not quantify them. Quantitative models are more valuable for understanding specific interactions between the Covered Species and their environment. Quantitative population models include both statistical and process models. Statistical and process models are distinguished based on how they represent the relationship between populations and environmental variables. Statistical models can quantify correlations between environmental variables and the abundance, vital rates, and spatial distributions of populations at different life stages. Statistical models often have weak predictive power, especially for forecasting the responses of populations to environmental conditions that the species have not experienced during the period of data collection.

Process models relate the rate of change in abundance (rather than abundance itself) to environmental and other explanatory variables via mathematical equations (often differential or difference equations). Process models attempt to represent how growth, mortality, reproduction, and movement (i.e., vital rates) are affected by environmental conditions. Process models can also integrate these vital rates across life stages to predict population-level responses, such as annual biomass, biomass production, long-term abundance, resilience (ability of a population to return to baseline after a perturbation), or persistence. Moreover, because they represent how changes in the environment may affect vital rates, process models can also be used to explore how alternative future states of the Delta might affect the population dynamics of the Covered Species. With such models, it is possible to explore the impacts of climate change scenarios, other major environmental changes, and the increasing demands on the Delta ecosystem and its resources. Process models also provide a platform for evaluation of the responses of populations to simultaneous changes in multiple environmental factors. The combined effects of these factors at the population level are often not obvious from the effects of individual factors on different life stages.

Process models are more difficult to validate than statistical models because process models do not have an evaluation criterion like a significance test. In addition, process models must be used cautiously because they include a large number of parameters, not all of the relevant mechanisms may be represented. Development of a comprehensive conservation and management plan will require the complementary use of statistical models and multiple types of process models.

An important step in linking the factors described in Tables 1-5 to population dynamics of the Covered Species is to correlate the spatial and temporal distributions of the environmental drivers with the life history stages of the species (Recommendation R23). For example, because salmon use the Delta as a migratory corridor, it is important to understand how the Delta affects juvenile migration (Figure 3). Vital rates of resident species such as Delta smelt are affected by movement of the species between the juvenile and adult habitats. Accordingly, statistical models can relate the movement of resident and anadromous fish to the environmental factors that cue migrations and flows at the tidal time scale that affect the migrations.

Statistical modeling should also be used to identify correlations between abundance and vital rates at different life stages and environmental variables (Tables 1-5). Although such correlations do not indicate causation, identifying relationships is valuable for developing the process models and prioritizing further analyses and data collection (Recommendation R24). For example, a relationship between Delta water exports and the survival of juvenile salmon passing through the Delta relative to those passing through the lower Sacramento River implicates water exports as a factor in the survival of a key life stage in the salmon life cycle (Brandes and White 2005). Quantifying how vital rates at each life stage are directly affected by Covered Activities, and applying statistical and process modeling to accumulate these effects over the life cycle, is critical to quantifying how the activities will affect the population dynamics of Covered Species.

An extensive database of monitoring information for the Delta is available, and Plan development should take advantage of the reviews and analyses that were performed for the biological opinions (BO), OCAP, the Environmental Water Account (EWA), and the POD. The OCAP review (Technical Review Panel 2005) dealt with the life cycle approach for salmon. The EWA analyses and panel suggestions are relevant given that EWA also was faced with quantifying how changes in water availability (albeit at a smaller scale than may be anticipated under BDCP) might affect the population dynamics of Delta smelt and other species. The POD effort concentrates on understanding the general decline of four species, which including two of the Covered Species. Note, however, that results of analyses conducted for other programs, while helpful, may not be sufficient for evaluating management and conservation actions proposed for the BDCP. Additional analyses tailored to the specific issues related to the BDCP will likely be needed.

R23. Develop statistical models that relate a) spatial and temporal distributions of environmental factors to life stages of the Covered Species, b) fish movement to environmental factors that cue migration, c) net and tidal flows to migration, and d) abundances of the Covered Species at different life stages to relevant environmental variables.

The Advisors emphasize that there are no shortcuts to understanding and realistically evaluating the effects of management and conservation actions on Delta species. Well-informed conceptual models are the foundation. Conceptual models are strengthened with statistical analyses that identify relationships among the species and biotic and abiotic properties of the species' critical habitats inside the Delta and, when relevant, outside the Delta (Figure 3). Finally, the accumulated conceptual and statistical information provides the basis for developing scientifically-sound process-based models of population dynamics (Recommendation R24). Some of the past efforts at process modeling for species in the Delta have tried to simply link correlative relationships across life stages. This rarely results in a process model with any predictive power, and is not recommended. Process-based population models with a long history of development and use, and based on well-known mathematics (e.g., matrix, projection, individual-based), are available for developing scientifically sound models of population dynamics (Caswell, 2000; Grimm and Railsback, 2005). The process models use the information from the statistical analyses, but are not simply a set of linked statistical relationships.

R24. When sufficient information is available and the questions to be addressed are tractable to model, develop and apply process models for Covered Species that are built upon the conceptual and statistical models. These process models can be used for predicting short-term, life stage-specific responses and, in some cases, for predicting long-term responses of population dynamics.

5.3 Cautionary Notes

Models for higher trophic levels are difficult to parameterize and validate because they require a diverse set of information both for their development and to evaluate the effects of many possible predictor variables over different temporal and spatial scales. Species at higher trophic levels also tend to have relatively complex life cycles and live for multiple years. As a result, models for higher trophic levels that truly address population responses must generate long-term predictions that span multiple generations in order to estimate the full effects of responses to environmental change and management actions. The Advisors suggest, as an initial step, the development of a series of process-based models that focus on separate life stages. This approach differs from statistical modeling, as it requires more extensive decisions about temporal, biological, and spatial scale. Before a model can be developed, for example, analysts must specify the time step and the duration of the simulations, the level of biological detail needed (e.g., total abundance, age-classes, individuals), how each of the vital rates will be represented (e.g., assign growth rates or simulate foraging), and the spatial resolution (size of cells). The extent and resolution of a model should reflect the questions it is being used to address.

It is important to consider the potential influence of density dependence on each of the key vital-rate processes. Density dependence usually is assumed to be compensatory (a negative feedback) because as abundance increases, resources become limiting, resulting in changes in the key processes that act to reduce net population growth rate and reduce population size (Rose et al. 2001). However, depensatory density dependence (or Allee effects) is a positive feedback on abundance and thus destabilizes population size. Depensatory density dependence operates when abundance becomes so low that mortality increases or reproduction decreases, thereby decreasing abundance even further (Liermann and Hilborn 2001). It is not clear whether the Covered Species exhibit depensatory density dependence, but because depensatory density dependence increases the probability of extinction of small populations, the possibility should be considered.

Models of higher trophic levels should be developed with great care and scrutiny to increase the probability that acceptable accuracy is obtained in their forecasts. Confidence intervals around model predictions must be quantified. Models will need to represent the environment of the Covered Species at the temporal and spatial scales that affect the vital rates of those species.

As a final cautionary note, the Advisors emphasize that no model, however carefully developed, will describe a sufficiently complete set of mechanisms to allow accurate and reliable prediction of future system states. This situation arises because of lack of knowledge of some key processes or variables, and because a large number of complex processes must be represented simply. Models are, by definition, simplifications of the real system. For example, models of Delta smelt must represent both their prey and their predators with relatively simple relationships based on available data. However, the population dynamics of prey and predators are neither simple nor well understood. Thus, while some aspects of the smelt population could be quite accurately represented in a model, (weight at age), the factors affecting those dynamics (e.g., salinity) might themselves vary in ways not represented in the model. Therefore, the process of developing a model should be seen as iterative, with scientific investigations applied to resolve uncertainties as the model is refined.

5.4 Exploring Future System States

The Advisors caution that models used to predict system responses must explain a considerable amount of the variation in the data used to construct the model. Further, the data used for calibrating the model must represent a broad range of antecedent conditions, including hydrologic and operational variability, in order to increase the ability of the model to assess future conditions. If predictions encompass new locations or time periods in which values of independent or response variables exceed the values used to build the model, the model forecasts need to be evaluated with great care

While a number of uncertainties currently limit our ability to predict all of the changes in critical processes and factors in the Delta ecosystem (Principle P), sufficient data and adequate tools exist to explore some of the anticipated changes. For example, the consequences of climate change in the Delta include sea level rise and a shift toward earlier peak runoff of precipitation. The Advisors recognize that existing process-based hydrodynamic models are of limited application if the structure of the Delta is altered (e.g., by levee failures or major siphons) or manipulated (e.g., by additional gates and barriers), but these models should be used to provide insight into the potential effects of climate change under the current Delta geometry (Recommendation R25).

R25. Use hydrodynamic models of the Delta built on fundamental processes to analyze the potential consequences of different future climate change scenarios (e.g., sea-level rise, timing and amount of runoff) on net and tidal flow patterns.

A subset of future conditions potentially can be examined with existing models. In some cases, however, the use of existing models in a predictive context may be misleading. For example, the ecological theory that spatial and temporal variability is important for maintaining the species richness of ecosystems has been extended to suggest that native species would benefit from increased variability in the Delta (Lund et al. 2007). Our ability to examine whether this concept indeed applies to the Delta is limited because, among other reasons, most data on the system have been collected during a period of reduced variability compared to historical conditions (Recommendation R26). Importantly, there is no one perfect model for use in conservation planning. Instead, planning can sometimes be better informed by results from several different models that address the same issue. However, in all cases data analyses and models should be fully documented and accessible (Principle N).

R26. Develop and apply statistical and process models to examine the potential effects of increasing variability in salinity and water temperatures on ecosystem processes and Covered Species in the Delta.

6.0 ADAPTIVE MANAGEMENT AND MONITORING

The BDCP must be developed despite great uncertainty about the outcomes of the selected management actions. These uncertainties arise because of lack of knowledge about the current state of the ecosystem, inherent variability, and the likelihood that the future state of the system will differ from the current state as a result of deliberate and unplanned events. Several approaches can be taken in the face of such uncertainty to increase the probability that conservation objectives will be achieved. First, analyses can be conducted to attempt to minimize the uncertainty about a particular course of action,. Exclusive of other measures, such an approach is unlikely to succeed because of the magnitude of the uncertainties discussed above. Second, an initial course of action can be taken with plans to revisit the action in the future and alter it if necessary. This approach is preferable to the first, but it fails to maximize application of the information that can be gained from the response of the system to the actions taken; this approach is essentially static, and passive. An improvement on these approaches is to investigate and learn systematically from the course of action taken using adaptive management, a formal process designed to reduce uncertainties and identify significant negative consequences as they arise (Holling 1978, Walters 1986). An adaptive management approach was formally incorporated into the Strategic Plan for the CALFED Ecosystem Restoration Program (CALFED, 2000) but adaptive management was never fully implemented. The Advisors recommend that conservation planning for the BDCP be founded on adaptive management as described here (Recommendation R27).

R27. Design a conservation plan based on adaptive management.

Adaptive management is a systematic process for continually improving management policies and practices by learning formally from their outcomes. First, conceptual models are developed to describe current understanding of the system and how a given action is expected to affect the system. These conceptual models are then developed into quantitative models that may be used, with some degree of uncertainty, to predict system responses. Management actions are designed to include collection of data needed to detect responses to the actions and to other variables that influence the system. Perhaps most crucially, a feedback loop is established by which monitoring data, model outputs, and other information are periodically assessed, the success of the action is evaluated, and, if appropriate, alternative actions are implemented.

Adaptive management is most powerful when an action can be implemented as a formal experiment with replicates and controls. However, active adaptive management is rarely possible for a large system under severe constraints. Passive adaptive management, in which the response of the system to a manipulative action is observed, is much less powerful because it is difficult to separate the effects of the action from other simultaneous environmental changes. Nevertheless, even passive adaptive management is a great improvement over less rigorous processes that fail to examine the effects of management actions.

Adaptive management has been criticized because of institutional impediments to implementation. One of the most challenging aspects of adaptive management is ensuring that information from monitoring of projects and system response is used to refine system models. Data must flow to managers and others overseeing implementation. The information needs of managers, in turn, must be used to guide collection of data. The process of adaptive management requires institutional mechanisms that provide for revisiting objectives and models over time as more is learned about the species and processes being targeted for conservation (Recommendation R28).

> ***R28. Identify and implement as soon as possible an administrative mechanism for the Plan to be modified in response to rapidly evolving information, data, and analyses.***

The Advisors think that adaptive management is well suited to the BDCP, but implementing adaptive management will require a sincere, ongoing commitment to the principle and the process, and a decision-making process specifically designed to accommodate adaptive management. A formal adaptive management program cannot be designed until conservation measures are more fully defined. However, the Advisors recognize the potential value of implementing the BDCP as an adaptive management program, and reiterate their advice that adaptive management be incorporated as early as possible in planning (Principle L). Accordingly, the Advisors recommend that the Steering Committee seek further input on the development of an adaptive management approach for BDCP planning and implementation (Recommendation R29).

> ***R29. Convene a group of science advisors to work with consultants, PREs, and implementing agencies to develop an adaptive management and monitoring strategy to support implementation of the BDCP.***

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APPENDIX A:

Workplan for Facilitating Independent Scientific Input

Science Advisory Process
Bay Delta Conservation Plan

1. Introduction and Purpose

The State of California's Natural Community Conservation Plan (NCCP) Act mandates a process for the inclusion of independent scientific input to ensure that each NCCP is informed with best available science. Regional Habitat Conservation Plans (HCP) developed under the federal Endangered Species Act are often guided by similar input. To meet this mandate for the Bay Delta Conservation Plan (BDCP), a group of independent scientists will be convened to identify and evaluate scientific information and provide objective insight and expert opinion pertaining to species, ecological communities, and habitats addressed by the plan. The role of the Science Advisory Group is to establish science-based conservation and natural resource management principles and standards that will be used to guide BDCP preparation.

This document outlines procedures for engaging independent scientific input for the BDCP, consistent with the requirements of the NCCP Act and guidance developed by the California Department of Fish and Game (August, 2002). Topics addressed include:

1. Communication protocols and ground rules for engaging independent scientific input;
2. A workplan for obtaining meaningful scientific input in a timely fashion;
3. Processes for selecting advisors, framing relevant conservation science questions, and developing work products; and
4. Guidelines for avoiding conflicts of interest.

Bruce DiGennaro (The Essex Partnership) and Dr. Wayne Spencer (Conservation Biology Institute) will collectively serve as the Facilitation Team for the BDCP independent science advisory process. This document is based on the Scope of Work adopted by the BDCP Steering Committee on May 4, 2007, the experience of other NCCP science advisory processes, and the NCCPA and guidance noted above.

2. Ground Rules for Engagement and Communication Protocols

The Facilitation Team will act as a neutral intermediary between the Steering Committee and the Science Advisors. In this capacity, the Facilitation Team will work with both the Steering Committee and the Science Advisors (coordinating closely with the Lead Scientist) to facilitate communications and maintain the integrity and independence of the process.

Communication between the Steering Committee and Science Advisers shall be channeled through the Facilitator. Questions from stakeholder groups or the public will be channeled through the Steering Committee to the Facilitator, who will forward appropriate questions to Science Advisors. The Facilitation Team will recommend which questions or other input are appropriate for the advisors to address. If there is not consensus among Steering Committee members based on the recommendations of the Facilitation Team, the Facilitation Team will make a decision in consultation with the Lead Scientist based on the input received and their collective experience.

The Lead Scientist, other Science Advisors, and the Steering Committee may communicate directly in meetings during the information gathering, field trip, and workshop phases of the science advisory process, and in briefings following submittal of the Science Advisor products to the Steering Committee. Steering Committee members will not contact the Lead Scientist or other Science advisors individually concerning BDCP matters. Similarly, Science Advisors (including the Lead Scientist) will not communicate with the Steering Committee or its representatives during their deliberative process except through the Facilitator.

Science Advisors (including the Lead Scientist) will be free to directly contact other members of the scientific community during the information gathering phase of the process for the purposes of obtaining existing data or other materials needed to inform their deliberations. To encourage informative deliberations, and for allow for transparency and recording of information sources, Science Advisors shall track their contacts with other scientists regarding BDCP matters, explicitly report the use of any such unpublished information in the science advisory reports. and provide the Facilitation Team with a summary of their interactions.

The Facilitation Team will ensure that all Science Advisors understand their roles pursuant to the NCCP Act. Science advisor recommendations are advisory only and not binding on the Steering Committee, member agencies, or consultants involved in NCCP/HCP preparation. Recommendations from the Science Advisors will be made available to the public after distribution to the Steering Committee.

Communications regarding the Science Advisors should be directed to the Steering Committee Chair or her designee or to Bruce DiGennaro (bruce@essexpartnership.com, 401-709-2449) as the designated points of contact for the Steering Committee and Facilitation Team respectively.

3. Workplan

The Facilitation Team proposes a workplan for engaging science advisors in the BDCP process that is tailored to meet the specific needs of the BDCP while providing focused and timely advice consistent with the requirements of the NCCP Act. The proposed workplan is described in Attachment 1 and shown graphically in Figure 1. The workplan includes topically focused interactions with the Steering Committee to facilitate input, as well as discrete deliverables designed to advance the planning process.

4. Process for Selecting Advisors

The Facilitation Team will be responsible for engaging Science Advisors, after appropriate input from the BDCP Steering Committee and Lead Scientist. Key steps in identifying and selecting Science Advisor shall include:

1. Development and review of Areas of Expertise
2. Nomination of potential Science Advisors
3. Selection and contact of Science Advisors

The BDCP Steering Committee, with input from the Facilitation Team and Lead Scientist, will create a "long-list" of science advisor candidates that possess appropriate expertise and qualities and that fit into the identified Areas of Expertise. The Facilitation Team will work with Steering Committee and the Lead Scientist to identify any potential conflicts of interest and to develop a "short list" of candidates based on expertise, experience, proven ability to work well with groups, and ability to contribute useful information on schedule. Using the short list, the Facilitation Team and the Lead Scientist will make initial contact with candidates to determine their interest and availability to serve. Once the Facilitation Team has assessed advisor interest, they will formally invite the science advisors into the process on behalf of the Steering Committee.

To the degree feasible, the Science Advisors will be balanced in terms of the following factors, keeping in mind that adequate coverage of key areas of expertise is the primary criterion:

- local, regional, and national perspectives
- species-specific expertise vs. more holistic ecosystem and conservation planning viewpoints
- previous independent science advisory experience

Final recommendations regarding the selection of advisors shall be made by the Facilitation Team. If there is not consensus among Steering Committee members, the Facilitation Team will make a final decision to ensure that there is no actual or perceived influence by the Steering Committee, consultants, Lead Scientist or other parties concerning the final composition of the group. The Facilitation Team can replace or supplement the initial group of advisors if need arises during the process. The Facilitation Team will establish appropriate agreements and arrangements for honoraria with individual advisors. The timeframe for selecting advisors is outlined in Attachment 1 (Proposed Workplan).

5. Process for Identifying Issues and Developing Questions

To help focus the Science Advisor's input, and to ensure the full range of pertinent scientific issues are addressed, an initial list of science questions will be developed by the Facilitation Team, in consultation with the Lead Scientist and the Steering Committee. The initial list of science questions will be provided to the Steering Committee for review and comment. Advisors may identify additional questions to address during their deliberations.

The Facilitation Team, in consultation with the Lead Scientist, will be responsible for channeling pertinent questions from the Steering Committee to the Science Advisors and communicating answers back to the Steering Committee, or ensuring that they are incorporated into the Science Advisors' work products. Questions to the Science Advisors will be addressed only if they are directly relevant to NCCP/HCP conservation goals and objectives. The Science Advisors will not make value judgments about policies, procedures, laws, economic costs, or societal values. However, it is appropriate for them to objectively address scientific implications of how policy decisions might affect biological resources, such as covered species populations or habitats, as well as how scientific information will be used.

6. Development of Work Products

The Facilitation Team will be responsible for coordinating development of Science Advisor work products. The Facilitation Team will work with the Science Advisors, including the Lead Scientist, to identify writing assignments and track completion of those assignments. The Facilitation Team will work with the Lead Scientist to compile and edit material from the Advisors to ensure that their products are understandable to a broad audience and meet the requirements of the NCCP Act. The Facilitation Team will also ensure that the products reflect the consensus of advisors wherever possible, or to clarify any areas of disagreement or scientific uncertainty that remain.

A draft Guidance Report will be prepared following the science advisor workshops. The draft will be distributed to the Steering Committee for review and comment prior to being finalized for public release. The purpose of this review is to identify any factual errors or portions of the report that may require additional clarification, and not to influence the substance of the report. In no case shall the Facilitation Team allow for the Steering Committee or any other parties to influence the nature of the scientific recommendations in the report, which must substantially reflect the consensus recommendations of the Independent Science Advisors. The Facilitation Team, in consultation with the Lead Scientist, will review comments provided by the Steering Committee and work with Science Advisors to make appropriate adjustments and produce a final Guidance Report.

7. Conflict of Interest

Individuals currently under contract to member agencies of the Steering Committee for work related to the BDCP will be precluded from serving as Science Advisors. At the outset of the process, all selected Science Advisors will be required to disclose for the record any activities they are, or have been, engaged in within the past three years in the Delta, including research projects, as well as any financial affiliations they may have with members of the Steering Committee. Service as a BDCP Science Advisor shall not preclude the pursuit of future grants or research related to the Delta.

ATTACHMENT 1
PROPOSED WORKPLAN FOR INDEPENDENT SCIENCE INPUT

The following outlines a proposed workplan for obtaining independent, timely, focused science input for the BDCP process. The workplan is organized over time as described below and shown graphically in Figure 1.

Initial Planning (by End of June 2007)
Initial planning for science advisor engagement. Specific tasks will include the following:
(a) the selection of advisors;
(b) initial written guidance for the scientific input process and
(c) framing science questions.

Deliverables:

- Guidelines for Scientific Input
- Identification and selection of Science Advisors
- Science Questions

Steering Committee Engagement:

- Meeting #1 – June 1, 2007; Review proposed plan and solicit input on areas of expertise and potential science advisors.
- Meeting #2 – June 15, 2007; Discuss science questions.

<u>Initial Engagement (by September 2007)</u>
The Science Advisors will be convened to participate in topically focused workshops. The exact number and focus of each workshop will be determined based on discussions with the Steering Committee and the Lead Scientist regarding the development of Science Questions (which will be used to frame the advisor discussions). Potential topics may include broad principles for guiding preparation of the Conservation Plan, as required by the NCCP Act. The exact timing of the workshops will be influenced by the availability of the selected Science Advisors.

Deliverables:

- Workshop Summaries
- Draft Guidance Report(s) containing Science Advisor observations and recommendations
- Final Guidance Report(s)

Steering Committee Engagement:

- Meeting #3 – TBD: Review initial workshop observations and recommendations
- Meeting #4 – TBD; Meet with Lead Scientist to discuss Guidance Report(s)

<u>Later Engagement (2008)</u>
Recognizing that additional science input on specific issues such as adaptive management and monitoring may be needed once a conservation strategy has been selected, the Facilitation Team recommends that the Steering Committee commit to a second engagement of Science Advisors in 2008. This additional independent scientific input could be used to advance discussion on specific elements of the selected conservation strategy (e.g., management and monitoring principles) as the well as the design of potential near-term conservation actions while longer-term investment strategies mature. The second engagement would also allow for advice regarding new information that may emerge after the initial engagement.

Deliverables:

- Input on specific issues or plan elements

Steering Committee Engagement:

- Meeting #5 – TBD: Review additional observations and recommendations
- Meeting #6 – TBD; Meet with Lead Scientist to discuss input

APPENDIX B:

Topics and Issues to be Discussed by Independent Science Advisors

BDCP INDEPENDENT SCIENCE ADVISORY WORKSHOP
SEPETEMBER 12-14, 2007
RYDE HOTEL

WORKSHOP TOPICS AND ISSUES TO BE DISCUSSED

The following major topics, and issues listed under each topic, are intended to help frame the advisors' discussions and not to rigidly dictate the scope of the discussions nor form the outline of the advisors' report. There is necessarily broad overlap and intertwining of issues amongst the major topic areas, and we have purposely structured the workshop to allow advisors to circle back to refine their input on particular topics or issues after moving on to other topic areas (in case discussion on a particular topic stimulates new thoughts on a topic already addressed).

Note also that the list of issues under each topic is not necessarily comprehensive. Additional issues are likely to arise before and during advisors' discussions and will be addressed as appropriate. We encourage Steering Committee members to continue submitting additional topics or issues to the Facilitation Team.

Conservation Principles

Charge: Formulate scientific principles for guiding ecosystem restoration and conservation of species and natural communities in the study area.

Issues to Consider:

a. The current, highly altered nature of the system
b. Invasive species
c. Flows and transport pathways
d. Water qualities
e. Future climate regimes
f. Physical and/or biological characteristics
g. Natural processes and self-sustaining outcomes
h. Ecological gradients (e.g., water depths, salinity, temperature regimes, substrate types)

Plan Scope

Charge: Identify natural communities, species, and processes that should be addressed to help achieve the plan's goals.

Issues to Consider:

a. The list of natural communities to be addressed by the plan
b. The list of species intended for coverage under state and federal take permits
c. Additional "planning" species, which may lack special protection status but may serve as useful indicators for other species, communities, or processes of interest
d. Effective ways of grouping species to assist in developing and assessing conservation strategies (e.g., species guilds, resident vs. anadromous species, species sharing limiting factors)

e. Physical and ecological processes to be addressed by the plan
f. The plan's geographic scope and how to address effects that extend beyond geographic boundaries
g. The temporal scope of the plan and how to address short vs. long-term effects

Knowledge Base for Planning

Charge: Review existing information and assess it's adequacy as a scientific foundation for conservation planning.

Issues to Consider:

a. Gaps in existing information that create uncertainties for planning, analyzing, managing, and monitoring
b. Additional data sources or literature that should be considered during planning and analysis
c. Methods for addressing data gaps and dealing with uncertainties
d. Physical or biological process models that might inform development of conservation strategies, (e.g., models of population dynamics, community dynamics, or nutrient or water flows)
e. Sufficiency of available data (including accuracy and precision) for use in models identified above
f. The need to expressly and specifically identify and document the implications of scientific uncertainties on the recommendations of the science advisors

Critical Processes

Charge: Identify critical physical and ecological processes for restoring and conserving species and natural communities, and methods for assessing, conserving, restoring, and monitoring such processes.

Issues to Consider:

a. Historic ecological processes that maintained ecosystem and species viability
b. Current state of those processes
c. Future desired states for those processes
d. Methods for achieving future desired states
e. Examples of processes to address:
    - Nutrient flows
    - Water flows
    - Population dynamics
    - Disturbance cycles
    - Ecological migration
    - Exotic species invasions
    - Harvest
    - Population genetics
    - Climate change

External Factors

Charge: Identify external factors or processes, not under direct influence of BDCP participants, that might affect BDCP covered resources, and how can these externalitices be addressed by BDCP analyses and actions.

Issues to Consider:

a. Climate change (e.g., how might it affect this ecosystem and the target species, and how can these effects be addressed by the plan?)
b. Current and future land uses in the vicinity of the Bay Delta, or beyond plan boundaries, that may directly or indirectly affect the success of BDCP conservation strategies
c. Other existing or ongoing regional conservation plans in the vicinity of the Bay Delta.

The following index table provides a summary of where within the Independent Science Advisors Report specific issues and topics are discussed.

Conservation Principles	
Charge: Identify scientific principles for guiding ecosystem restoration and conservation of covered species and communities in the study area. Response Summary: Sixteen principles were formulated reflecting broad, fundamental concepts deemed important to acknowledge and understand in the process of developing an HCP / NCCP for the Delta.	
Specific Issues:	Report Section Reference
Current altered state of the system	Section 2 (Principles – A, B, & E)
Invasive species	Section 2 (Principles – A, B, F & P)
Flows and transport pathways	Section 2 (Principles – D, C, F, H, I, & J)
Climate change	Section 2 (Principles - B & P)
Physical characteristics	Section 2 (Principles – A, B, C, D, G, I, & J)
Biological characteristics	Section 2 (Principles – C, E, K, & M)
Natural processes / Sustainable outcomes	Section 2 (Principles – A, B, D, E, F, G, J, K, L, & O)
Ecological gradients	Section 2 (Principles – C, D, E, G, H, & I)

Plan Scope	
Charge: Identify natural communities, species, and processes that should be addressed to help achieve the plan's goals. Response Summary: The report provides preliminary observations and advice regarding geographic and temporal scope of the plan, covered species, communities, processes, and conservation strategies based on currently available information. The Advisors recommend seeking further advice on these topics as the Covered Activities become more defined.	
Specific Issues:	Report Section Reference
List natural communities to be addressed by plan	Section 3.5
List species intended for coverage under state and federal permits	Section 3.3
Identify additional "planning species"	Section 3.4
Identify effective ways of grouping species, communities, or processes of interest to assist in developing and assessing conservation strategies	Section 3.5
Identify physical and ecological processes to be addressed by the plan	Section 4.0
Geographic scope of the plan	Section 3.1
Temporal scope of plan	Section 3.2

Knowledge Base for Planning	
Charge: Review existing information and assess its adequacy as a scientific foundation for conservation planning. Response Summary: The Advisors have made observations on the current state of knowledge, its limitations, and made several recommendations for addressing data gaps and refining predictive ability. These observations are generally summarized in Section 4 and its associated tables.	
Issues:	Report Section Reference
Gaps in existing information that create uncertainties	Section 2 (Principles – N & P) Section 4.2 Tables 1-5
Additional data sources of literature that should be considered during planning and analysis	Tables 1-5 Section 4.3 Section 5
Methods for addressing data gaps and dealing with uncertainties	Section 2 (Principles – N, O, & P) Section 4.2 & 4.3 Section 5
Physical or biological process models that might inform development of conservation strategies	Section 2 (Principle - O) Section 5
Sufficiency of available data for use in models	Section 2 (Principles – N, O, & P) Tables 1-5
The need to expressly and specifically identify and document the implications of scientific uncertainties on the recommendations of the advisors	Section 2 (Principles – L, N, & P) Tables 1-5 Section 5

Critical Processes	
Charge: Identify critical physical and ecological processes for restoring and conserving species and natural communities, and methods for assessing, conserving, restoring, and monitoring such processes. Response Summary: The Advisors identified certain process interactions considered to be particularly important for understanding the response of Covered Species to changing conditions. Boundary conditions (e.g. river inflows, diversions, tides) combine with the geomorphic template (the physical structure of the system) to influence physical, geomorphic, foodweb, and chemical processes, which in turn act on each other and influence species population dynamics in a variety of ways.	
Issues:	Report Section Reference
Historic ecological processes that maintained ecosystem and species viability	Section 2 (Principles – A, B, D, & E) Section 4.1
Current and future desired states[62] of ecological processes	Section 2 (Principles – A & B) Tables 1-5
Methods for achieving future desired states	Section 2 (Principles – K & L) Section 4,2 & 4.3 Section 5
Example processes to address:	
Nutrient flows	Tables 1, 4 & 5
Water flows	Tables 1 & 2
Population dynamics	Section 4.3
Disturbance cycles	Section 2 (Principles – D & E)
Ecological migration	Section 2 (Principles – C, D, E, G, & H) Section 4.3
Exotic species invasions	Section 2 (Principles – A, B, C, D, & G) Section 3.4 Table 4
Harvest[63]	Section 2 (Principle C)
Population genetics	Section 2 (Principles – C & E) Section 4.3
Climate change	Section 2 (Principles – B & P) Section 3.5 Tables 1, 2, &3 Section 5.4

[62] The Advisors did not evaluate specific future Delta conditions or conservation strategies.
[63] The Advisors focused on ways in which harvest can be considered in studies of population dynamics rather than its specific role

External Factors

Charge: Identify external factors or processes, not under direct influence of BDCP participants, that might affect BDCP covered resources, and how these externalities can be addressed by BDCP analyses and actions.

Response Summary: The Delta is part of a larger river-estuarine system that is affected by both rivers and tides as well as by long-distance connections, extending from the headwaters of the Sacramento and San Joaquin rivers into the Pacific Ocean.

Issues:	Report Section Reference
Climate Change	Section 2 (Principles – C & H) Table 1 Section 3.5 Section 5.4
Current and future uses in the vicinity of the Bay Delta or beyond plan boundaries that might affect BDCP conservation strategies	Section 2 (Principles I & M) Table 1 Table 5
Other existing or ongoing regional conservation plans in the vicinity of the Bay Delta[64]	

[64] The Advisors did not specifically examine other plans. However, they did draw on work from POD, DRERIP and IEP in their deliberations.

APPENDIX C:

Additional Questions Submitted to the Independent Science Advisors from the Steering Committee

The following table lists additional questions provided to the Independent Science Advisors by Steering Committee before the September 2007 Advisors Workshop and provides references for where within the Advisor's report these questions are generally discussed. Because many of these questions are very specific, requiring detailed investigations beyond the scope of the Advisor's initial charge, the Advisors did not attempt to specifically answer each question. However, the questions were used to better understand the interests of the Steering Committee and to help frame the overall discussion of the Advisors. In the course of developing Principles for Conservation Planning and other general guidance, the Advisors did touch upon several of the fundamental issues underlying many of the specific questions posed, as noted in the index table below.

Questions Provided by Non-Governmental Organizations	
Question	Report Section Reference
Understanding that ecosystems are dynamic and past conditions cannot be duplicated, how can information about historical conditions in the Bay-Delta estuary and historical relationships between Bay-Delta habitat conditions and biological resources best be used to guide development of the conservation strategy?	Section 2 (Principles - A & E)
Flows have been the most obvious driver of ecological conditions in the Bay-Delta estuary. Is it possible to protect and restore covered species without significantly improving flow conditions in this system?	Section 2 (Principle F)
The degree to which most previous management actions protect Bay-Delta ecological resources have been implemented has been very small in scale when measured against the degree of human alteration of the Bay-Delta estuary's habitats, hydrology, etc. To what extent should the consideration of the magnitude of potential management changes[65] in habitat, hydrology and other ecological conditions help both in generating meaningful data and in securing significant improvement in estuarine functions?	Section 4.3 Section 5 Section 6
Is there any quantitative basis for concluding that factors other than flow and exports are affecting covered species at the population level?	Section 2 (Principle F) Section 4.3

[65] The Advisors did not consider specific management strategies.

Questions Provided by Potentially Regulated Entities	
Question	Report Section Reference
Do biological evaluation criteria developed to help screen conservation strategy options adequately address the range of issues adversely affecting the covered species?	The Advisors did not examine the criteria.
What are the factors influencing the populations of covered species and their relative importance?	Tables 1-5 Section 4
Can a more variable Delta hydrologic regime (variation between freshwater outflow and saltwater inflow) be detrimental or beneficial to covered species?	Section 2 (Principles – F & M) Section 3.5 Section 4.3 Section 5.4
Has climate change affected the necessary conditions for native species in the Delta that are at the southern most extent of their range? How would climate change affect the covered species in the future under each of the climate change scenarios described in DWR's report, *Progress on Incorporating Climate Change in to Management of California's Water Resources* (July 2006)[66]. Under the projected effects of climate change is there a time in the future when the Delta will no longer be suitable habitat for one or more covered species?	Section 2 (Principles – A, B, E, & P) Section 3.5
Has reduced turbidity affected the necessary conditions for native species in the Delta? Can the effects of reduced turbidity be addressed by the conservation strategy options?	Section 2 (Principles – A & E) Section 5.2 Table 2
Please review the Delta smelt/*eurytemora* co-occurrence analysis by BJ Miller Does food supply (zooplankton density and geographic distribution) appear to be a major determinant of smelt population? How can food supply be considered in the conservation strategy?	Section 4.1 (Table 4)
Would a more variable Delta hydrologic regime be detrimental or beneficial to non-native species such as the zebra or quagga mussels?	Section 2 (Principle D) Section 3.5 Section 5.4
Will replacing riprap-lined levees with riparian vegetation have a substantial positive effect on the population of covered species? Should this be included as part of our conservation strategy options? For which species?	Section 2 (Principle G) Section 3.5 Section 5.1

[66] The Advisors did not consider the implications of specific climate change scenarios

Does increasing shallow water habitat improve populations for covered species?	Section 2 (Principle G) Section 3.5
Is it possible to create refugia for foundational species of the Delta ecosystem such as *eurytemora*?	This specific question was not addressed.
Is it environmentally beneficial to covered species be able to move large Delta water diversion points based on the location of habitat needs of the Delta's native species?	Section 2 (Principle M) Section 4.3
What conclusions are supported by the data on the effect of unscreened in-delta diversions on covered species:	The Advisors did not specifically examine these data.
A. Can screening in-Delta diversions improve conditions for the Delta's native pelagic and anadromous fish?	Section 2 (Principle G) Section 4.3.2
B. How does the #/AF of entrainment due to in-Delta diversions compare to entrainment caused by exports?	Section 4.3.2
Is there sufficient data to determine if toxic events in the north Delta, and municipal and agricultural wastewater discharges throughout the Delta have affected the viability of zooplankton, pelagic, and anadromous species in the Delta? Should toxics and wastewater discharge control program for areas in and immediately adjacent to the Delta be included in the conservation strategy options?	Section 4.1 Table 5
What effects do upstream diversions on the San Joaquin River tributaries have on the covered species?	Section 2 (Principle C) Table 1
Is it possible to achieve recovery of the Delta smelt by addressing only the effects of pumping at the SWP and CVP pumping plants?	Section 2 (Principle F)
Given the uncertainty of some of the science surrounding the covered species and the associated Delta ecosystem what strategies can be incorporated into the conservation plan to address known data gaps? What uncertainties do you feel are most important to consider when developing specific conservation measures or adaptive management protocols?	Section 4.1 Tables 1-5 Section 6

Appendix G-2

Bay Delta Conservation Plan Independent Science Advisors
Report Concerning Non-Aquatic Resources

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Bay Delta Conservation Plan

Independent Science Advisors Report Concerning Non-Aquatic Resources

Prepared For
Bay Delta Conservation Plan Steering Committee

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November 2008

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1 Introduction

This report summarizes recommendations from a group of independent science advisors (ISA) concerning the treatment of non-aquatic species and communities by the Bay Delta Conservation Plan (BDCP). The intent of the ISA process is to ensure that the plan has access to the best available science. Our recommendations are not binding, and are not intended to either question or promote particular plan goals or policies, but are intended to help inform the planning process. Attachment A provides brief biographies of the advisors.

Contents of this report reflect discussion among the science advisors at a workshop held on September 30, 2008 (Attachment B) and their review of various draft plan documents (Attachment C). A previous ISA workshop and report (Reed et al. 2007) focused on the aquatic species and communities that have been the BDCP's highest priorities. This second workshop and report, by a different set of science advisors, focuses on non-aquatic species and communities that could be affected by plan actions.

2 Covered Species

This section provides information concerning what non-aquatic species may be affected by BDCP implementation, either positively or negatively. The intent is not to recommend which species should or should not be covered by regulatory take authorizations or permits under endangered species regulations. It is up to the potentially regulated entities (PREs) to decide which species they wish to obtain permit coverage for, whether under Endangered Species Act Section 10 and the NCCP Act or under other regulations (e.g., Section 7 of the ESA or Section 2081 of the Fish & Game Code). Moreover, it is up to the fish and wildlife agencies to determine for which species permit coverage is ultimately warranted, under what regulations, and with what terms and conditions. We offer the following scientific information and advice to be considered as BDCP participants make decisions about species coverage and conservation actions.

2.1 Species Selection Process

The advisors generally concur with the evaluation criteria and process that was used to identify potentially covered species by the consulting team (Attachment C, Document #3). However, we have some questions and concerns about how the four evaluation criteria (listing status, occurrence in planning area, potential to be affected, and information sufficiency) were applied, and we suggest reconsidering the evaluation of certain species.

First, the advisors were unclear how the original list of 111 species that SAIC evaluated for coverage was derived, and are concerned that some at-risk species or subspecies that may occur in or near the planning area were not evaluated. For example, several birds that are California Species of Special Concern (SSC) (Shuford and Gardali 2008) are known or potentially occur in the planning area, but were apparently not evaluated, such as the Modesto song sparrow (*Melospiza melodia mailliardi*) and yellow warbler (*Dendrocia petechia*).

Listing Status. For some species, advisors question how the determination was made that they were unlikely to be listed, in light of myriad uncertainties and considering the proposed 50-year permit duration. We believe it is prudent to err on the side of caution in making such determinations, because an unexpected listing can be disruptive to plan implementation[1]. In particular, the advisors note that there is an inherent circularity in the logic to not cover some SSC on grounds they are unlikely to be listed. Inclusion on the California SSC list indicates that a species meets some or all criteria for California Threatened or Endangered status, and that highlighting this at-risk status may help prevent the need to list the species by encouraging conservation and recovery actions for it (Shuford and Gardali 2008). The advisors therefore recommend treating SSC as if they are likely to be listed. If the planning area is important to viability of an SSC, the plan should evaluate whether implementation may adversely affect it and therefore warrant coverage.

Occurrence in Plan Area. The advisors note that survey coverage in the plan area is sparse for many species, and that it is difficult to assume absence on the basis of existing data, such as CNDDB records. This is particularly true for plants and invertebrates. Some species occurring in the vicinity of the Bay Delta have been found outside their known geographic ranges after being listed and could occur in the plan area. We also note that species ranges are dynamic, and that shifts in response to climate change and other factors are being documented for numerous taxa in California and throughout the world (Moritz et al 2008, Parmesan 2006, Root et al. 2003). We therefore recommend carefully considering the potential for species to occur within the plan area over the proposed 50-year permit duration.

We understand that some plan actions may occur outside the planning area (the statutory boundary of the Delta) but that only species occurring inside the boundary were evaluated. We recommend identifying all at-risk species that may be affected by the plan (i.e., listed, SSC, or CNPS list species), whether inside or outside the plan boundary (e.g., by an around-Delta conveyance or by restoration actions in Suisun Marsh). We recognize that permits for BDCP effects on some species may be obtained via other regulatory means than BDCP take authorizations (e.g., project-specific Section 7 or 2081 authorizations), but it seems wise to anticipate the full range of potential effects to inform such decisions as early as possible.

Potential to be Affected by Plan Actions. The advisors also feel it is prudent to err on the side of caution when considering the potential for species to be affected by plan actions, whether positively or negatively, because the nature and extent of the plan's covered actions and conservation measures are not yet fully defined. For example, we understand that the consultants only considered an eastern alignment in determining whether species may be adversely affected by an around-Delta conveyance. It appears from maps and other information we reviewed that additional species could be adversely affected by other alignments, especially a western alignment. Until the conveyance alignments and other plan measures are more fully developed,

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[1] For example, during development of the San Diego Multiple Species Conservation Plan (MSCP) the Quino checkerspot butterfly (*Euphydryas editha quino*) was considered unlikely to be listed and was not covered. The butterfly was listed as Endangered one year after MSCP approval, triggering project delays and a costly plan amendment.

we recommend keeping an inclusive list of potentially affected species, and winnowing the list as decisions are made and uncertainties resolved.

Advisors question the assumption that siphoning aqueducts under tidal channels, streams, and sloughs can completely avoid impacts on riparian habitat or other floodplain habitats. While the impacts of siphons may be lower than alternative conveyance solutions, based on observations of existing siphons elsewhere in the Central Valley, advisors are uncertain whether all direct and indirect impacts associated with construction and maintenance of siphons can be completely avoided. We recommend not relying on this assumption in considering species for coverage until facility design is sufficiently advanced to remove such uncertainties.

Restoration actions intended to benefit aquatic species may positively or negatively affect habitat for or populations of terrestrial species. For example, restoration of tidal marshes in lowland portions of the plan area could flood habitats currently occupied by covered terrestrial plant and animal species, while increasing habitat potential for marsh species.

Even if plan actions do not directly affect habitats or populations of certain terrestrial species, they have potential to constrain conservation or recovery actions for these species by other plans. For instance the Antioch Dunes represent a rare sand dune habitat that supports a number of rare, endemic plants and animals, such as the federally endangered Contra Costa wallflower (*Erysimum capitatum* ssp. *angustatum*), Antioch Dunes evening primrose (*Oenothera deltoides* ssp. *howelli*), and Lange's metalmark butterfly (*Apodemia mormo langei*). We agree that this community and its endemic species are not likely to be directly affected by BDCP actions. However, due to the extreme rarity and conservation importance of this community, we recommend analyzing whether any covered actions might constrain the possibility of future habitat restoration within this very limited geographic area by other entities, or whether BDCP conservation actions could contribute to recovery of these species.

Sufficiency of Information. The advisors were unclear about how this determination was made for each species, given uncertainties about the distribution of many species in the plan area and the preliminary nature of the covered actions and conservation measures. We assume that the determination focused on whether scientific understanding is sufficient to determine how covered actions and conservation measures might affect each species, provided the species is present in affected areas. We understand the rationale that there must be sufficient scientific understanding about how covered actions and conservation measures may affect a species to determine whether that species should ultimately be covered by take authorizations. However, where there is not sufficient information to make such a determination at this time, we believe it is prudent to keep the species on a comprehensive species list as the plan develops, in case sufficient information becomes available to make the assessment, rather than to remove such "uncertain" species from the list prematurely.

The explanation for this criterion (Attachment C, Document #3, Page 8) states, "A guide for this criterion is if the species is covered or proposed for coverage under other HCPs and NCCPs, which indicates a confidence that sufficient information is available to cover the species." We point out that the nature of BDCP covered actions and conservation measures differs considerably from that of most other HCPs and NCCPs, which usually involve trading off habitat losses due to development, primarily in upland areas, with conservation and management of habitat preserves in other locations. In contrast, BDCP actions will likely result in complex and widespread changes in hydrodynamics, water qualities, etc., as well as potentially widespread habitat restoration projects, especially of wetland communities. Such actions may affect covered species in ways not addressed by other HCPs and NCCPs in the region. Moreover, how these changes may interact with climate change and other factors to influence habitat and populations of covered species is highly uncertain. We believe that where existing scientific information is not currently sufficient to determine plan effects on species, those species should be retained on the list of potentially covered species until sufficient information becomes available to determine that the plan is unlikely to have effects on them (e.g., until covered actions are more fully defined and more comprehensive surveys can be performed). These uncertainties about plan effects on diverse species reemphasize the critical importance of a solid adaptive management and monitoring program for the BDCP.

2.2 Potential Covered Species Additions

Based on the above review of the species selection criteria, we believe the following species should be considered (or reconsidered) for coverage, because they are listed or have potential to be listed as Threatened or Endangered and they could be affected by plan actions. These include some species not addressed in the consultants' evaluation, and others that were evaluated but determined unlikely to require coverage due to one or more of the evaluation criteria. For example, they include several SSC that we believe should be treated as likely to be listed, for reasons explained above. Finally, they include some species about which the consultants were uncertain for one or more of the evaluation criteria.

- **Riparian woodrat** (*Neotoma fuscipes riparia*[2]). The consultants' evaluation was uncertain about this federally endangered species' occurrence in the plan area and likelihood of being affected. Surveys are being performed for the species in appropriate habitats within the BDCP area, and we recommend awaiting results of those surveys before determining whether to pursue coverage. Before 2003 riparian woodrats were thought to survive only at Caswell Memorial State Park and a few other areas along the lower Stanislaus River. However, the species was found in 2003 at the San Joaquin River National Wildlife Refuge, just south of the planning area, and it may be more widely distributed than previously thought. Ongoing riparian habitat restoration efforts at the San Joaquin River NWR and elsewhere will likely lead to population and range expansion. In addition to loss of habitat, riparian woodrats are threatened by fires and floods, as evidenced by population reductions in San Joaquin River NWR following a wildfire there in 2004 and major flooding in 2006. Riparian woodrats are expected to respond favorably to riparian habitat restoration programs.
- **Northern harrier** (*Circus cyaneus*) has been a California Bird SSC since 1978 (Shuford and Gardali 2008). Recent declines throughout the Central valley have been attributed to habitat loss, intensified agricultural practices, and increases in nonnative predators (cats, dogs, and eastern red foxes). Harriers are known to breed regularly at the Cosumnes Reserve and were found in 69 widely scattered blocks in the Sacramento County Breeding Bird Atlas. The

[2] Taxonomic revision will likely result from studies that are presently ongoing by Marjorie Matocq at University of Nevada, Reno (P. Kelly).

nests of this ground-nesting species are highly vulnerable to disturbance from humans, dogs, livestock, and agricultural activities during the breeding season. Conservation measures, such as restoring wetland habitats in what are currently uplands, could adversely affect a small number of harriers. Further information on occupancy, persistence, and ideally nesting success in protected areas is needed.

- **Lesser sandhill crane** (*Grus canadensis canadensis*). This recent addition to the California bird SSC list (Shuford and Gardali 2008) winters in large numbers within the Delta (Christmas Bird Count data). Like the greater sandhill crane (which was included as potentially covered in the consultant's evaluation) the greatest threats to the species are changes in agricultural practices and habitat loss. Management actions, such as promoting late (February) discing of grain crops, managing grasslands with cattle, providing shallow wetlands, and preventing collision with power lines, will benefit both the lesser sandhill crane and the greater sandhill crane.

- **Least Bell's vireo** (*Vireo belli pusillus*) was not evaluated by the consultants, presumably because it has not been found in the plan area since before the species was listed as Endangered in the 1980s. Least Bell's vireo was restricted to a few small populations in southern California at the time of listing, but it has since been increasing in population and expanding northward within its historic range in the Central Valley. In recent years least Bell's vireos have nested as far north as Gilroy (Santa Clara County) and San Joaquin River National Wildlife Refuge (Merced County). Experts consider it likely to re-occupy riparian habitats in the BDCP area in the near future.

- **Yellow warbler** (*Dendroica petechia*) was not evaluated by the consultants. A California SSC since 1978 (Shuford and Gardali 2008) this species has declined significantly as a breeding bird throughout the state and in the Central Valley and may be close to extirpation (Heath 2008). Extensive surveys in the Bay Delta and San Joaquin valley in the late 1900s failed to locate breeding populations. Possible breeding records in Contra Costa County and a new expanding population on the San Joaquin River NWR (Hospital Creek) suggests high potential for this species to return to the delta in healthy numbers. An early seral-stage, riparian-dependent species, restoration programs that restore ecosystem processes (e.g., natural flood events), a mosaic of riparian habitat, and healthy understory will benefit this easily monitored species (Riparian Habitat Joint Venture 2004).

- **Modesto song sparrow** (*Melospiza melodia*, "Modesto" Population) was not evaluated by the consultants. This resident California bird was considered a valid subspecies (*M. m. mailliardi)* until 2001 (Patten 2001), and may be again under additional taxonomic research (Gardali 2008). Regardless of whether the "Modesto population" of the song sparrow is ultimately determined to be a valid subspecies, it is a California SSC that is endemic to the Sacramento Valley (Gardali 2008). The Bay-Delta is one of two areas with the highest population densities. Major loss (> 90%) of its preferred wetland and riparian habitat has led to a significant reduction in range and abundance. While it can be locally abundant along riparian corridors or small wetlands it is rare along irrigation canals, levees, and in mature riparian habitat. The protection and restoration of wetlands and dynamic riparian systems with understory and habitat mosaics will aid in this species' recovery.

- **Western pond turtle** (*Clemmys marmorata*). The western pond turtle is a California state SSC. The turtle's habitat includes freshwater sloughs and marshes in the Delta (Zeiner et al.

1988-1990). Salt-water intrusion brought about by reducing freshwater flows into the Delta could have a negative effect on local populations.

- **California tiger salamander** (*Ambystoma californiense*) is a federally threatened species with recent sightings in the vernal pool habitats on the western edge of the project area. This area is included in designated Critical Habitat for the species (U.S. Fish and Wildlife Service 2004), and actions there, such as construction of a western around-Delta conveyance, have the potential to adversely affect the species. The consultants' evaluation was uncertain about the potential for plan actions to affect the species, presumably because covered actions are not yet fully defined.

- **California red-legged frog** (*Rana aurora draytonii*) is federally Threatened and a California SSC that is known to occur in the plan area. The consultant's evaluation concluded that plan actions were unlikely to affect the species. The advisors are unclear how this determination was made given that locations of covered actions and conservation measures have not yet been fully defined and that surveys sometimes find this species in unexpected locations. Red-legged frog could be adversely affected if covered actions occurred in or near occupied or potential habitat. We recommend including this as a potentially covered species pending further analysis as covered actions and conservation measures are better defined.

- **California black walnut** (*Juglans hindsii*) was considered by the consultants' evaluation to be unlikely to become listed. However, this California endemic is a CNPS list 1B.1 species (seriously endangered in California) and has a Natural Heritage Rank of G1/S1.1. It is known to hybridize with other species of walnuts. Although it has been widely planted and used for root stock, natural occurrences are limited, and only one confirmed natural stand appeared viable as of 2003 (http://cnps.web.aplus.net/cgi-bin/inv/inventory.cgi). We recommend considering covered status for this species if natural populations occur in the plan area that could be positively or negatively affected by covered actions.

- **Bristly sedge** (*Carex comosa*) is found along the margins of marshes, swamps, and in wet meadows. The consultants' evaluation was uncertain about this species' potential to be listed. We share this uncertainty, and believe there is a small potential for it to be listed in the next 50 years. We therefore agree with the consultants "undetermined" finding and suggest keeping this species on the list until uncertainty is reduced.

- **Various plant species** found in vernal pools, swales, or flats that could be adversely affected by plan actions, especially in combination with climate change, or have the potential to benefit from the plan's conservation actions. The consultant's evaluation determined that these species were unlikely to be affected by covered actions, or they were uncertain about the potential for effects. We are also uncertain about potential plan effects on these species, given that plan actions aren't yet fully described, and believe they should be retained until uncertainties are resolved.
    - Bogg's Lake hedge-hyssop (*Gratiola heterosepala*)
    - San Joaquin Valley Orcutt grass (*Orcuttia inaequalis*)
    - Heartscale (*Atriplex cordulata*)
    - Brittlescale (*Atriplex depressa*)
    - Vernal pool smallscale (*Atriplex persistens*)

- o Round-leafed filaree (*Erodium macrophyllum*)
- o Fragrant fritillary (*Fritillaria liliacea*)
- o Lesser saltscale (*Atriplex minuscule*)

We agree with the consultant's evaluation that the following species, which are associated with the extremely rare Antioch Dune community, are unlikely to be directly affected by the covered actions or conservation measures currently under consideration. However, as explained earlier, we recommend evaluating whether BDCP implementation could contribute to the recovery of these species or whether BDCP implementation might indirectly constrain potential conservation and recovery actions for these species by other entities.

- Delta green ground beetle (*Elaphrus viridis*)
- Lange's metalmark butterfly (*Apodemia mormo langei*)
- Antioch Dunes evening primrose (*Oenothera deltoides* ssp. *howelli*)
- Contra Costa wallflower (*Erysimum capitatum* spp. *angustatum)*

2.3 Potential Covered Species Deletions

The consultants' draft evaluation concluded that the following species should be considered for coverage, or stated that this conclusion was "undetermined." The advisors believe that these species are unlikely to require coverage, and they could be deleted from the list.

- **Snowy plover** (*Charadrias alexandrinus,* interior population). Since 1945 there are only three breeding records for this species in the Central Valley (all in Yolo County). Its extremely rare occurrence and preference for agricultural evaporation ponds and alkali playas in the Valley suggest that BDCP is unlikely to affect this species and that the delta is not an area in which to focus conservation efforts for it.
- **Coast horned lizard** (*Phrynosoma coronatum*) does not likely inhabit the plan area (Stebbens 2003) or areas likely to be affected by around-Delta conveyances.
- **Caper-fruited tropidocarpum** (*Tropidocarpum capparideum).* This species was believed to be extinct for several decades, but was rediscovered in Monterey County at Fort Hunter Liggett in 2000-2001. It primarily occupied valley grasslands, with some documented locations within the plan area. However, it has not been re-located in the plan area in recent years and is presumed extirpated.

2.4 Planning Species

The advisors are concerned that the plan focuses so strongly on species for which regulatory coverage is being sought (e.g., listed threatened and endangered species) that it might not adequately account for ecological processes and community interactions that are essential to all species in the area, including covered species. Some conservation plans identify additional "planning species" for which regulatory coverage may not be necessary, but that can serve as indicators of ecological conditions or processes in covered communities. Indicator species can be effective monitoring tools in adaptive management plans, especially where intensive monitoring of covered species is infeasible. We recommend considering whether some additional planning species should be evaluated in the plan and included in the monitoring program to help meet BDCP goals.

One approach for identifying useful planning species is to identify groups of species whose vulnerability can be attributed to a common threat or stressor, such as loss of habitat area or alteration of a natural disturbance regime. For each group, one or more species are selected that are both highly sensitive to the threat category and relatively easy to monitor. Such species can thus serve as indicators for that group. We recommend that the plan identify what threat categories are most appropriate for non-aquatic communities in the BDCP area, systematically evaluate whether the proposed list of covered species already has sufficient indicator species for each threat category and each community type, and then supplement the covered species list as necessary to fill any gaps in this matrix with additional planning species.

One example system for identifying threat categories that has been applied in previous conservation plans is based on Lambeck (1997) who identified four groups of species. We suggest adjusting this general approach to the BDCP issues and area to identify planning species that may help attain plan goals and objectives. The following groups could be modified or supplemented with others, as appropriate for this purpose.

- *Area-limited species* have large home ranges, occur at low densities, or otherwise require large areas to maintain viable populations. Examples include large mammals (especially carnivores) and large raptors, such as northern harrier. Although this category has proved useful in design of large-scale, terrestrial reserve systems, the advisors do not necessarily recommend selecting large, wide-ranging terrestrial species as good planning species for BDCP. However, it may be useful to identify species that require relatively large habitat patches or habitat mosaics as indicators of successful habitat restoration efforts, if covered species do not already meet this need for all communities.
- *Dispersal-limited species* are limited in their dispersal capacity, sensitive to particular movement barriers such as highways or canals, or are vulnerable to mortality when trying to move through a human-dominated landscape. Examples include salamanders, turtles, large snakes, flightless insects, and large-seeded herbaceous plants. The advisors believe that some of the potentially covered species may adequately cover this category for most communities (e.g., California tiger salamander, Valley elderberry longhorn beetle).
- *Resource-limited species* require specific resources or habitats that are very rare or at least occasionally in short supply. Classic examples include nectarivores, cavity-nesting birds, cliff-nesting birds, vernal pool species, or burrow-dwelling animals. The advisors recommend considering whether there are resource specialists in the planning area that could serve as useful indicators for rare ecological communities or resources that may not be adequately addressed by covered species. For example, tree swallows and possibly spotted sandpipers are good indicators of healthy floodplain environments, diverse aquatic insect communities, and fish breeding habitat (gravel bars).
- *Process-limited species* are sensitive to details of the disturbance regime (e.g., the frequency, severity, or seasonality of floods or fires) or other manifestations of natural processes, such as hydroperiod, salinity gradients, or fire-return intervals. Examples include riparian plants like sycamore and elderberry that establish following floods, or vernal pool species which

require seasonal flooding, such as Contra Costa goldfields (*Lasthenia conjugens*). Early seral species such as song sparrows and yellow warblers are good indicators of ecosystem processes such as periodic flooding (Chase and Geupel 2005).

To this list of four categories, we suggest adding one for invasive species that serve as indicators of where management intervention is required. For example, wetland margins are often highly invaded by non-native species like Lepidium; and black rats (*Rattus rattus)* seem ubiquitous in riparian habitat in the Central Valley. Rats are nest predators of birds, including the Modesto song sparrow (Hammond 2008), and unpublished data from the Endangered Species Recovery Program suggests that woodrat reproductive success is lower in areas with high *Rattus* densities (P. Kelly).

3 Covered Communities

Due to the BDCP's focus on conserving imperiled fish species, the plan currently includes three "covered communities" and seven "other communities." [3] We recommend considering whether the plan should add more covered communities, in recognition of the interdependences among ecological communities within a broader ecosystem context. We point out that (1) many of the potentially covered species are found in the "other communities" rather than in the covered communities; (2) some of the rarest communities in the plan area are disproportionately vital to imperiled species, such as inland dune scrub and seasonal wetlands; and (3) community types are interdependent in complex ways and should not be treated in isolation of one another. For instance, changes in water level, flooding period, or nutrient deposition from flooding in certain habitats will likely impact adjacent habitats and associated covered species. Moreover, many covered species require resources from multiple community types (e.g., amphibians that require wetlands and uplands). Even if all communities in the plan area are not treated as "covered communities," the advisors at least recommend describing and assessing all communities within the plan area with a comparable level of detail and care, and describing community interdependencies in an ecosystem context. We expand on this in our review of the Existing Ecological Conditions chapter in Section 4.1.

We further recommend that analysis and documentation of plan effects recognize the finer vegetation types or habitat conditions that exist within these broadly defined natural community types[4]. The plan documents we reviewed (e.g., Attachment C, Document #2) appropriately recognize these finer distinctions by providing cross-walk tables of the various plant associations and alliances (Hickson and Keeler-Wolf 2007, Sawyer and Keeler-Wolf 1995) within each natural community type. We recommend continuing to recognize these finer distinctions, especially where they are important to assessing plan effects on covered species. For example, the category "natural seasonal wetlands" includes diverse types of seasonal wetlands, from vernal pools to alkali flats, which differ tremendously in ecological conditions and in the suite of covered species each supports.

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[3] BDCP Planning Agreement: Attachment C, Document #1.
[4] Community types were defined based on the CALFED Bay-Delta Program Ecosystem Restoration Program Volume 1 and Multiple Species Conservation Strategy (CALFED 2000), which defined 18 "broad" natural communities, while recognizing that there are finer habitat types and vegetation communities within each of these.

The Antioch Dunes represents a unique ecosystem of critical conservation concern that lies entirely within the project area. The dunes once extended along a two-mile reach of the southern shore of the San Joaquin River immediately east of the town of Antioch (Powell 1983) and totaled approximately 190 acres. This unique, isolated ecological community supports a diversity of rare and endemic species of plants and insects. For example, the Antioch Dunes are the type locality for 27 insect species, including eight that are endemic to the Dunes, and four that are considered extinct (Bettleheim 2005). Today, only 55 acres of remnant aeolian dunes are protected within the Antioch Dunes National Wildlife Refuge, although an additional 12 acres of dunes are found on the adjacent Pacific Gas & Electric property. A comprehensive conservation plan was issued by the U.S. Fish & Wildlife Service in 2002, but few if any of the management needs have been fully addressed. The Antioch Dunes National Wildlife Refuge was identified as a potential area for habitat restoration under the Ecological Restoration Program of CALFED (1999).

As discussed earlier, we recognize that the Antioch Dunes community is unlikely to be directly impacted by BDCP covered actions, but in light of the extreme rarity of this community and its associated species, we recommend assessing whether BDCP actions may in any way constrain restoration and recovery actions within this community, or whether BDCP conservation actions could contribute to recovery actions (e.g., by including restored dune habitats as a possible component of BDCP restoration plans in appropriate locations).

Communities need to be considered not just in isolation but as interdependent communities of species that affect one another within mosaics and across gradients. This is important in assessing effects of covered activities and designing conservation measures (e.g., locating restoration areas). The goal should be to recreate and maintain natural transitions between communities along gradients (such as elevation, salinity, and moisture gradients) rather than creating isolated habitat types with “hard edges.” For example, the unnaturally abrupt transitions from marsh vegetation to uplands that are created by dikes around marshlands provide no safe haven for rails and other species during flood events, subjecting them to high predation rates. Naturally connected and transitioning communities along elevation and moisture gradients will (1) benefit the covered fish species, (2) provide more natural habitat mosaics to support terrestrial and wetland species, and (3) create more sustainable conditions during climate change and sea-level rise.

Each community type has a characteristic set of species (of all kinds, not just plants). The advisors urge more consideration of the sets of species in each community and how they interact. As discussed in Section 2.4, it would be valuable to identify species that are indicators of particular communities. It may also be useful to identify common species associations or guilds typical of particular habitat types, plant assemblages, or limiting resources. Such species groups can provide useful indicators of biological integrity within ecological communities, which can be useful in adaptive management and monitoring.

4 Draft Plan Documents

In general, the advisors were impressed with the quality of documents and maps we reviewed. The following general comments are intended to improve what already appear to be thoroughly researched and thoughtfully prepared information products.

4.1 Existing Ecological Conditions

We recommend that the existing ecological conditions chapter begin with a broader treatment of the Bay-Delta ecosystem, natural communities, and processes, including those important to non-aquatic species. All communities in the study area should be described to a similar level of detail as the three covered communities. Currently, the three covered communities are treated fully, with detailed depictions of physical conditions, vegetation, fish and wildlife, non-native species, ecosystem processes, environmental gradients, and future conditions under a changing climate. However, the seven "other communities" have briefer descriptions of only the physical conditions, vegetation, fish, and wildlife, and these are more cursory than those for covered communities.

Section 2.3.2 on existing ecosystem processes does a good job of describing the broad suite of physical, chemical, and biological processes occurring within the project area. Likewise section 2.3.3 describes well the physical processes, and 2.3.4 describes the covered communities. What is missing is an integration of community types to describe how they are arranged or interconnected in spatial mosaics, and how these mosaics work to provide ecosystem services and support covered species. For example, it would be useful to characterize patterns of adjacency and intergradation among different community types and whether the boundaries between communities are (1) natural vs. artificial (e.g., separated by dikes, roads, or ditches), or (2) gradual vs. abrupt (e.g., transitioning along natural gradients or having sharp, discrete edges). How different habitat types interact both physically and through the movement of organisms across habitat boundaries or gradients is important to understanding likely affects of plan actions and other changes on covered species. Physical interaction is likely through the interdependence of water levels in adjacent (undiked) habitats and fluxes of sediments and nutrients. In the absence of additional species-specific information, the adjacency of habitats is expected to provide a measure of the flux of organisms across habitat boundaries, and barriers of various kinds (dikes, roads, railroads, etc.) may hinder the movement of certain species. Conservation measures should strive to create habitat mosaics with natural transitions between adjacent communities along gradients. Such mosaics will be more robust in the face of changes in hydrology and sea-level rise by allowing species, communities, and processes to adjust gradually over space and time. We expand on these concepts in Section 5.

4.2 Species Accounts

The draft species accounts that we reviewed were generally well researched, organized, and accurate. We recommend producing similar accounts for all potentially covered species, with perhaps shorter accounts for those species that were considered but not retained on the potentially covered list.

Below is a sampling of minor improvements that the advisors recommend for particular species. In Section 4.4 we provide additional information sources that should be consulted and referenced in the species accounts.

- Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*). It is important to note that, although this species has been proposed for delisting by the U.S Fish & Wildlife Service, it is still officially listed and should continue being treated as such. The delisting process is not yet final, and even once it is finalized, there will still be a required monitoring period of 5 years.
- The riparian brush rabbit account should be updated with the latest information developed by the Endangered Species Recovery Program (ESRP) at California State University – Stanislaus[5]. Note that the accounts currently available on the ESRP website are not particularly current, as results of recent and ongoing research are not yet incorporated. Surveys are being conducted within the BDCP plan area, the results of which should be used to update the account.
- An account should be prepared for the riparian woodrat using the latest information from ongoing surveys and research by ESRP[4]. As with the riparian brush rabbit, please note that the species account on the ESRP website is not particularly current. For example, recent unpublished data suggest that woodrat reproductive success is lower in areas with high black rat densities than in areas where black rats are systematically removed (P. Kelly). Riparian woodrats were first captured by ESRP in the San Joaquin River National Wildlife Refuge on March 26, 2003. Although they are captured periodically there, they are not abundant, especially since a wildfire in 2004 and major flooding in 2006. Woodrats usually build stick houses (also called nests, dens, or middens) on the ground, making them susceptible to flooding. However, they can also den arboreally in stick nests and cavities, which makes them somewhat less vulnerable to flooding than riparian brush rabbit populations. Fires may therefore be a more serious threat to riparian woodrats than flooding. As with the riparian brush rabbit, surveys are being conducted within the BDCP plan area over the next two years, the results of which should be used to update species information.

4.3 Species Habitat Models

We reviewed preliminary draft maps prepared by the consultants for a selection of covered species, to assess the general modeling approach they are using to predict habitat distribution for covered species. The approach has been to use available GIS layers (especially land cover types) and known or assumed habitat associations to depict the potential distribution of each species in the plan area.[6] This approach is fine when the relationships between species occurrence and mapped land-cover types (or other discretely mapped GIS polygons) are well established and reliable. However, errors of omission and commission are common, and their extent or frequency is difficult to assess. Overlaying available occurrence records onto these maps offers some additional information and a rough indication of model accuracy. However, when

[5] Please contact Pat Kelly at pkelly@esrp.csustan.edu for more information.
[6] The term "models" is somewhat misleading because the maps are more like compilations of information and expert opinion rather than being based on any graphical or mathematical algorithm.

occurrence records are sparse or spatially biased, for instance when based on ad-hoc reporting of occurrences to CNDDB, they are not in themselves reliable indicators of model accuracy.

A more thorough approach to habitat modeling would be to use niche models to statistically quantify the relationship between occurrence (or abundance) and habitat conditions (e.g., Guisan and Thuiller 2005, Elith et al. 2006), although we recognize that species occurrence records are too sparse for most covered species to build reliable statistical models. Regardless of the method used, all distribution maps must be applied and interpreted with great caution due to uncertainties.

Furthermore there is a need to consider more fully the likely distribution of habitat 50 years into the future based on climate change predictions. Habitat models can be coupled with climate envelope models to forecast changes in species ranges under different climate change models (e.g., Loarie et al. 2008).

4.4 Information Sources

We recommend considering the following information sources to bolster the scientific foundations of the plan and plan documents.

- California Riparian Habitat Restoration Handbook (Griggs 2008). This recent publication is based on years of experience designing, implementing, and monitoring riparian and riverine habitats in California, and serves as a practical "how-to" guide for planners and practitioners.
- California Bird Species of Special Concern (Shuford and Gardali 2008).
- California Mammal Species of Special Concern.[7]
- Contra Costa County Breeding Bird Atlas (http://www.flyingemu.com/ccosta/).
- State Wildlife Action Plan (Bunn et al. 2005).
- Antioch Dunes National Wildlife Refuge Comprehensive Conservation Plan (USFWS 2002).
- The most recent publications and model results concerning climate change effects on species ranges and phenologies that pertain to the study area and species. For example, Loarie et al. (2008) assessed likely effects of climate change on California's flora, and predicted that about 2/3 of our endemic plant species will experience >80% range contractions over the next century, with major disassociation of current plant communities likely. Hijmans and Graham (2006) discuss the accuracy of predictions from widely used climate-envelope models, and Green et al. (2008) showed that such models are able to retroactively predict range shifts for bird species.
- ClimateWizard is a climate change modeling and analysis "toolbox" that should be ready for public use in the near future. It may be useful for investigating how climate change may

[7] Unfortunately, the most current version of this document has been under review for several years now and is not yet available. We recommend checking on the status with the California Department of Fish and Game. See also: http://www.dfg.ca.gov/wildlife/species/ssc/mammals.html

affect covered species and communities in the BDCP area. See http://faculty.washington.edu/girvetz/ClimateWizard/index.html for more information.

- PRBO Conservation Sciences has created predictive models of species distribution for 19 different bird species using a machine-learning algorithm called Maxent (Phillips et al. 2006, http://www.cs.princeton.edu/~schapire/maxent/). The models predict distributions based on species occurrence locations and GIS-based environmental data layers. This approach can significantly improve predictive ability over simple habitat suitability index (HSI) or wildlife habitat relationship (WHR) models, which are often based on broad-scale habitat associations that are not necessarily applicable throughout a species' range. CADC (http://www.prbo.org/cadc/) provides links to maps for 19 species of land birds the Central Valley that includes the delta region, including California Bird SSC and California Partners in Fight (http://www.prbo.org/cms/258) focal species. For more information on modeling methods: see http://data.prbo.org/cadc/tools/lip/background.php.

5 Conservation Measures

Based on our review of information provided by the consultants, the advisors offer some recommendations about how conservation measures under consideration to benefit aquatic communities and species may affect terrestrial communities and species, along with some additional recommendations for conservation actions specific to the terrestrial resources. Our discussions focused primarily on the following pragmatic questions:

- What potential positive or negative effects might the proposed conservation measures (Attachment 3, Documents 4-8) have on non-aquatic species and communities? How can potential negative effects be avoided, minimized, or mitigated, and how can potential positive effects be enhanced?
- How can restoration of floodplain, intertidal marsh, channel margin, and riparian vegetation designed to benefit covered fish species be implemented or refined to also benefit non-aquatic species?
- Is establishing appropriate hydrologic conditions sufficient to provide for the natural establishment of native woody riparian vegetation ("passive restoration") or is more active restoration, such as planting trees and shrubs, necessary?
- Will native species and communities naturally shift ranges in response to changes in hydrological regimes (e.g., upslope shifting of intertidal plants) or colonize restored habitats, or is more active intervention necessary (e.g., transplantation or reintroduction)?
- What additional conservation actions should be considered to benefit covered non-aquatic species, beyond those conservation measures already being considered to benefit aquatic species?
- Are there specific locations in the planning area that are essential to sustaining populations of covered terrestrial species, or "hotspots" where numerous species coexist, and that therefore should be focal areas or avoidance areas for conservation measures?

Based on these discussions, we have organized recommendations for BDCP conservation measures into the following sections on conservation design principles, recommended analyses, locations of conservation concern, restoration recommendations, and species-specific conservation actions.

5.1 Conservation Design Principles

We recommend the following general principles be considered during the selection, design, and implementation of conservation measures:

- Plan conservation measures hierarchically, working from ecosystem to community to species-level considerations. Do not plan conservation measures for specific covered species or communities in isolation, without considering their relationships with other species and communities in the broader ecosystem.
- Design reserve or management areas to achieve mosaics of community types within areas large enough to support the most area-dependent covered (or planning) species and desired ecological services, and to accommodate future shifts due to climate change (e.g., sea-level rise, changing runoff patterns, shifting climate "envelopes").
- Strive for representation of all community types in habitat mosaics well distributed across the Delta, but considering site-specific conditions. Where possible, maintain or create "soft edges" or natural transitions along environmental gradients, as opposed to abrupt transitions or "hard edges" between community types.
- Bigger is better for habitat conservation and restoration sites, but don't ignore small areas that support rare communities or species. For example, small areas of seasonal wetlands, inland dunes, or alkali flats support disproportionate numbers of imperiled species.
- Seek to preserve and enhance natural heterogeneity in elevation, water depth, flooding frequency, nutrient conditions, vegetation types, and adjacency of different habitat types within and among the conserved, restored, or maintained habitat mosaics.[8]
- Enhance and preserve habitat connectivity where possible to maximize potential for natural range shifts, population expansions, escape from disturbance events (fires, floods), and maintenance of ecological processes, and to avoid isolating small populations of those species having limited dispersal abilities.
- Strive to create self-sustaining systems, but recognize that some communities and species may need active or perpetual management. For example, some invasive, nonnative species may require prolonged control efforts to sustain covered species or communities that they adversely affect.

5.2 Recommended Analyses

We recommend the following analyses be performed prior to finalizing the plan's conservation design, to assess likely effects of proposed covered activities and conservation measures on non-aquatic resources, and to inform how best to design and locate covered activities and conservation measures.

[8] A variety of observational studies demonstrate that species diversity is higher in heterogeneous habitats than in homogeneous habitats (Harman 1972; Abele 1974; Pollock et al. 1998; Williams et al. 2002).

- Do an overlay analysis for covered actions (e.g., facilities, conveyance alignments) and conservation measures (e.g., potential wetland restoration sites) with known and potential locations of covered species and communities. This should include an assessment of how changing hydrological regimes (water depth, flows, flooding, etc.) overlay onto existing ecological communities and species. Assess how the combination of changes will affect the conservation design principles discussed in section 5.1 (e.g., community representation, habitat patch size, environmental heterogeneity, natural gradients, maintenance of rare communities, and adjacency and connectivity of existing community types within mosaics). Pay particular attention to the potential for rare communities, such as seasonal wetlands and inland dune scrub, to be impacted. This should include consideration both of direct effects (e.g., flooding of rare upland habitats for wetland restoration) as well as potential indirect effects (e.g., constraining options for restoration efforts that could be carried out by other entities or under other plans).
- Assess for each covered species whether natural range shifts or colonization into restored habitat is likely to occur with changing conditions (e.g., hydrological and sea-level changes, restoration actions), or whether translocation/transplantation is required. For species not likely to shift naturally, prioritize avoidance of occupied areas and consider translocation/transplantation plans as part of the adaptive management program.
- Assess the distribution of “hard” vs. “soft” edges and determine where restoration actions can be used to soften edges. For example, determine where covered wetland or transitional plants are located at unnaturally sharp transitions to other physical conditions or habitat types that may constrain their ability to shift range over time in response to climate change and rising water levels. This analysis can inform where restoration actions could be prioritized to sustain ecological shifts due to water-level changes (including grading to create gradual elevation gradients and revegetation to create wetland-upland vegetation gradients).
- Use climate envelope models coupled with habitat models (Loarie et al. 2008, Hijmans and Graham 2006, Green et al. 2008) to identify potential effects on covered species over a 50-year horizon. This could inform where offsite conservation actions may be more effective in hedging against climate change for some covered species.

5.3 Locations of Special Concern

The advisors discussed whether there are certain geographic locations in the BDCP plan area that are of particular importance to at-risk species or communities, or to maintaining critical ecological processes. The following are a few key locations where impacts should be avoided or where additional conservation, restoration, and management may be beneficial. We realize that these locations and their importance are likely already well known to BDCP participants, but felt their importance was worthy of emphasis.

- **Staten Island** is a critical wintering area for sandhill cranes and other birds, due in large part to wildlife-friendly agricultural practices.
- **Franks Tract State Recreation Area**. In addition to its importance to aquatic resources, the marshes of Frank’s Tract are a hotspot of bird diversity and support a variety of rare and imperiled species, including California black rail, yellow warbler, yellow-breasted chat, and song sparrow.

- Occupied areas for riparian brush rabbits, including **Stewart Tract**, and near Lathrop. Occupied areas should be better defined by surveys currently underway by ESRP.
- **Antioch Dunes** represent a small remnant of a very rare ecological community that supports numerous endemic and imperiled species (see Sections 2 and 3). Remaining dunes have become isolated by urban development, limiting potential for restoring or expanding habitat.

5.4 Restoration Recommendations

- Recognize that restoration is a process, not a one-time action. We recommend following the restoration process designed by River Partners (Griggs 2008) for riparian and riverine restoration projects.
- Passive riparian restoration (just restoring semi-natural flooding regimes) is unlikely to be effective due to invasive weeds and insufficient colonization by dispersal-limited species. Some planting of woody vegetation, including both understory and overstory plants is recommended (Riparian Habitat Joint Venture 2004). Also, follow-up management to control invasives may be needed for up to 10 years post restoration to ensure success, and translocation may be necessary for some species.
- Given that water level changes will occur (due to conveyance changes, restoration efforts, and climate change), design and engineer plan facilities and structures in a manner that allows for control of water flows and depths to maintain diverse ecological conditions and particular species' needs. We recommend assigning a BDCP Work Group or Technical Team to evaluate the range of conditions desired to support the diverse requirements of covered species, communities, and processes in the plan area (terrestrial as well as aquatic). Recognize that optimizing how these metrics can best be manipulated to sustain covered species should be a focus of the systematic adaptive management and monitoring program.
- All else being equal, locate habitat restoration areas near existing habitat areas to expand or connect similar habitats, and to facilitate population expansions for covered species. For example, consult The Nature Conservancy's Cosumnes Watershed Plan and prioritize adjacent or nearby restoration sites. On the other hand, distributing restoration sites across the plan area will capture broader gradients in ecological conditions and may help spread the risk of restoration failures, maximize habitat diversity, and deal with uncertainties due to climate change and other dynamics.
- For floodplain restoration, consider leaving breached levees at least partially in place to provide physical habitat diversity and serve as refugia for species during floods ("bunny mounds"). Such physical features provide for habitat heterogeneity and increased bird diversity (Riparian Habitat Joint Venture 2004). However, it is important that old levees or other elevated areas be vegetated or revegetated with natural, local, plant palettes to provide escape cover during flood events as well as year-round habitat for diverse covered species.
- Also for floodplain and marsh restoration, meandering and dendritic channels are better than straight, undivided, and unbraided channels. Where floodplain areas are to be graded to create proper depths and drainage, consider leaving some permanent aquatic habitat (slightly deeper ponds or channels) to provide habitat for giant garter snakes, so long as these are configured to prevent fish stranding.

- Strive to create natural combinations of habitat types in mosaics that transition along physical gradients, rather than restoring single community types in isolation. For example, where tidal emergent marsh restoration is planned, also restore adjacent transitional and upland vegetation communities moving up the elevation gradient. This establishes the natural mosaic of habitat conditions required by many species, increases biological diversity and foodweb complexity for covered species (including fish), and will help accommodate ecological shifts due to changing climate and water levels.
- Use restoration to increase the rarest habitat types, if feasible. Seasonal wetlands (vernal pools) stand out as a rare habitat type that may be affected by project actions. Although vernal pool creation is controversial as a mitigation action, there may be opportunities for enhancing or restoring existing or former vernal pool areas in appropriate locations. If adverse impacts to vernal pools and associated species are unavoidable, offsite conservation of intact vernal pool systems may be preferable to attempting to create or restore vernal pools within the plan area. Inland dune scrub is also extremely rare. Although we do not anticipate direct negative plan effects on inland dune communities, BDCP actions have potential to create opportunities for restoring dune communities in some locations, perhaps to be implemented by other entities or plans.
- Use restoration to create "soft edges" between habitat types along ecological gradients. For example, many populations of potentially covered plant species occupy narrow bands of conditions along the elevation-tidal gradient, and many are currently up against "hard edges" (i.e., sharp transitions to other physical conditions or habitat types) due to dikes, levees, or other artificial features. This provides little or no opportunity for these populations to shift ranges with changing water levels or hydrological regimes. Where possible, restoration should be used to soften such edges via grading and/or revegetation to create opportunities for gradual range shifts and other adjustments to changing conditions.

5.5 Species-specific Conservation Actions

The advisors do not recommend relying on species-specific mitigation actions or structures (e.g., artificial burrows, nest boxes, nesting islands, "bunny mounds," created pools) as *primary* conservation tools. Conservation, maintenance, and restoration of intact habitat mosaics and ecological communities must be primary. However, the following specific mitigation actions should be considered as supplements to conservation and management of diverse habitats to enhance habitat value, particularly where covered species face specific life-requisite shortcomings despite habitat conservation and restoration:

- **Artificial burrows** are sometimes used by nesting burrowing owls, but have not been shown to increase owl populations in the long term. It is better to maintain natural burrow conditions and healthy prey populations (e.g., no ground squirrel control programs or insecticide use). Artificial burrows may be beneficial in certain situations where natural burrows are limiting as a supplemental mitigation measure.
- "**Bunny mounds**," or areas of ground elevated above the highest expected flood levels, are important in floodplain habitats to allow for escape by riparian brush rabbits and other species. These can be expensive to create from scratch, especially if fill has to be transported from other sites, but high mounds that are vegetated with brushy cover can contribute significantly to sustaining individuals and populations during floods, and create habitat

heterogeneity that also benefits diverse communities of birds and other taxa. Look for opportunities to get "free bunny mounds" such as, by leaving portions of the old levee as elevated ground when breaching levees for floodplain restoration. These should be revegetated with appropriate trees and shrubs, if necessary.

- **Nesting islands.** Creating or leaving some higher ground within subtidal and intertidal restoration areas can provide nesting islands for some shorebirds as part of an overall heterogeneity strategy.
- **Brown-headed cowbird trapping** (following guidelines of the North American Cowbird Advisory Council http://cowbird.lscf.ucsb.edu/) can benefit populations of songbirds that are adversely affected by nest parasitism by this species, such as least Bell's vireo and yellow warbler.
- **Contaminant control**, including control of herbicides, rodenticides, and light pollution may be an important management measure in conservation areas.
- **Vegetation management** on levees. We do not recommend burning, mowing, or herbicide use to control vegetation on levees.
- **Feral cat control** may be necessary in conservation areas or other areas important to covered species. Restrictions on maintaining feral or free-roaming cat populations should be enforced throughout the plan area.

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Attachment A – Advisor Biographies

Dr. Peggy L. Fiedler, Senior Botanist & Co-Director, Ecosystem Science and Natural Resources Management Services, WSP Environment & Energy, LLC. Dr. Fiedler has 30 years of experience in field research and teaching in conservation biology, ecology and evolutionary biology, and waters/wetlands ecosystem restoration. Her current interests are focused on designing plant community types in mega-diverse floras for ecosystem restoration, applying population viability models and metapopulation theory to the reintroduction of rare plant species, understanding demographic patterns of rare plants (including hybrid taxa) and improving monitoring protocol in waters/wetland ecosystem restoration.

Geoffrey R. Geupel, Director, Terrestrial Ecology Division, PRBO Conservation Science, Petaluma, CA. Geoff has over 28 years of experience in ornithological monitoring and conservation research in California. Recent publications and presentations have helped define bird monitoring protocols now used throughout North America. He has taught numerous technical workshops on bird monitoring and currently oversees more than 20 projects that use bird data to evaluate conservation actions. Current areas of interest include breeding and population biology, demographic monitoring, bird response to habitat restoration and management, and developing measurable populations metrics for conservation planning. He is currently Co-chair of California Partners in Flight and is formally involved with five of the six habitat joint ventures in the state.

Dr. Marcel Holyoak, Professor, Environmental Science and Policy, University of California at Davis. Dr. Holyoak is broadly trained as a population and community ecologist, with interests in conservation, biostatistics, and theoretical ecology. Much of his recent work addresses the responses of individual species and ecological communities to habitat fragmentation. His research group has conducted most of the work on the federally threatened Valley Elderberry Longhorn Beetle that has been performed in the last decade. He has a PhD. from the University of London (Imperial College) in ecology and biostatistics from 1992, and a BSc. in biology from the same university in 1989. He is acting Editor-in-Chief of a top-ranked ecology journal, *Ecology Letters*, and will become the new editor for this journal in January 2009.

Dr. Patrick A. Kelly, **Coordinator and Director of Endangered Species Recovery Program (ESRP) and Professor of Zoology, California State University, Stanislaus**. Dr. Kelly's main research interests are in mammalian ecology and conservation, and his current research focuses on the conservation and recovery of endangered mammals in California, including the riparian brush rabbit and riparian woodrat. He joined ESRP as Assistant Director in July 1993 and became Director in January 1996. Pat received a B.Sc. from University College Galway, Ireland, in 1981, and a Ph.D. from the University of California, Berkeley, in 1990.

Dr. Wayne Spencer, Senior Conservation Biologist, Conservation Biology Institute, San Diego, CA. Dr. Spencer is a conservation biologist and wildlife ecologist with expertise in conservation planning and endangered species recovery. He has worked on various regional NCCPs and HCPs in California as a consulting biologist, science advisor, and science facilitator. His research focuses primarily on rare and endangered mammal species, including the Pacific fisher, Stephens' kangaroo rat, and Pacific pocket mouse. He is also a Research Associate with the San Diego Natural History Museum. He served as the Facilitator for this BDCP Non-aquatic resources workshop and report.

Dr. Glenn Wylie, **Research Wildlife Biologist, USGS Western Ecological Research Center, Dixon, CA**. Dr. Wylie is a wildlife biologist specializing in wetland ecology as is concerns migratory birds and listed species in California. In the last 10 years he has been researching the distribution, abundance, and ecological requirements of giant garter snakes. Dr. Wylie was a science advisor for the Recovery Team for giant garter snakes and has advised habitat conservation planning for the city of Sacramento. He is currently advising Solano County in developing a habitat recovery plan as well as participating in the Yuba/Sutter and Yolo County efforts in habitat conservation planning.

Attachment B – Workshop Agenda

AGENDA
Bay-Delta Conservation Plan
Independent Science Advisors' Workshop
Concerning Non-aquatic Resources

30 September 2008

Hawthorn Suites Hotel, Crocker Room
321 Bercut Road, Sacramento. 916-441-1200
(Exit Richards Blvd East off of I-5, take first left at Bercut)

0900 – 1030 Orientation Session (Science Advisors and Consultant Team)

0900 – 0915	Welcome, introductions, and logistics
0915 – 0930	Overview of science advisory process and workshop goals (Wayne Spencer)
0930 – 1000	Overview of BDCP conservation approach and issues (Pete Rawlings, John Gerlach, and Jim Estep)
1000 – 1030	Q & A session and open discussion
1030 – 1045	Break

1045 – 1600 Advisors Only Session

1045 – 1130	Review of proposed covered species list and process
1130 – 1200	Review of existing conditions documents (Existing Ecological Conditions, stressors summaries, species accounts, distribution maps, habitat measures)
1200 – 1300	Working lunch (provided) – continued discussion of existing conditions documents and maps
1300 – 1400	Principles for addressing data gaps and uncertainties
1400 – 1500	Principles for conservation, restoration, and management of species, communities, and ecological processes
1500 – 1515	Break
1515 – 1600	Outline report and writing assignments
1600	Adjourn

Attachment C – Documents Reviewed By Advisors

Advisors reviewed the following documents in preparing this report. All documents (accept Document 1, BDCP Planning Agreement) are unpublished Draft reports, memoranda, chapters, or handouts prepared by SAIC.

1. October 6, 2006. Planning Agreement regarding the Bay Delta Conservation Plan.
2. March 7, 2008. Draft existing ecological conditions chapter and covered species accounts (on CD).
3. May 22, 2008. Proposed covered species selection process and potential species for coverage under BDCP.
4. September 5, 2008. Steering Committee Handout 1. Summary table: Other Stressors Working Group recommended conservation measures for consideration by the BDCP Steering Committee.
5. September 5, 2008. Steering Committee Handout 2. Other Stressors Working Group recommended conservation measures for consideration by the BDCP Steering Committee.
6. September 5, 2008. Steering Committee Handout 3. Summary table: Draft other stressors conservation measures by working biological objectives.
7. September 19, 2008. Steering Committee Handout 1. Restoration Program Technical Team recommended conservation measures for consideration by the BDCP Steering Committee.
8. September 19, 2008. Steering Committee Handout 2. Summary table: Draft habitat restoration conservation measures by working biological objective.
9. September 19, 2008. Draft plant species accounts and associated distribution maps for the following species:
    - Alkali milk-vetch
    - Delta button celery
    - Delta mudwort
    - Delta tule pea
    - Heckard’s peppergrass
    - Legenere
    - Mason’s lilaeopsis
    - San Joaquin spearscale
    - Soft bird’s beak
    - Suisun Marsh aster
10. September 19, 2008 Draft animal species accounts and associated distribution maps for the following species:
    - California black rail
    - California clapper rail
    - Conservancy fairy shrimp
    - Giant garter snake
    - Greater sandhill crane

- Longhorn fairy shrimp
- Riparian brush rabbit
- Salt marsh harvest mouse
- Suisun shrew
- Swainson's hawk
- Tri-colored blackbird
- Valley elderberry longhorn beetle
- Vernal pool fairy shrimp
- Vernal pool tadpole shrimp
- Western burrowing owl
- Western spadefoot toad
- Yellow-breasted chat

11. September 30, 2008. Poster-sized maps and PDFs of the following plan maps:

- BDCP natural communities
- Elevation-based restoration suitability categories
- Aerial imagery of the planning area
- DWR agricultural classes
- BDCP conveyance route options

Appendix G-3

Bay Delta Conservation Plan Independent Science Advisors' Report on Adaptive Management

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BAY DELTA CONSERVATION PLAN

INDEPENDENT SCIENCE ADVISORS' REPORT

ON

ADAPTIVE MANAGEMENT

Prepared for
BDCP Steering Committee

Prepared by

Independent Science Advisors:
Cliff Dahm, CALFED Science Program
Tom Dunne, University of California Santa Barbara
Wim Kimmerer, San Francisco State University
Denise Reed, University of New Orleans
Elizabeth Soderstrom, American Rivers
Wayne Spencer, Conservation Biology Institute
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John Wiens, PRBO Conservation Science
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Science Facilitator:
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February 2009

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Executive Summary

This report summarizes recommendations from a group of independent scientists (Advisors; Appendix A) convened in December 2008 (Appendix B) concerning incorporation of adaptive management into the Bay Delta Conservation Plan (BDCP). The report includes a general review of pertinent BDCP documents and a recommended framework for incorporating adaptive management into the planning, design, and implementation of the BDCP.

Comments on BDCP Documents

It is clear from documents reviewed by Advisors (Appendix C) that efforts to develop an Adaptive Management Program (AMP) for BDCP are in their early stages. The documents show progress toward defining the elements of an AMP but lack several elements essential to effective adaptive management. The incomplete state of the documents made it difficult to evaluate the plan's scientific foundations, and many statements in the documents suggest a need to more fully assimilate and apply existing knowledge about the Delta to the development of conservation measures and the AMP.

The Advisors offer the following general comments and recommendations:

Existing Knowledge and Peer Review - Far more is known about the Bay-Delta ecosystem than is suggested by the BDCP documents we reviewed. The extensive knowledge base about the Delta should be fully exploited in selecting and designing BDCP actions. The omission of critical knowledge about the functioning of the Bay-Delta ecosystem also indicates the need for more development of the conservation plan itself. **We strongly recommend that technical documents that form the basis of the BDCP be reviewed by independent technical experts to ensure the credibility of the program and a sound foundation for conservation actions.**

Goals and Objectives - We agree that goals and objectives should be placed within a hierarchy of ecosystems, communities, and species. However, most objectives stated in the documents, and the conservation measures meant to address them, apply only to the species level. **We recommend developing explicit community and ecosystem objectives to reflect the hierarchical approach described in BDCP documents.**

Modeling - Models are extremely valuable for formalizing the link between objectives and proposed conservation measures to clarify how and why each conservation measure is expected to contribute to objectives. This key element of adaptive management is largely missing from BDCP documents we reviewed. **We recommend more extensive and explicit use of models to formalize knowledge about the system and to select, design, and predict outcomes of conservation measures to be implemented and monitored.**

Feedback – Formal processes for devising actions to maximize learning, and for assimilating new knowledge to provide the feedback that is key to adaptive management, were not discussed in the documents. **We recommend that greater attention be given to the learning value of actions, and to establishing a formal process by which new knowledge is used to alter actions or revise goals or objectives.**

Integration - The documents reviewed by the Advisors did not link the various conservation measures together as a package, and there was little sense of synergy or potential conflict among these clearly related actions. **We recommend the development of models to show clearly how various actions relate and how interactions will be integrated across multiple conservation measures and the entire adaptive management process.**

Guidance for a Robust Adaptive Management Program

Effective adaptive management includes several key steps, some of which are not included in the documents we reviewed. Adaptive management does far more than simply adjust actions as new information becomes available (which is merely common sense). It is a more comprehensive process of deciding how to choose initial actions in the face of uncertainty and systematically learning and evaluating how the manipulated system responds to those activities so that changes can be made as events unfold. Key missing elements of adaptive management in BDCP documents include (1) the formal setting of goals *based on problems to be addressed*, (2) the establishment of objectives (as distinct from goals), and (3) the use of conceptual or simulation models to bring the knowledge base to bear on the problems to be solved and predict outcomes of conservation actions. In addition, (4) monitoring must be more clearly and formally designed to establish criteria to evaluate effectiveness, and (5) monitoring results must be analyzed and assimilated to provide the information necessary for the feedback critical to adaptive management. Most critical are the succeeding steps (6) of capturing and interpreting information from monitoring and other sources to evaluate how the actions are working, what they are accomplishing, and how the knowledge base is changing. These critical steps require substantial investment in time, people, and resources.

We suggest that particular attention be paid to the following:

The Adaptive Management Approach - The form of adaptive management to apply (active vs. passive)[1] to a given conservation measure depends on the scope of the measure and its degree of reversibility. In the design phase, it is important to recognize where an adaptive management strategy resides on the active-to-passive spectrum.

Knowledge Base - The knowledge base comprises the scientific understanding of a system; it should be used to identify likely influences of conservation measures on the ecosystem and the degree of confidence in those influences. It provides the context for establishing goals and objectives, the information base for models, and the foundation for selecting, designing, and monitoring conservation measures.

Assessment and Synthesis - Assessment is critical to making monitoring useful. In the adaptive management framework, monitoring provides a quantitative basis for analysis, synthesis, and evaluation of knowledge to support management decisions.

[1] Active adaptive management is experimental, involving manipulations intended to achieve conservation goals but also to improve knowledge. Passive adaptive management is not experimental, but is nevertheless approached from a scientific perspective to improve knowledge and adapt strategies during project implementation.

Continual Assimilation of Knowledge and Decision Making - The weakest aspect of most adaptive management plans is in the sequence of steps required to link the knowledge gained from implementation and other sources to decisions about whether to continue, modify, or stop actions, refine objectives, or alter monitoring. This step must be much more fully developed than was evident in the BDCP documents we reviewed. Responsibility for this step should be assigned to a highly skilled agent (person, team, office) having the right mix of policy and technical expertise. This investment is critical to making adaptive management effectively support the BDCP.

1 Introduction

This report presents recommendations from a multidisciplinary group of independent science advisors concerning the use of adaptive management in the development and implementation of the Bay Delta Conservation Plan (BDCP). The advice and recommendations are intended not to question or promote particular plan goals or policies, but to provide guidance for incorporating adaptive management into the BDCP.

The group of nine advisors (Appendix A) was convened by the BDCP Steering Committee at a facilitated workshop held on December 17-19, 2008 (Appendix B). Prior to the workshop, advisors were provided with several draft BDCP documents for review (Appendix C). Comments in this report are based on the documents we reviewed and brief discussions with representatives of the BDCP planning team, who presented overviews of the emerging plan and important unresolved issues during two open sessions at the workshop.

Because the draft documents provided to us were in an early stage of development and did not describe a comprehensive Adaptive Management Program (AMP), we did not evaluate them in detail as a finished plan. Rather, we focused our effort on providing guidance for structuring an AMP for the BDCP that would support effective application of existing and evolving scientific understanding to BDCP decisions both before and during its implementation.

Section 2 articulates eight principles that we suggest be used as a foundation for the BDCP AMP. Section 3 incorporates these fundamental principles into an adaptive management framework tailored specifically to the BDCP and describes key elements of that framework. Appendix D provides two detailed examples of how draft BDCP conservation measures could be revised to better reflect the suggested framework.

2 Principles for Adaptive Management

The following principles for effective adaptive management emerged from our deliberations and are integral to our proposed adaptive management framework (see Section 3):

1. The scope and degree of reversibility of each proposed action (i.e., conservation measure) determines the form of adaptive management that can be applied (e.g., “active” or experimental adaptive management versus “passive” adaptive management).
2. The knowledge base about the ecosystem is key to decisions about what to do and what to monitor, and includes all relevant information, not just that derived from monitoring and analysis within the context of BDCP.
3. Program goals should relate directly to the problems being addressed and provide the intent behind the conservation measures; objectives should correspond to measurable, predicted outcomes.

4. Models should be used to formalize the knowledge base, develop expectations of future conditions and conservation outcomes that can be tested by monitoring and analysis, assess the likelihood of various outcomes, and identify tradeoffs among conservation measures.
5. Monitoring should be targeted at specific mechanisms thought to underlie the conservation measures, and must be integrated with an explicitly funded program for assessing the resulting data.
6. Prioritization and sequencing of conservation measures should be assessed at multiple steps in the adaptive management cycle.
7. Specifically targeted institutional arrangements are required to establish effective feedback mechanisms to inform decisions about whether to retain, modify, or replace conservation measures.
8. A dedicated, highly skilled agent (person, team, office) is essential to assimilate knowledge from monitoring and technical studies and make recommendations to senior decision makers regarding programmatic changes.

In the following section we expand on these principles and provide details of the proposed adaptive management framework.

3 Framework for Adaptive Management

Figure 1 presents a framework for incorporating adaptive management into the planning, design, and implementation of the BDCP. The framework is based on previously developed adaptive management frameworks, but has been refined to make key aspects of the process more explicit and to tailor the approach to the needs of the BDCP. The framework is specifically intended to improve the approach described in the draft BDCP documents and to avoid shortcomings of many previous AMPs. **We recommend adopting this refined framework to guide BDCP planning and implementation.**

In the following sections we detail elements of this adaptive management framework, while expanding on the principles presented in Section 2. Appendix D provides two detailed examples of how elements of the proposed BDCP Conservation Measures might correspond to the elements of the diagram and be guided by the proposed framework and principles.

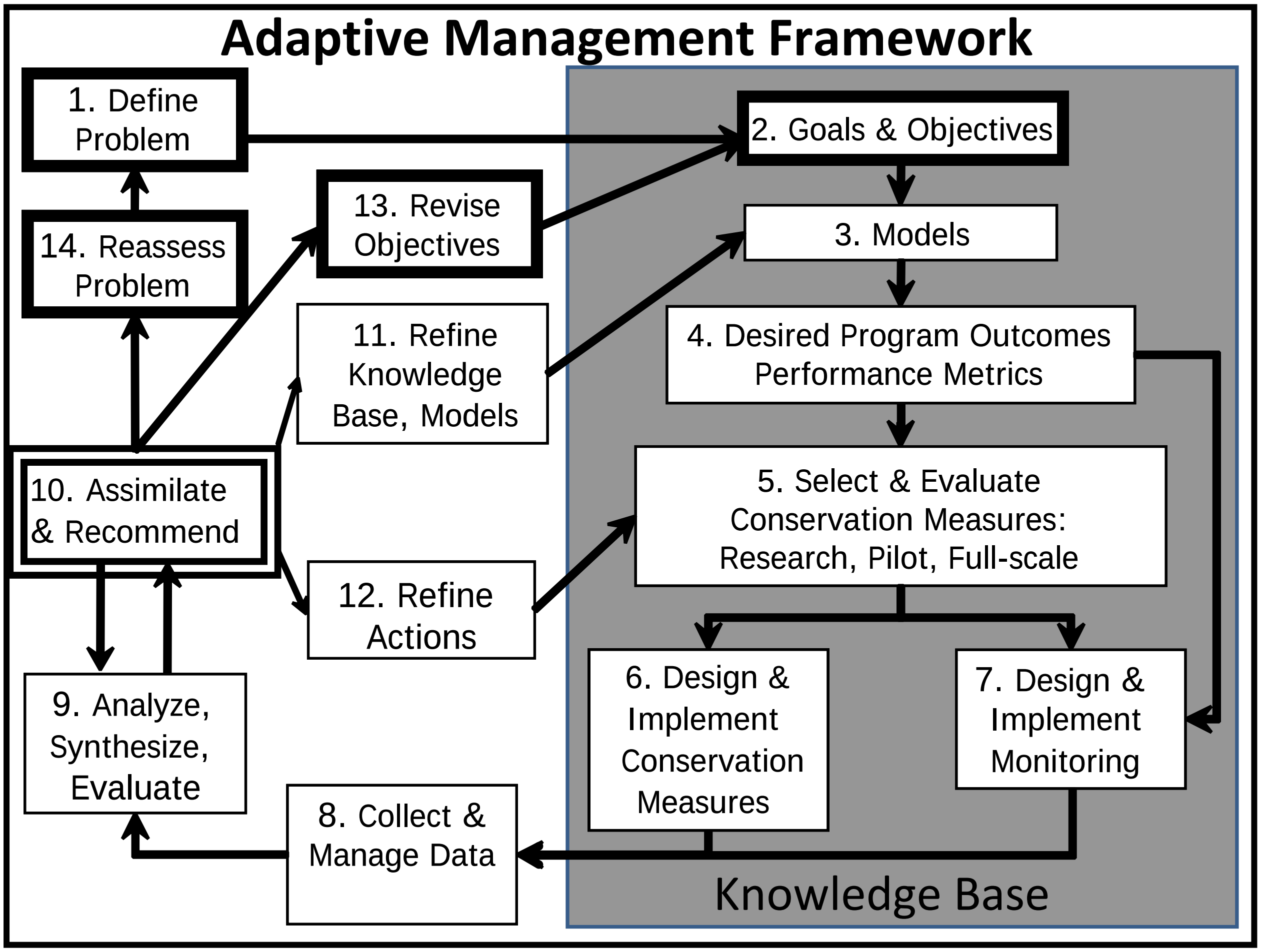

Figure 1. *A recommended AMP framework for BDCP showing the flow of information and responsibilities of different entities.* The large shaded box underlying the right side of the figure represents the knowledge base for defining goals and objectives, designing predictive models, predicting outcomes, identifying performance metrics, and designing and implementing conservation measures and monitoring actions. Boxes framed with thin lines represent tasks performed by technical staff, such as scientists, land and water managers, and other analysts. Boxes framed with bold lines represent tasks performed by senior decision makers (i.e. policy makers and program managers who control program objectives and funding). The box framed with double lines (Box 10) represents a key step that is missing from most AMPs: Assimilate and Recommend. This task requires a body of skillful "polymaths" who understand both the technical and policy implications of the information passed along by technical staff (who analyze, synthesize, and evaluate monitoring and other data; Boxes 8 and 9). The task represented by Box 10 is to assimilate this diverse information, understand its consequences, and formulate recommendations to both the senior decision makers and the technical staff, such as revising plan objectives or conservation measures.

3.1 Form of Adaptive Management (Principle 1)

The literature on adaptive management defines two broad categories: active and passive. Active adaptive management is experimental, involving manipulations intended to achieve conservation goals but also to improve knowledge. Passive adaptive management refers to actions that are not experimental, but that are nevertheless approached from a scientific perspective in order to improve knowledge and adapt strategies during project implementation.

The form of adaptive management applied to a given conservation measure depends on the scope of the measure and its degree of reversibility. At one extreme, there is only one Delta, ruling out simultaneous replication of actions that broadly affect the system. In addition, some conservation measures, such as major investment in an around-Delta conveyance, are unlikely to be reversed, so temporal replication is also impossible. In such circumstances, monitoring of processes and of system responses to natural and managed events form the basis for learning, as is the case in various non-experimental sciences. At the other extreme, there are many opportunities for experimental manipulation to achieve goals while simultaneously learning. For example, gates on Delta tidal channels could be operated on a schedule intended to produce contrasts with predictable and testable consequences. It is crucial to recognize that passive adaptive management differs from active only in the use of experimental manipulations and the consequently greater power to detect the influence of the manipulations. Otherwise, these two forms of adaptive management proceed according to identical principles and processes, as outlined in Figure 1. Note also that research aimed at particular sources of uncertainty can be part of an adaptive management program (Box 5 in Figure 1).

3.2 Applying the Knowledge Base (Principle 2)

The knowledge base (large gray box in Figure 1) is key to decisions about what conservation measures might be implemented and what responses to monitor. It forms the foundation for all steps from formulation of goals and objectives (Box 2) to the selection, design, and implementation of conservation measures and monitoring (Boxes 6 and 7). The knowledge base comprises the scientific understanding of the system and is used to identify likely influences of conservation measures on the ecosystem. It also includes knowledge of the feasibility, costs, and probable external implications of projects for the broader society and economy of the region. The knowledge base provides the context for establishing goals and objectives, the source of information for models used to project conservation outcomes, and the basis for believing that an action will have a certain outcome. The knowledge base is continually updated as new information becomes available and as adaptive management proceeds.

Far more is known about the Bay-Delta ecosystem than is suggested by BDCP documents we reviewed, which strongly emphasized (1) uncertainties about the system, (2) a central role for hypothesis testing, and (3) the role of monitoring data in reducing uncertainties. We certainly do not discount the importance of these issues, but point out that the extensive knowledge base about the Delta and the planning context should be fully exploited in selecting and designing BDCP actions. Enough is known about the Bay-Delta ecosystem, or can be inferred from studies of other systems, to conclude that:

1. Certain outcomes can be predicted with confidence[2].
2. Most scientific knowledge about the Delta has been derived by approaches other than hypothesis testing (e.g., analysis of monitoring data, modeling, and parameter estimation).
3. Not all pertinent knowledge comes from regular monitoring; knowledge may also stem from short, targeted field campaigns and observations in single natural events that cannot be replicated.
4. Monitoring adds no knowledge without a dedicated process for data management and analysis.

A thorough understanding of the knowledge base is essential for modeling, monitoring, and other actions to be efficiently focused on reducing key uncertainties.

For this plan to incorporate "best available scientific information" requires that the components of the overall knowledge base used for each step in the process be synthesized and referenced. The information in the knowledge base should be used according to a hierarchy that emphasizes peer-reviewed science and other formal evaluations. Published papers should be given the greatest weight (especially highly influential or often-cited, and therefore highly scrutinized and replicated papers), followed by unpublished papers, technical reports, newsletter articles, and presentations or personal communications from experts. Review or summary articles can be used in lieu of extensive lists of publications. Personal communications should be cited with the name and affiliation of the person and the date of the communication. Local knowledge of experts or stakeholders is also an important component of the knowledge base, even if not published, but such knowledge should be recorded explicitly so that it can be reviewed.

Although peer review is the gold standard of scientific publication, it may not always provide assurances as to the quality of the data or the accuracy of statistical analyses, since reviewers rarely have time to replicate reported analyses or examine raw data. Therefore studies used as a basis for significant decisions should be thoroughly checked and analyses replicated if possible.

Data used in analyses must have undergone a quality assurance check. Generally this is done routinely for widely-used data, such as daily flows, salinity, and fish abundance indices. Documents using the knowledge base should promote transparency by explaining clearly what we know and how we know it, with full citations to the sources of information (e.g., papers, data sets, websites, personal communications with affiliation) and ensuring that these are readily available (e.g., posting technical reports on websites).

The incomplete state of the draft BDCP documents we reviewed made evaluation of scientific content of the plan difficult. However, many statements in these documents suggest an incomplete knowledge of the Delta among the project team. For example:

- Literature citations were sometimes inaccurate (e.g., Handout #5 lines 41-45: "highly productive" and similar statements are not true and not stated in the reference).

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[2] For example, field studies in the California Bay-Delta and elsewhere indicate that restoring intertidal marsh will increase carbon input to estuarine food webs for well-understood biogeochemical reasons, although monitoring and research would be essential to show the magnitude of this input and its long-term fate.

- Inappropriate citations were used (e.g., the use of Kimmerer 2004 to support a statement about tidal marshes and sea-level rise on page 2-43 of the March 2008 Draft Existing Ecological Conditions Chapter and Covered Species Accounts).
- Often the most recent published findings were not used (e.g., Feyrer et al., 2007).
- Unpublished data and presentations appear to be given equal weight to published findings (e.g., Handout #5 page 28 line 33).
- Several statements fail to reflect the current state of knowledge or provide little substantive foundation, for example, in handout #4 page 14:
  - Lines 41-42: "These zooplankton can reduce phytoplankton to very low concentrations, resulting in a clear water state" is poorly supported by the citations provided. In fact, published work indicates that phytoplankton biomass in the Delta is rarely if ever limited by zooplankton (Kimmerer 2004).
  - Line 35: "Additionally, the statistical analyses used in this paper may be questionable" should be amplified and supported by reference to specific work.

Note that these and several other examples in Appendix D are presented only to illustrate a broad and pervasive problem identified by the Advisors in the documents that were provided. **We recommend that the technical documents that form the basis of the BDCP plan and conservation actions be reviewed by independent technical experts to ensure the credibility of the program and a sound foundation for conservation actions.**

3.3 Problem Statement Leads to Goals and Objectives (Principle 3)

A clear problem statement should link directly to program goals, which in turn are linked to specific objectives. The BDCP documents we reviewed generally failed to distinguish among these elements. The CALFED Ecosystem Restoration Program (ERP) Strategic Plan defines goals and objectives for ecosystem restoration, which BDCP planners might find helpful.

The problem statement specifies the issue or concern that proposed conservation measures are intended to solve or mitigate. If the problem is not stated clearly, the linkages to everything else in the adaptive management framework will be weak or inconsistent, compromising the entire approach.

Goals are broad, general intentions or visions for some aspect of the system. Goals propose broad solutions and encapsulate desired future conditions. For example, a central problem statement for BDCP is that some native fishes are in danger of extinction. One goal therefore is to restore the abundance of those species (ERP Goal 1). However, declines in each species may be linked to broader, systemic problems. Therefore, additional goals call for rehabilitation of natural processes (Goal 2) and habitats (Goal 4), and reductions in the rate of introduction of new species (Goal 5) and in contaminant effects (Goal 6). The last two goals are included regardless of whether a quantitative link can be made to the abundance of a particular species, because it is widely believed that accomplishing these goals is highly likely to favor several species and other societal preferences.

Objectives are specific, often quantitative, statements of outcomes that reflect the goals that the program is expected to achieve. Some objectives can be stated as quantitative targets for species or locations in a hierarchical arrangement (see Figure 4-2 of the CALFED ERP Strategic Plan). However, given uncertainties, it is not yet possible to develop quantitative conservation objectives for many species, communities, or processes, so many objectives must be stated in qualitative form. Nevertheless, as information accumulates, objectives can be refined and made progressively more quantitative. This step need not always await monitoring data, because predictive models applied within the context of the knowledge base can also assist in developing quantitative objectives (Box 3 in Figure 1).

Note that objectives for different species or communities may conflict or require tradeoffs (for example, altering flows to benefit one species may harm another). Such conflicts should not preclude development of objectives for each species or community. Rather, it would be beneficial to explicitly articulate such competing objectives and thereby highlight tradeoffs implicit in planning and management decisions.

We strongly recommend that the problem, goals and objectives, and the linkages among them, be clearly articulated steps in the process. The Advisors agreed with the approach of placing goals and objectives within the hierarchical scaling framework of ecosystems, communities, and species that was included in the draft BDCP Goals and Objectives documents. Careful consideration of program objectives within this context may help identify possible undesirable interactions and minimize conflicts among objectives that might occur if developed independently at the species level. In fact, most examples of objectives in the draft BDCP documents address individual species, with less attention to community and ecosystem level objectives. Thus, they fail to address the array of potential conflicts among objectives. Although the advisors encourage the continued inclusion of these species-specific objectives in the plan, **we recommend development of explicit community and ecosystem objectives to reflect the hierarchical approach described in the BDCP documents.**

3.4 Use of Models (Principle 4)

Models (Box 3) are used to formalize and apply the knowledge base, develop expectations, assess the likelihood of success, and identify tradeoffs. In particular, models should be used to formalize the link between objectives and proposed conservation measures to make clear how and why each conservation measure is expected to contribute to objectives. This key element of adaptive management is missing from the BDCP documents we reviewed, except for mention of hydrodynamic and particle tracking models. The use of models would make more explicit the relative potential benefits of different conservation measures and how they may interact (conflicts, tradeoffs, or synergies). Our impression on reviewing the BDCP documents is that this formal analytical step was skipped in jumping directly from objectives to potential conservation measures.

The types of models used in adaptive management should include at least conceptual, statistical, and process models. Conceptual models are used to make clear the expected links between actions and outcomes, the roles of other factors, the degree of confidence in the outcomes, and potential tradeoffs (e.g., among species or alternative conservation measures). The roles of conceptual models are described in Chapter 3 and Appendix B of the ERP Strategic Plan and the uses of conceptual diagrams (as components of conceptual models) are explained at http://ian.umces.edu/pdfs/stc_2008_conceptualdiagrams.pdf. A formalized approach to the development of conceptual models has been developed under the auspices of the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) and should be used to guide the development of any additional conceptual models needed for the BDCP. Statistical models may allow us to characterize empirically how a system works. However, statistical models may not allow us to predict all system responses, because they apply only within the range of conditions over which data have been collected.

Process models rooted in underlying mechanisms provide a much stronger basis for predicting system responses to environmental change (i.e., extrapolating beyond available data), although model calibration and validation of process models are more challenging than for statistical models[3]. Process models should be used increasingly as the knowledge base becomes more diversified and complex. Process models (e.g., population models, particle tracking models) express the mechanisms responsible for the relationships in conceptual models as mathematical equations and can incorporate uncertainty and system variability. Process models are especially useful in analyzing complex actions and developing plans for irreversible changes to the system (e.g., an around-delta conveyance). Given the expense and potential for unforeseen consequences of large-scale permanent changes to the system, process model simulations offer a relatively inexpensive way of anticipating problems and developing operational criteria or other design elements to minimize problems.

Process models also provide a powerful tool for refining reversible actions. For example, BDCP action FLOO1.1 (Yolo Bypass) includes a reference to varying operations to "adaptively manage" floodplain conditions and extensive monitoring to track changes. Such post-hoc monitoring will likely have low power to detect effects given background variability. Enough is known about this system to develop process models to forecast the magnitude of effects of these manipulations and maximize the value of the manipulation and the monitoring. Modeling will allow calculations of the monitoring effort needed to detect effects and comparisons between expectations and observations during the manipulations.

3.5 Desired Program Outcomes and Performance Metrics (Principle 5)

A key component of our proposed adaptive management framework is definition of measurable outcomes and associated performance metrics (Box 4 in Figure 1) that are directly related to the programmatic objectives via models (Box 3 and Section 3.4). These measurable outcomes and performance metrics are critical for several reasons. First, they document desires and expectations about how the system could function in the future following implementation of conservation measures. Second, they are used to track progress toward meeting the objectives. Third, they help define the monitoring essential to the evaluation of any chosen conservation measure. Measurable outcomes can be predicted using models (see Section 3.4). Each outcome should have at least one associated performance metric, a target for successful achievement of

[3] See BDCP Independent Science Advisors Report, November 2007 for a more detailed description of the potential application of statistical and process models to BDCP issues.

that outcome, a monitoring program designed to identify progress toward that target, and decision points for amending actions if acceptable progress is not being made.

3.6 Select and Evaluate Conservation Measures (Principles 2 and 4)

The specific actions to be taken as part of an adaptive management program (i.e., conservation measures) should be selected and evaluated based on a comprehensive and formal application of the knowledge base and models, with full consideration of possible interactions among the actions. At this step in the process (Box 5) critical decisions are made about which conservation measures to implement, as well as whether each measure is to be implemented as a full-scale action, as a pilot study, or as a research program. This decision regarding the nature or level of each action depends on each action's physical and temporal scale, the degree of confidence in its benefits, and the consequences of being wrong:

- A full-scale action is taken to solve a large-scale problem when (1) the action is considered highly likely to achieve or contribute to one or more key objectives, (2) the benefits are believed to outweigh potential detriments, and (3) there is little additional benefit to performing pilot studies or research before implementing the action.
- A pilot action is taken if there is good reason to think that the action will have an effect, but there are uncertainties that can be resolved only through manipulation of the ecosystem.
- Research is considered a conservation measure if it is directed at resolving specific issues key to implementation of the Plan.

The DRERIP scientific evaluation process initiated by the ERP Science Board includes an approach for evaluating conservation measures using conceptual models. Where available, process models may be more suitable for this task.

It is also important to consider the interactions among various conservation measures. The documents reviewed by the Advisors did not clearly link the various conservation measures together as a package, and there was little sense of synergy or potential conflict among the actions. Yet, many of the actions are clearly linked or represent different aspects of the same manipulation. For example, design of an around-Delta conveyance would perforce include operational requirements on inflows and outflows, cross-channel gate operations, south Delta flows, X2, and other flow-related aspects of the system. Thus, most if not all of the conservation measures would be influenced by, or result from, the new operational criteria. Likewise, changes in outflow (WAOP9) are acknowledged as the principal cause of changes in salinity in Suisun Bay and the western Delta (WAOP10), yet they are presented as if they were separate. It is confusing and inaccurate to present these conservation measures as independent actions. This also results in excessive repetition and impedes comprehension of the documents.

3.7 Prioritization and Sequencing of Conservation Measures (Principle 6)

As part of developing goals, objectives, and outcomes, attention should be given to determining the priority and sequencing of conservation measures. *Priority* indicates the relative importance or urgency of a conservation measure, while *sequencing* indicates the order in which the measures are implemented. It is unlikely that funds and other resources necessary for implementing all conservation measures will be immediately available when the plan is finalized and implementation begins. Even though priority and sequencing may be determined by financial or political considerations, the decision-makers should be provided with an assessment of the consequences of their choices that has been developed using the knowledge base.

Prioritization should involve the allocation of conservation measures to categories (e.g., High, Medium, or Low Priority) rather than ranking all measures relative to one another. This categorization should be based on consensus criteria that consider the scale and breadth of the expected outcomes relative to the objectives. For example, measures contributing to more than one objective should generally receive a higher priority ranking than those contributing to only one. In addition, measures *essential* to achieving an objective should receive a higher priority than measures that may further an objective but are not essential.

Sequencing criteria could include (1) ease of implementation, (2) interdependence of measures, (3) feasibility of near-term implementation, (4) availability of funding, (5) uncertainty of measure implementation and outcomes, and (6) the potential for synergies among measures.

3.8 Design and Implement Conservation Measures and Monitoring (Principles 5 and 6)

Once conservation measures have been evaluated and selected (Box 5) they must be designed, analyzed, implemented, and constructed (Box 6). By "design" we mean to clearly describe the actions to be undertaken, including exactly what will be done, where, on what schedule, how, by whom, with what anticipated results, and with what accompanying monitoring actions. In cases where the measure is being implemented as part of an adaptive management experiment, the design need not adhere to formalisms of strict experimental design. It should focus on achieving the desired conservation outcomes but should also consider how monitoring will be conducted and how data will be managed and analyzed to assess the relative performance of the experimental units. The design should carefully consider the pertinent knowledge base, including results of any relevant research, pilot studies, or full-scale studies performed in the previous step (Box 5).

The monitoring plan for a conservation measure is designed and implemented in parallel with the conservation measure itself (Boxes 6 and 7) to generate data useful in comparing system performance to expected outcomes. The National Research Council (1990) defines three classes or purposes of monitoring: *compliance, model verification,* and *trend*. Building on this concept, the Advisors identified four types of monitoring that seem appropriate within our proposed adaptive management framework:

1. *Compliance* monitoring is built into permit requirements and focuses on whether the conservation measures are being implemented as planned.
2. *Performance* monitoring identifies whether individual conservation measures are achieving their expected outcomes or targets.
3. *Mechanistic* monitoring demonstrates whether the mechanisms thought to link conservation measures to desired outcomes are working as predicted.

4. *System-level* monitoring is used to identify the degree of success of the entire program (i.e., the cumulative effects of numerous conservation measures) relative to ultimate desired outcomes as described in the BDCP documents. This requires a sustained, long-term commitment to monitoring of critical features of the whole system, rather than the response of a single measure in the vicinity of a single locality.

Current monitoring practice is usually limited to compliance and system-level monitoring, with some performance monitoring. However, the outcomes of most conservation measures are likely to be influenced by external factors that are uncontrolled or unobserved. Mechanistic monitoring is therefore essential to understand whether changes at the system level are a result of one or more conservation measures or are due to external factors beyond the control of BDCP. Thus, mechanistic monitoring is crucial to adaptive management because it allows effects of the conservation measures, acting through the proposed mechanisms, to be distinguished from other effects.

Table 3X[4] lists a series of hypotheses associated with each conservation measure and monitoring target. Framing the monitoring targets as hypotheses makes clear the links to mechanistic monitoring. In order to be useful, however, scientific hypotheses should be stated in ways that allow them to be tested. For example, the first hypothesis in the table, "Increase production of organic carbon in support of food production within the Delta" is not stated as a hypothesis, and contains two concepts that should be separate if they are to be tested. This could be restated as: (1) The production of labile organic carbon will increase during the additional periods of flooding; and (2) The production of zooplankton (i.e., food for fish) in the estuarine foodweb will increase during periods of flooding. Note that some hypotheses lend themselves to formal tests, whereas others are more suited to parameter estimates (e.g., in the above example, the quantitative increases in carbon production and zooplankton production). Also note that hypotheses may not apply to all monitoring targets, particularly compliance and system-level monitoring.

Much of the trend monitoring and some of the other types of monitoring for aquatic species are already being conducted by the Interagency Ecological Program (IEP) and other agencies. BDCP should capitalize on these ongoing efforts to the fullest extent possible. However, these other monitoring programs may be altered or discontinued by the controlling agency; therefore, BDCP should coordinate with those agencies to ensure continuity of monitoring required specifically for evaluating the performance of the BDCP.

3.9 Collect, Manage, Analyze, Synthesize, and Evaluate Data (Principle 7)

Assessment is crucial to making monitoring useful. Much of the current monitoring in the Bay-Delta produces data that are under-analyzed and therefore under-used. The purpose of monitoring in the adaptive management framework is to provide a quantitative basis for analysis, synthesis, and evaluation. These activities are essential steps in the feedback to management decisions that are hallmarks of adaptive management.

[4] This was a draft summary table titled “Conservation Measure Effectiveness Monitoring and Potential Adaptive Management Responses” provided to advisors in December 2008.

Monitoring data must be made readily available online as soon as quality-control analyses have been completed. This has not always been the case with Bay-Delta monitoring programs, but it is essential for ease of access and transparency. Data management is also critical to allow analyses, synthesis, and evaluation. Data management must include the metadata required to identify how the data were collected, the methods used, any calculations employed, time and date, and site locations and characteristics. Effective data management is designed before data collection begins and is integral in the budgeting of successful monitoring frameworks.

Figure 1 highlights the expectation that the consequences of any conservation measure will be monitored and assessed to improve understanding of whether and how the measure is having the desired effects. No data should be collected under BDCP without a specific plan for analysis and synthesis by a particular person or group, with an adequate budget expressly allocated for data analysis and synthesis. This budget should be at least 10% of the cost of the monitoring, based on the Advisors' collective experience. The synthesis should provide answers to the questions implicit in the design of performance metrics: how have things changed, have they changed in expected ways, and what might have caused deviations from the expected trajectory? Note that expectations, generated by conceptual or simulation models, are essential to this effort. Although expectations often will not be met, they provide a basis for evaluating the data and trends. The results of these analyses should be published in technical, peer-reviewed reports to ensure both a degree of external review and easy access.

3.10 Translating Information into Action (Principles 7 & 8)

The weakest aspect of most adaptive management plans is in the sequence of steps required to link the knowledge gained from the implementation of conservation and monitoring actions (Boxes 3 through 9) to the governance actions of sustaining, refining, or replacing program goals and objectives or judging an action to be complete and successful (bold boxes in Figure 1). However, adaptive management plans rarely define the process and the responsibility for assimilating this information into the governance of the conservation plan. In the absence of this step, the adaptive management plan cannot really be adaptive. Information from technical reports is often captured and transmitted to decision-makers in irregularly scheduled exercises, such as ad hoc white papers and through conferences to brief managers or policy-makers. Such processes are inefficient and ineffective as a means of informing decision-makers, and lack the transparency needed in adaptive management.

To assimilate information and formulate recommendations (Box 10) requires both policy and technical expertise. This step is fundamental to the successful integration of accumulating knowledge and information into plan policies, such as revising goals and objectives, refining analytical models, or allocating funding. This step also is a key responsibility that is generally lacking from AMPs, a flaw that undermines successful implementation of adaptive management. The link between the technical step of "Analyze, Synthesize, Evaluate" and the decision-making step of "Assimilate and Recommend" requires regular interaction and exchange of information between technical staff and decision makers.

Box 10 in Figure 1 therefore highlights the need for some highly skilled agent (person, team, office) to be assigned the responsibility for continually assimilating scientific information generated by investigations *both within and external to the adaptive management program* and transforming it into knowledge of the kind required for management actions. Boxes 11 through 14 indicate that such actions may include (1) refining a particular conservation measure, (2) refining the knowledge base and models of system behavior that are extracted from the knowledge base, (3) revising objectives of an entire conservation measure, and (4) reassessing whether the original target problem is solved, transformed, or still a problem. This last action may also be affected by external events such as changing societal preferences, newly recognized environmental threats, or other changed or unforeseen circumstances.

The actions of the agent represented by Box 10 need to be carried out continually but on a range of time scales. For example, individual components of the knowledge base might be refined gradually and annually, whereas particular conservation measures might be refined only after a few years of project implementation. The entire problem might be re-assessed or re-visited once in a decade. The key principle, however, is that *the process of transferring and transforming the results of technical analyses into knowledge to support decisions cannot be taken for granted in the hope that it will occur in the absence of a body specifically charged with making it happen*. This function requires remarkably skillful people, who are truly inter-disciplinary ("polymaths"). Whatever their training, these individuals (or team of individuals) need to be comfortable with a wide range of technical information, as well as understand the functioning of government, law, economics, and the management of large projects.

Although this component of the adaptive management process is not well-developed in the field of environmental and resource management, examples of it are widespread in other, well-capitalized areas of human affairs. For example, the medical and biotechnology industries support highly trained personnel to monitor the myriad scientific results relevant to that field and to convey that information into forms that support the goal of the industry to deliver products and make a profit. This is the foundation of evidence-based medicine (Elstein 2004). Military Departments support links to the scientific community (e.g., Army Research Office, Office of Naval Research, Strategic Environmental Research and Development Program) to assimilate their useful results and recommend support for relevant studies. In government, the Congressional Budget Office, Government Accountability Office, and the Office of Science and Technology Policy all employ people who can assimilate disparate technical information into forms required for government decision-making.

Investment in some entity with the specific role of assimilating knowledge from the technical studies and making recommendation for changes is an essential component of large, complex environmental management projects. **We strongly recommend that BDCP put considerable thought and investment into institutionalizing an entity that is specifically tasked with assimilating knowledge and recommending adaptive changes to goals, objectives, models, conservation measures, and monitoring, as illustrated in Box 10 of Figure 1.** We consider this investment critical to the success of BDCP and to making adaptive management an integral part of the plan.

4 Literature Cited

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Appendix A – Advisor Biographies

Cliff Dahm, Ph.D., Lead Scientist, CALFED Science Program, Sacramento, and Professor, Department of Biology, University of New Mexico. Dr. Dahm is an ecosystem ecologist with expertise in restoration ecology, biogeochemistry, microbial ecology, hydrology, climatology and aquatic ecology. He is presently on loan to the US Geological Survey to serve as lead scientist for the CALFED Science Program from the University of New Mexico (UNM), where he is a professor in the Department of Biology. He emphasizes interdisciplinary approaches required for understanding aquatic ecosystems. He has served as interim director for the Sevilleta Long-Term Ecological Research (LTER) Program at the Sevilleta National Wildlife Refuge in central New Mexico, director for the Freshwater Sciences Interdisciplinary Doctoral Program at UNM and is currently a member of the Science Steering Group for the Global Water Budget Program of the U.S. Global Change Research Program. He has served as a program director for the Division of Environmental Biology of the National Science Foundation and was awarded the NSF's Director's Award for Program Management Excellence. He has worked on adaptive management protocols in Florida and Queensland, Australia. Dr. Dahm received a B.S. in Chemistry from Boise State University, an M.A. in Chemical Oceanography from Oregon State University, and a Ph.D. in aquatic ecology and oceanography from Oregon State University.

Tom Dunne, Ph.D., Professor of Environmental Science & Management and of Earth Sciences, University of California Santa Barbara. Dr. Dunne conducts field and theoretical research in fluvial geomorphology and in the application of hydrology, sediment transport, and geomorphology to landscape management and hazard analysis. He has worked on hydrology and geomorphology in many parts of the world, including New England, Northern Canada, Kenya, the Pacific Northwest, and the Andean and lowland parts of the Amazon River Basin. His current work concentrates on sediment transport and river channel evolution in gravel-bed rivers of the Sacramento and San Joaquin basins, including the relationship between physical and biological processes in a restored reach of the Merced River. He has served on many National Research Council Committees, the CALFED Ecosystem Restoration Program, the CALFED Independent Science Board, as well as the Adaptive Management Forum of the US Fish and Wildlife Service. Dr. Dunne received his Ph.D. in Geography from The Johns Hopkins University.

Wim Kimmerer, Ph.D., Research Professor of Biology, Romberg Tiburon Center for Environmental Studies, San Francisco State University. Dr. Kimmerer's research focuses on the San Francisco Estuary, emphasizing effects of human activities on the estuarine ecosystem. Research topics include zooplankton ecology, effects of introduced species and variable freshwater flow, population dynamics of fish such as salmon, striped bass, and the threatened delta smelt, simulation modeling of populations, and analysis of the extensive monitoring database from the estuary. Dr. Kimmerer is chair of the Interagency Ecological Program's Estuarine Ecology Team, and has assisted the IEP with long-range planning and design of monitoring programs. He was a member of the CALFED Ecosystem Restoration Program Core Team, developing a strategic plan for the program, and the Ecosystem Restoration Program Science Board, providing guidance on the application of adaptive management in the program. He is also serving as a science advisor to the CALFED Science Program, and has participated on numerous review panels on key issues in the Delta. Dr. Kimmerer received his Ph.D. in biological oceanography from the University of Hawaii.

Denise Reed, Ph.D., Professor, Department of Earth and Environmental Sciences, and Interim Director, Pontchartrain Institute for Environmental Sciences, University of New Orleans. Dr. Reed's research interests include coastal marsh response to sea-level rise, the contributions of fine sediments and organic material to marsh soil development, and how these are affected by human alterations to marsh hydrology. She has worked on coastal issues on the Atlantic, Pacific, and Gulf coasts of the US, as well as other parts of the world, and has published the results in numerous papers and reports. She is involved in restoration planning both in Louisiana and in California, and in scientifically evaluating the results of restoration projects. Dr. Reed has served on numerous boards and panels concerning the effects of human alterations on coastal environments and the role of science in guiding ecosystem restoration, including the Chief of Engineers Environmental Advisory Board, a number of National Research Council Committees, and the Ecosystems Sciences and Management Working Group of the NOAA Science Advisory Board. She received her B.A. and Ph.D. from the University of Cambridge in England and has worked in coastal Louisiana for over 20 years.

Elizabeth Soderstrom, PhD., Senior Director of Conservation for American Rivers. Previously, Dr. Soderstrom was the Senior Director for Sierra and International Rivers at the Natural Heritage Institute, during which time; she managed the Sharing Water Project on the Okavango River in Southern Africa, launched the Mountain Meadows Initiative, and applied adaptive management principles to river restoration as a Switzer Leadership Fellow. She also assisted both the CALFED Science Program and the Sierra Nevada Conservancy in developing and using performance measures. Dr. Soderstrom has also served as an International Engineering and Diplomacy Fellow with the American Association for the Advancement of Science at USAID's Center for the Environment in Washington, DC, and at USAID's Regional Center for Southern Africa based in Gaborone, Botswana. In these positions, she implemented the International Coral Reef Initiative, was an advisor and representative to the Ramsar Convention on Wetlands of International Importance, and the Convention on Biodiversity, and researched and designed a role for United States assistance in the management of international rivers in southern Africa. Dr. Soderstrom received a B.A. in English Literature, and a B.S. and M.S. in Biological Sciences from Stanford University, and a Ph.D. from the University of California, Berkeley.

Wayne Spencer, Ph.D., Senior Conservation Biologist, Conservation Biology Institute, San Diego. Dr. Spencer is a conservation biologist and wildlife ecologist with expertise in conservation planning and endangered species recovery. He has worked on various regional NCCPs and HCPs in California as a consulting biologist, science advisor, and science facilitator. His research focuses on rare and endangered mammal species, including the endangered Stephens' kangaroo rat, Pacific pocket mouse, and Pacific fisher. He has also worked extensively on approaches to designing landscape-level reserve systems and maintaining ecological connectivity. He is a Research Associate with the San Diego Natural History Museum and a science advisor to numerous conservation NGOs. He received his B.S. in Biology and Wildlife Management at the University of Wisconsin, Stevens Point, his M.S. in

Wildland Resource Science at UC Berkeley, and his Ph.D. in Ecology and Evolutionary Biology at the University of Arizona.

Inge Werner, Ph.D., Associate Adjunct Professor and Director of the Aquatic Toxicology Laboratory, University of California at Davis, School of Veterinary Medicine. Dr. Werner's research focuses on the molecular, biochemical and physiological responses of fish and aquatic invertebrates to anthropogenic environmental stressors, and interpreting these in an ecological context. Her work includes aquatic monitoring programs to assess pollutant impacts in California's Sacramento-San Joaquin watershed and delta, studies on the impact and efficacy of alternative pest control methods in orchard and field agriculture, and the effects of elevated temperature, pesticides and heavy metals on aquatic organisms. She has worked on various zooplankton, amphipod and clam species, as well as native fishes including Chinook salmon, steelhead trout, delta smelt, and green sturgeon. Dr. Werner has an M.S. in Limnology from the University of Freiburg, Germany, and a Ph.D. in Zoology with specialization in aquatic toxicology from the University of Mainz, Germany.

Susan Ustin, Ph.D., Professor of Environmental Resource Science, Department of Land, Air, and Water Resources, University of California Davis. Dr. Ustin is an ecosystem ecologist with 25 years experience in environmental applications of remote sensing. Her current research involves working at a variety of scales from leaf level radiative transfer modeling to quantify landscape biogeochemistry to global mapping of wildfire occurrence. She has extensive experience in developing methods of analysis for hyperspectral imaging data, focusing on detection of environmental stresses and degradation. She has worked on many projects in the San Francisco estuary and delta, starting with her dissertation research and most recently mapping invasive aquatic plants in the delta region. She received a B.S. and M.S. in Biological Sciences from California State University Hayward and a Ph.D. in Botany from the University of California Davis in 1983 in the area of plant physiological ecology with work on physiological responses to salinity and drought stress in wetland plant species in the California Delta.

John Wiens, Ph.D., Chief Conservation Science Officer, PRBO Conservation Science, Petaluma. John Wiens grew up in Oklahoma as an avid birdwatcher. Following degrees from the University of Oklahoma and the University of Wisconsin-Madison (M.S., Ph.D.), he joined the faculty of Oregon State University and, subsequently, the University of New Mexico and Colorado State University, where he was a Professor of Ecology and University Distinguished Professor. His work has emphasized landscape ecology and the ecology of birds, leading to over 200 scientific papers and 7 books. John left academia in 2002 to join The Nature Conservancy as Lead Scientist, with the challenge of putting years of classroom teaching and research into conservation practice in the real world. In 2008, he joined PRBO Conservation Science as Chief Conservation Science Officer. His aim is to build on the long-standing work of PRBO on bird populations to address conservation in a rapidly changing world – "conservation futures." Climate change is affecting species distributions, economic globalization is altering land uses, and demands for the goods and services provided by nature are changing how people relate to nature. John is working with PRBO staff and partners to develop guidance for assessing the impacts of these changes and how management practices can help natural systems adapt.

Appendix B – Workshop Agenda

DECEMBER 17-19, 2008

<u>Wednesday - December 17, 2008</u>

1. **<u>CLOSED SESSION</u> - Embassy Suites Sacramento – Steamboat Rm.** **12:00 – 1:30**
   (Advisors Only)
   - *Advisors meet to review charge*

– **2:00 – 4:00**

3. **<u>CLOSED SESSION</u> - Embassy Suites Sacramento – Steamboat Rm.** **4:00 – 5:00**
   (Advisors Only)
   - *Organize Review*
   - *Homework assignments*

<u>Thursday - December 18, 2008</u>

1. **<u>CLOSED SESSION</u> - Embassy Suites Sacramento – John Sutter Rm.** **8:00 – 12:00**
   (Advisors Only)
   - *Discuss program strengths and weaknesses*
   - *Discuss successful elements from other programs*
   - *Craft initial recommendations*

Lunch **12:00 – 1:30**

2:00 – 3:30

3. **<u>CLOSED SESSION</u> – Resources Building – Rm. 1131** **3:30 – 5:00**
   (Advisors Only)
   - *Refine recommendations*
   - *Work on findings memorandum.*

<u>Friday - December 19, 2008</u>

<u>CLOSED SESSION</u> - Embassy Suites Sacramento – John Sutter Rm. **8:00 – 12:00**
(Advisors Only)
- *Finalize language for findings memorandum*

Adjourn **12:00**

Appendix C – Documents Reviewed By Advisors

Adaptive Management Section, Chapter 3, Conservation Strategy; Draft. December 2, 2008. BDCP Steering Committee Meeting, Handout #6, December 5, 2008.

An Overview of the Conservation Strategy for the Bay Delta Conservation Plan. December 12, 2008.

Annotated BDCP HCP/NCCP Document Outline. Bay Delta Conservation Plan Steering Committee Meeting, Handout #6, November 21, 2008.

Bay Delta Conservation Plan Independent Science Advisors Report, Independent Science Advisors (Reed et al.), November 16, 2007.

Bay Delta Conservation Plan Independent Science Advisors Report Concerning Non-Aquatic Resources. Independent Science Advisors (Spencer et al.), November 2008.

BDCP HCP/NCCP Biological Goals and Objectives; Working Draft. BDCP Goals and Objectives Working Group, Technical Meeting. December 11, 2008.

Biological Goals and Objectives: Hierarchical Relationships. Goals and Objectives Working Group meeting. November 21, 2008.

Chapter 2 Existing Ecological Conditions. Science Applications International Corporation, March 7, 2008.

Designing Monitoring Programs in an Adaptive Management Context for Regional Multiple Species Conservation Plans. USGS, 2004.

Draft Water Operations Conservation Measures. Bay Delta Conservation Plan Steering Committee Meeting, Handout #5, October 31, 2008.

Examples Demonstrating Relationships Among Goals and Objectives, Viability Attributes, Monitoring, and Adaptive Management For Selected Species. Bay Delta Conservation Plan Steering Committee Meeting, Handout #11, November 21, 2008.

Guidance for the NCCP Independent Science Advisory Process, California Department of Fish and Game, August 2002.

Monitoring and Adaptive Management Sections for Selected Conservation Measures; Draft. Science Applications International Corporation, December 12, 2008.

Section 3.3 Approach to Conservation: Overview of Key Conservation Measures and their Integration; *Working Draft.* Bay Delta Conservation Plan Steering Committee Meeting, Handout #5, November 21, 2008.

Table 1. Proposed Conservation Measures Contributing to Improving Viable Salmonid Population (VSP) Parameters for the Sacramento River Winter-Run ESU. Science Applications International Corporation, December 5, 2008.

Table 3.X. Conservation Measure Effectiveness Monitoring and Potential Adaptive Management Responses. Science Applications International Corporation, December 5, 2008.

Third Draft Habitat Restoration Conservation Measures. Bay Delta Conservation Plan Steering Committee Meeting, Handout #3, October 31, 2008.

Third Draft Other Stressors Conservation Measures. Bay Delta Conservation Plan Steering Committee Meeting, Handout #4, October 31, 2008.

Appendix D.

Examples of Recommended Adaptive Management Framework Applied to Two Proposed Conservation Measures

The Advisors selected two examples of BDCP proposed conservation measures to illustrate how our proposed Adaptive Management Framework would apply to them and to developing additional conservation measures. These examples illustrate the need for goals and objectives to be articulated clearly and that the existing knowledge base must be integrated into models (conceptual or otherwise) to identify expected outcomes. This will connect goals and objectives, expected outcomes, performance metrics, and monitoring in a logical manner. We also point out inaccuracies or gaps in how these examples are presented in the draft BDCP documents. We recommend that these examples be used to improve the development, analysis, and presentation of conservation measures for the BDCP.

Other Stressors Example

Conservation measure TOC01 is to "Reduce the Load of Ammonia in Effluent Discharged from the Sacramento Regional County Sanitation District into the Sacramento River…If Warranted Based on Research." [5]

Knowledge Base

The knowledge base is currently provided in the form of a rationale in draft BDCP documents. Although information from a few key scientific publications is cited, the rationale does not provide a satisfactory summary of the knowledge base with respect to ammonia/ammonium and effects on different trophic levels of the Delta, as well as secondary effects due to trophic interactions. The information provided is also not well substantiated. Ammonia and ammonium are some of the best-characterized contaminants in this system, and information on concentrations producing toxic effects for fish and other species is relatively abundant. The BDCP documents should explain in a more specific manner why ammonia and ammonium are of concern in the Lower Sacramento River. Examples of available information that should be included are data on total ammonia/ammonium concentrations collected by Sacramento Regional County Sanitation District (SRCSD), California Department of Water Resources, and the Interagency Ecological Program toxicity information reviewed in US EPA (1999), as well as many scientific papers in the peer-reviewed literature. Results from Teh et al. (2008) are misquoted, as no conclusive evidence was found to support the statement that ammonium caused the observed reduction in survival of prey species (copepods) for delta smelt and longfin smelt.

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[5] This goal is inaccurately worded, and this inaccuracy is perpetuated throughout BDCP documents. The terms ammonia and ammonium refer to two chemical species that are in equilibrium in water (un-ionized ammonia and ionized ammonium). Chemical tests usually measure both ammonia and ammonium (NH_3, NH_4^+), while the toxicity is primarily, but not completely, attributable to the un-ionized form. Ammonia concentration is not directly measured but can be calculated if temperature and pH are known.

Goals and Objectives

This conservation measure is essentially a research and monitoring program, but no clear goals or objectives are provided, and the title of the conservation measure is inconsistent with the performance measure or measures of success, which are focused on adverse effects on fish (see below). For example, a clear goal statement would be:

Minimize or eliminate direct and indirect toxic effects of ammonia and ammonium from Sacramento Regional County Sanitation District (SRCSD) effluent on covered species.

Objective statements could then be:

1. Reduce the load of ammonia and ammonium in SRCSD effluent to levels which will not cause adverse indirect or direct effects to covered species in the Lower Sacramento River.
2. Reduce the load of ammonia and ammonium in SRCSD effluent to ….mg/L (quantitative threshold).
3. Reduce the load of ammonia and ammonium in SRCSD effluent to minimize or eliminate risk of indirect and direct ammonia/ammonium toxicity to covered species in the Lower Sacramento River.

This would lead directly to specifications of performance metrics and potential research goals, such as monitoring total ammonia/ammonium concentrations as well as pH and water temperature downstream of the outfall in areas where fish habitat and elevated concentrations coincide (Objective 2; relatively easy), reducing ammonia/ammonium to “safe” concentrations of ammonia/ammonium for covered fish species and their prey (Objectives 1 and 3) and identifying performance metrics for monitoring adverse effects on Delta species at different trophic levels (more difficult).

This conservation measure is stated as contingent upon ongoing or planned research. The BDCP documents should explain specifically what the goals of this research are, and what outcomes will warrant the implementation of the full-scale conservation measure.

Tradeoffs are not explicitly addressed, but should be. For example, it is possible that a reduction in nutrient input due to an increased level of treatment could affect primary productivity or phytoplankton community composition downstream of the treatment plant. It is important to discuss different levels of wastewater treatment (nitrification or coupled nitrification and denitrification to achieve removal as nitrogen gas) and their expected outcomes. This should be discussed in the context of studies by Dugdale et al. (e.g., 2007; ammonium inhibition of diatom growth), Jassby et al. (2002; 2008; nutrient loading and dynamics), and Lehman et al. (2005, 2008; *Microcystis aeruginosa*), as well as related publications and ongoing studies referred to in the “Rationale.”

Models

Models should capture and formalize the knowledge base. A conceptual model could provide the framework for the conservation measure and inform selection of performance metrics, but sufficient data already exist to create a more quantitative model. For example, information on the oxidation of ammonia and ammonium in municipal wastewater treatment effluent after upgrading to tertiary treatment (nitrification only) is readily available from the Stockton Wastewater Treatment Plant, which recently switched from secondary to tertiary treatment. Information on total ammonia/ammonium concentrations in the Lower Sacramento River is also available (DWR, SRCSD, Interagency Ecological Program (IEP) Pelagic Organism Decline (POD)). There also is a relatively large body of information on the acute and chronic toxic effects of ammonia and ammonium on fish and some aquatic invertebrates, and US EPA water quality criteria exist (US EPA, 1999).

Desired Program Outcomes and Performance Metrics

Contingent upon the goals and objectives, it is important to clearly state the desired outcomes of the conservation measure: While it is relatively easy to define desired outcomes and performance metrics if the goal is to "reduce the load of effluent-related ammonia and ammonium…," it is more difficult to define these if the goal is to "reduce adverse direct or indirect effects on covered fish species." The latter requires information on acute, chronic, and sublethal effects of ammonia and ammonium on covered fish species and their prey under current conditions and conditions projected under reduced loading. It also requires seasonal assessment of ammonia and ammonium loads under variable pH and temperature and the hydrodynamic transport and fate of the ammonia and ammonium downstream in the Sacramento River and within the Delta.

Select and Evaluate Conservation Measures

The choice about whether to implement a conservation measure as a full-scale action, as a pilot study, or as a research program depends on its physical and temporal scale, the degree of confidence in its benefits, and the consequences of being wrong (see Section 3.6). A full-scale action is taken to solve a problem when the action is considered highly likely to achieve or contribute to one or more key objectives, and there is little additional benefit to performing pilot studies or research before implementing the full-scale action. Clearly, this is not the case here. At present, the actual conservation measure TOC01 provided in the BDCP document consists of a research program to "evaluate the need and, if demonstrated to be necessary to protect covered fish species, reduce the levels of SRCSD effluent-derived ammonia and ammonium entering the Delta." The "need" is defined by the goal "to protect covered fish species." The full-scale action would be to improve the SRCSD wastewater treatment process to reduce ammonia and ammonium in the effluent. To realize this measure, the plan calls for monitoring total ammonia/ammonium concentrations in the river, and for performing studies to provide conclusive evidence of whether or not the discharge of ammonia and ammonium in effluent from the SRCSD Wastewater Treatment Plant has substantial adverse direct or indirect effects on covered fish species.

It would facilitate evaluation and future adaptive management decisions if the development of this conservation measure was described in detail, provided clear information on goals and objectives, specified research objectives, and detailed why presently available data are insufficient to implement a full-scale action.

Design and Implement Conservation Measures

As stated above and in Section 3.6, the actions to be undertaken under this conservation measure should be described in greater detail. What are the specific research goals and hypotheses, and what is monitoring expected to show? How is risk to covered species defined? Provide details of the design to be used in determining what levels of ammonium and ammonia have adverse direct or indirect effects on covered fish species, and how often these levels are exceeded. Specific information gaps that lead to uncertainties should be addressed clearly. What actions will be taken to reduce uncertainties? Text in Lines 16-18 of the draft plan describes neither uncertainties nor risks. Identify alternative strategies if identified partner entities choose not to collaborate on the conservation measure.

Collect, Manage, Synthesize, and Evaluate Data

Performance metrics should provide useful information to evaluate the success of the conservation measure and should be directly related to the objectives. For example, data collection and management planning should address the questions of how and where will monitoring be conducted, what sorts of inputs may be required to model the system, and how will results be analyzed? As an important example, monitoring of total ammonia/ammonium should involve simultaneous pH and temperature measurements so levels of un-ionized ammonia can be calculated. The spatial and temporal scope of data collection also needs to be considered as impacts to foodwebs and covered species are evaluated. A well designed data collection and management plan will facilitate effective synthesis and evaluation of the resulting data as the BDCP is implemented.

Remaining Components of the Adaptive Management Framework

The full-scale action to reduce the ammonia/ammonium load in the Lower Sacramento River by improving treatment technology at SRCSD would be costly and largely irreversible. This conservation measure makes the full-scale action contingent upon the significant risk of direct or indirect toxic effects on covered fish species due to effluent-derived ammonia/ammonium. Establishing the "need" for the full-scale action, or refining the conservation measure to achieve this goal, requires in-depth scientific knowledge of ecotoxicological principles and risk assessment strategies. Highly skilled individuals are needed to successfully include results provided by research in adaptive management decisions.

Riparian Restoration Example

The stated conservation measure is to "restore between XX and XX acres of riparian forest and scrub communities as a component of restored floodplain, freshwater intertidal marsh, and channel margin habitats."[6]

Knowledge Base

The benefits to covered species of restoring riparian forest and scrub are presumably supported by previous science and applied management, but little of this background knowledge is apparent in the plan documentation. Only two citations are provided to support elements of the rationale for the conservation measure.

While it is not necessary to provide complete documentation of all of the knowledge that underlies development of the plan, the knowledge base should be developed sufficiently to provide a clear and transparent foundation and justification for the proposed plan.

Goals and Objectives

Goal NACO1 is to "Protect, enhance, and restore tidal perennial aquatic, tidal freshwater emergent, brackish freshwater emergent, floodplain, and valley riparian communities to provide habitat and ecosystem functions to increase the natural production (reproduction, growth, and survival), abundance, and distribution of covered species."

This goal is too broad and includes implicit assumptions that may not be warranted. The first part is about plant communities, the second about unspecified habitat, the third about functions of unspecified parts of the ecosystem, and the fourth is about population processes of unspecified species. Moreover, this goal includes five habitat types and production, abundance, and distribution characteristics for each habitat type. This makes it impossible to define clear metrics for each of these important Delta habitats. This goal should be broken into parts that logically hang together. Again, the ERP Strategic Plan provides guidance on this. More carefully stated, this might read as four goals, each having a discussion of why these goals have been selected:

1. Protect, enhance, and restore tidal perennial aquatic, tidal freshwater emergent, brackish freshwater emergent, floodplain, and valley riparian plant communities.
2. Protect or restore functional habitat types.
3. Restore and enhance ecosystem functions such as….
4. Increase the natural production, abundance, and distribution of covered species.

Objective NACO1.5 is to "Restore at least XX acres of riparian forest and scrub within the Delta to provide habitat and ecological functions in support of covered species."

This is a clearly stated and measurable objective, although it is not clear what variables or processes qualify as "ecological functions." The objective should lead to specific outcomes that

[6] The documents we reviewed did not supply acreages, but explained these would be determined in the future.

can be evaluated to determine whether the goal (as expressed in this objective) is being achieved. What does "support" mean operationally?

Models

There is no indication in the documentation we received that modeling of any sort has been used to assemble and synthesize the knowledge base about the dynamics and controlling factors of riparian forest and scrub communities and their linkages to various habitats in the Delta. Such models might be used, for example, to determine *how* restoration of riparian forest and scrub will actually provide habitat and "ecological functions" to covered species. Is XX acres a sufficient amount of forest or scrub to provide habitat to which covered species (species differ in the amount of habitat needed to support functioning populations)? One might use existing information on breeding birds in riparian habitats, for example, to model how restoration at different levels might affect reproduction, growth, or survival of different species. Spatial optimization models might be employed to assess the consequences of different spatial arrangements of riparian forest and scrub restoration within different areas of the Delta, and to explore tradeoffs among different approaches to riparian restoration. At a minimum, the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) conceptual models could be used to be more explicit about the relationships between the covered species and riparian forest and scrub.

Desired Program Outcomes and Performance Metrics

Expected outcomes are scattered through the description of Riparian Habitat Restoration conservation measures. For example:

- "At floodplain restoration sites that function hydrologically as flood bypasses (e.g., the Yolo Bypass), riparian vegetation is expected to establish along margins of existing and created drains and channels and other locations with suitable hydrology."
- "Levees constructed and maintained by other entities that incorporate "green" levee components would also increase the extent of riparian habitat … by allowing for the establishment and growth of riparian vegetation on levee surfaces."
- "Restoring riparian forest and riparian scrub habitats is expected to … increase the extent of valley elderberry longhorn beetle habitat and nesting habitat for Swainson's hawk and yellow-breasted chat; … increase … instream cover … through contributions of instream woody material; … increase production and export of terrestrial invertebrates into the aquatic ecosystem; and … increase cover for rearing juvenile salmonids and Sacramento splittail."

In general, these outcomes are framed in ways that enable conservation measures to be developed and measurements designed to assess progress in meeting the goal and objectives. Thinking about outcomes could be broadened to include other benefits, such as the potential role of riparian vegetation in flood abatement, water retention or in carbon sequestration. In general, outcomes could be more broadly considered in the context of ecosystem services.

Metrics to measure progress toward realizing these outcomes are not provided; this section is still in preparation.

Select and Evaluate Conservation Measures

Presumably the evaluation and selection among several potential conservation measures has already occurred, although this measure is sufficiently broad that it likely includes several alternatives. It would facilitate adaptive management if the conservation measures were developed in greater detail, to indicate how restoration is to be accomplished, where restoration will be targeted, what factors will be considered in determining whether, when, where, and how to undertake restoration, and the like. For example, the approach embraces a "build it and they will come" philosophy – e.g., "riparian habitat would be allowed to naturally establish in floodplain habitat areas that are restored…"[7] A more proactive approach to ensuring that the desired type of riparian habitat becomes established may be more effective. This additional level of detail will be needed before this measure can be evaluated using the DRERIP tools.[8]

The possibilities of conducting preliminary research or pilot studies to evaluate whether the conservation measures are likely to produce the expected outcomes in a cost-effective and timely manner are not considered; this may be an outcome of the recent scientific evaluation using the DRERIP tools. Pilot projects can be invaluable tools for generating public support for restoration actions and for the design of larger-scale projects (e.g., Toth et al. 1998).

Design and Implement Conservation Measures

Details of the design(s) to be used in restoring riparian habitat are not provided; it may not be the intent of this plan to include such details, but they will be needed in order to design effective monitoring programs.

Design and Implement Monitoring

The BDCP documents indicated that monitoring will be conducted to assess the use of restored habitats by covered species, factors that govern the establishment and growth of native riparian vegetation, the need to control non-native invasive species, and the ability of restored habitat to provide unspecified "desired ecosystem and covered species benefits."

Monitoring must be adequate to determine whether the expected and desired outcomes are being met. This requires a monitoring plan be developed that describes what will be monitored, at what spatial and temporal intervals, by what methods, and how the data will be used to assess performance.

Remaining Components of the Adaptive Management Framework

The report mentions using adaptive management to (1) improve the design and management of restored areas to provide for the successful establishment, growth, and benefits of restored riparian habitats, and (2) evaluate the need for control of non-native invasive species or the use of riparian plantings to improve success. These are appropriate adaptive management responses.

[7] Although the report acknowledges that this approach could allow the establishment of non-native invasive species, it does not fully address the implications of this issue.

[8] The BDCP independent science advisory report concerning non-aquatic resources (November 2008) also noted that simply restoring semi-natural hydrological regimes in floodplains won't restore natural riparian conditions, that restoration is a process rather than a one-time action, and that there is a useful knowledge base for guiding restoration actions that should be fully integrated into restoration planning, implementation, and monitoring.

The application of adaptive management to riparian habitat restoration, however, would be enhanced by considering the potential management responses to various outcomes *as part of the conservation plan*. The use of models to explore likely scenarios would help managers anticipate and plan for adaptive management actions as the effects of the conservation measures undertaken become evident through focused monitoring.

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Appendix G-4

Bay-Delta Conservation Plan Delta Science Program Panel
Review of the "Logic Chain" Approach

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BAY-DELTA CONSERVATION PLAN

DELTA SCIENCE PROGRAM PANEL

REVIEW OF THE "LOGIC CHAIN" APPROACH

Prepared for
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19 March 2010

Background

The Bay-Delta Conservation Plan (BDCP) is being prepared through collaboration among several government, non-government, and private-sector entities. The goal of BDCP is to identify actions that will contribute to the recovery and protection of endangered and sensitive species and their habitats in the Sacramento-San Joaquin Delta of California while maintaining or improving water supplies to a diversity of users. To this end, a "logic chain" has been proposed as a framework for linking recovery goals for covered fish species with BDCP goals, objectives, conservation measures, monitoring, and adaptive management.

The review panel convened by the Delta Science Program met in Sacramento on March 2-4, 2010, to evaluate this approach. In this review, we drew heavily from the following documents: Logic Chain Status Report, Chapters 3.3 and 3.4 of the draft BDCP, SAIC Draft Effectiveness Monitoring for Conservation Measures document, Summary Report of the DRERIP Evaluations of BDCP Draft Conservation Measures, Independent Science Advisors' Report on Adaptive Management, and examples of logic chains provided by American Rivers and The Bay Institute.

The Charge

The charge to the review team had three elements. The first was to address whether the logic chain framework is a useful tool for refinement of BDCP goals and objectives. The second was an assessment of the logic chain framework with a focus on determining if the internal logic was sound and if there were critical gaps. The third element was to recommend next steps for populating key logic chains and to consider where additional science was needed in the BDCP process. This report addresses these three elements of the charge to the review team.

Recommendations

Adequacy of the logic chain framework

- The general logic-chain approach should continue to be developed and then applied, as it has the potential to clearly articulate and link goals, objectives, actions, and outcomes.
- The logic chain should be first applied to the covered fish species.
- The revisions to the logic chain structure developed by the review panel should be incorporated, as appropriate, to reduce areas of ambiguity and refine the logic chain.

Assessment of the logic chain framework

- BDCP should distinguish between order-of-magnitude approximations of BDCP goals and objectives that are acceptable in the early planning phase and the more detailed descriptions that will be necessary as the plan is finalized and ready for implementation.
- The projected outcomes should be framed as testable hypotheses linked to specific conservation measures and evaluated against actual outcomes. Outcomes must be quantified, with specified and measurable parameters and appropriate metrics. The analytical methodology to be employed should also be specified. It is important to know with clarity whether a conservation measure is working as intended.
- Use metrics to evaluate the success of outcomes that clearly link to biological functions; consider the judicious use of surrogate metrics. For example, accurate quantification of rare and endangered fish species may not be possible but overall community structure that characterizes native and non-native groups could serve as a surrogate measure.
- Constraints to implementation of the conservation measures (e.g., financial, environmental, logistical) should be considered as part of the planning process rather than as factors to be included only when one comes to implementing conservation measures. This will ensure that expectations about implementation are commonly understood. For example, budgetary requirements to make the necessary monitoring measurements and analyze the resulting data should be developed as soon as possible so that this information can be used in the prioritization of conservation measures.
- The potential impacts of system dynamics, variation, and change (especially those associated with climate variability, climate change, and sea-level rise) on the effectiveness of conservation measures should be explicitly addressed in the logic chain. A steady-state equilibrium, in which the system varies around some stable long-term state (i.e., stationarity), cannot be assumed.
- The adaptive management framework should be developed in greater detail, recognizing that analysis is *not* the endpoint of adaptive management. Adaptive management

approaches should be incorporated into the body of the logic chain rather than relegated to something that is done at the end, after measures have been implemented.

Next steps and science needs

- Rather than developing all logic chains at the same pace, logic chains should be developed in detail for 2-3 species and then evaluated as a proof of concept. These logic chains should be for species for which understanding is high (e.g., splittail). A user-friendly version of the logic chain that describes the approach and its uses in readily understandable terms should be developed now.

- The upper section of the logic chain (problem, recovery/species goals, and recovery/species objectives) should be developed and populated by the responsible regulatory and permitting agencies. This needs to be done immediately, because the application of logic chains to BDCP goals and objectives and the evaluation of hypotheses that feed into adaptive management depend on a clear statement of the problem to be addressed and well-defined recovery/species goals and objectives.

- The middle section of the logic chain (BDCP goals and BDCP objectives) should be developed through collaborative efforts. A limited number of experts from the permitting agencies, non-governmental organizations, and the potentially regulated entities should participate in developing this section of the logic chains.

- A science expert workshop should be convened to populate the lower part of the logic chain, focusing on the conservation measures, outcomes, monitoring, metrics, and the form of an adaptive management process once the upper and middle sections of the logic chains have been completed.

- Simulation models and scenario analysis should be used to explore the potential consequences and cost-effectiveness of conservation measures as part of the planning process, before measures are actually implemented.

- The formalisms of other approaches such as cost-benefit analysis, return-on-investment, or ecological risk analysis should be used to help set priorities and evaluate outcomes. Such tools should be used to inform decision making and negotiations, to consider tradeoffs, and to establish priorities among conservation measures.

General Comments

Before dealing with the details of the logic-chain, we offer several general comments as broad guidance for further development of the approach. First, our ability to recover or manage covered species depends on a clear understanding of what factors are limiting or creating stress to populations. These are the factors that must be removed or mitigated by the conservation measures. Such factors may be identified in recovery plans or may require additional information obtained from the scientific literature and/or expert opinion, and should be refined through the adaptive management process.

Second, there is an underlying (but unstated) assumption of stationarity that runs through the logic chain approach, the draft BDCP documents, and recovery plans. This assumption leads to the expectation that there is a stable "baseline" condition for the Bay-Delta ecosystem and the populations it supports. Given the massive changes in this ecosystem over the past century, this is almost certainly not true now. The potential effects of climate change on sea level, tidal fluxes, Sierra snowfall, and the timing of freshwater runoff make it even less likely to hold in the future. The logic chain and BDCP should explicitly incorporate non-stationary dynamics into the framework.

Third, it is important to incorporate study designs, monitoring protocols, and metrics as part of the logic chain. In particular, consideration of the statistical power required for detecting the effects of conservation measures, coupled with a determination of acceptable levels of response of covered species or other targets to conservation measures, may help to determine the feasibility or priority of particular measures.

Fourth, although it is important to have a clear and logical structure for developing hypotheses about the consequences of conservation measures and the efficacy of these measures in addressing BDCP goals and objectives, the framework should not be so highly structured and prescriptive that it constrains thought or resists the exercising of dynamic adaptive management. The Bay-Delta ecosystem is complex. The responses of covered species to conservation measures will always be clouded by uncertainty – did a species respond to a measure or to something else? Dealing with such uncertainties requires flexibility in planning and implementation.

Evaluation of the Logic Chain

In order to understand the logic and function of the logic chain, the review team chose to delve into the logic chain example for the Delta Smelt (Appendix 2). We reviewed and assessed this example from top to bottom; here are our observations and comments, utilizing the terminology of the example provided.

<u>Problem statement, goals and objectives</u>

The problem statement, goals, and objectives need to match or encompass those in the recovery plan(s). Broad statements for the species/populations as a whole are acceptable at this level.

<u>Conceptual models</u>

This part of the logic chain only references *conceptual* models. Various types of models -- conceptual, statistical, process, simulation, etc. – can be used to identify factors that limit the population as a whole, and different models and types of models consider factors such as population dynamics, hydrology, predation, or habitat availability. These models (or perhaps a nested set of increasingly more specific models) can be used to identify what limiting factors or stressors (if any) occur within the planning area and, therefore, would be addressed by BDCP actions. In addition, when these models are used, they relate to what has caused the problem, as articulated in the problem statement.

Hypotheses

The "hypotheses" (which as stated in the logic chain are actually assumptions rather than hypotheses) can better be characterized as specific "BDCP goals" with each goal statement articulating how a limiting factor might be addressed *within the BDCP planning area*. One goal statement for each limiting factor (e.g., increase food in the pelagic zone by 15 percent to improve sub-adult survival) specifying season and location would be necessary.

The limiting factors framed as goals do not need to be directly tested as formal hypotheses. The process relies on the models (above) or the wider knowledge base to identify the limiting factors and assumes that alleviating those factors will in fact address the problem.

Desired change

To link with the goal statements described above, the "desired change" category would be logically called "BDCP objectives." The level of quantification of the objectives depends on whether they will be used to develop prioritizations in the early planning phase (in which case they can be order-of-magnitude approximations) or if they are part of the finalized plan. If the latter, the objectives would need to be the so-called "SMART objectives" that are specific, measurable, achievable, relevant and time-based.

In some cases, the terminology "thresholds of change" has been used instead of "desired change," suggesting that there is a lower threshold of detectability of an effect or an upper threshold beyond which additional changes have no additional beneficial effects. These levels define an envelope of effects or change that is either detectable or relevant. We find the use of this terminology confusing and, in some instances, inaccurate. It needs to be clear whether this is something to be achieved (like a target) or exceeded (like a minimum acceptable achievement).

Conservation Measures

The conservation measures are the BDCP conservation measures or actions. They relate directly to the BDCP goal and objective statements and reduce the limiting factors within the BDCP planning area. Linking proposed conservation measures to BDCP goals and objectives will help to show gaps, such as objectives for which no appropriate measure exists.

Once the conservation measures have been described, a clear prioritization process would be useful, as not all measures will be logistically, financially, or politically feasible. Such prioritization could be based on an evaluation of cost effectiveness of measures relative to their outcomes and the linkages between implementation, analysis, and adaptive management. Negative consequences and the timing of actions (sequencing) would also need to be considered.

Outcomes

The projected outcomes currently are not framed as quantitative, testable hypotheses. It is at this level of the logic chain where such hypothesis testing should occur. Stated as such, these hypotheses would drive the analytical approaches for evaluating the hypotheses and the form and structure of monitoring (i.e., gathering the information to evaluate or test the hypotheses).

The monitoring design (or experimental design) may vary among different conservation measures or be applied in different ways to different places for the same conservation measure (i.e., a real experiment). It will be critical to determine what level of measurement, monitoring, and analysis would be considered not too little (to demonstrate an effect), nor not too much (a huge investment in limited resources), but just right (the Goldilocks approach). Costing of the analytical methods and monitoring would be a consideration in the prioritization of conservation measures mentioned above. The monitoring structure will in turn lead to the selection of appropriate metrics and consideration of such key attributes as spatial and temporal resolution, statistical power, analytical framework to employ, and best representation and visualization of results.

Analysis

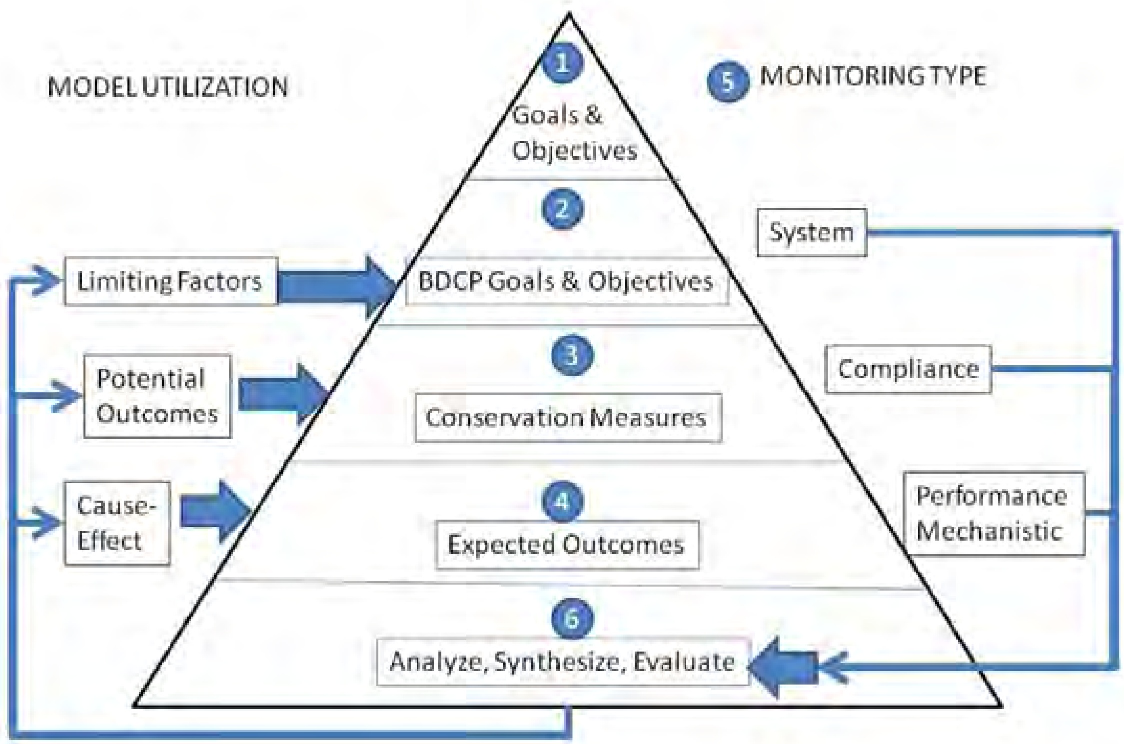
The analysis box in the Delta smelt logic chain provided would benefit from being more detailed and expanded to include the adaptive management loop. Adaptive management is not the same thing as the hypothesis testing that is included as part of the logic chain. Implementation of conservation measures leads to actual outcomes that must be monitored and analyzed. The comparison of projected outcomes (the hypotheses) with the actual outcomes is the focus of analysis. These results then feed into the adaptive management loop and back into other components of the logic chain (see next section). This is also where the system metrics may come in - how do the outcomes relate back not only to the specific objectives (e.g., food supply), but to the broader objectives (e.g., population growth, survival).

The adaptive management phase involves not only the analytical element, but the synthesis/interpretation component – what does analysis comparing projected and actual outcomes mean in terms of the objectives, identification of limiting factors, goals, or problem statement? To be effective, adaptive management needs to be part of the process, not an add-on at the end or a post-facto component once the actions have been taken. The details of adaptive management are missing from the logic chain.

There are two aspects of the hypothesis testing/analysis/interpretation components that must be distinguished: (1) the “virtual,” in which the analysis is conducted as a sophisticated conceptual or analytical modeling exercise, to explore the *anticipated* consequences of a conservation measure and the adaptive management loop; and (2) the “real,” in which the conservation measure has been implemented and we are looking at what *actually* results.

An Alternative Approach

Although there is much of value in the logic-chain approach, our evaluation and comments suggest that there is room for improvement, especially to clarify some of the logical relationships in the logic chain. We offer here an alternative approach that incorporates elements of the logic chain. The following diagram traces the main elements of this approach; the following comments are keyed to the numbered sections in the diagram.



1. At the top of triangle are the recovery/species goals and objectives. Because the BDCP needs to contribute to recovery of the covered species, there must be a clear link to the needs of those species. This is best defined by existing recovery plans for the species. If a recovery plan is not available, the responsible agencies should provide guidance on appropriate goals and objectives for the species as a whole.

2. The contribution to recovery made by BDCP is not predefined. Expert opinion and conceptual models of the species can be used to identify limiting factors/stressors for the species; BDCP should further select those limiting factors/stressors that can be addressed by the potentially regulated entities (PREs) and that occur within the planning area. From this subset of limiting factors, BDCP can then identify more specific goals and objectives that are within its scope and that are scaled by the level of effort envisioned for the Plan.

3. Conservation Measures must be identified that have the capacity to achieve the BDCP goals and objectives. Candidate measures can be screened using simple models (e.g., conceptual, statistical) to assess potential outcomes, both positive and negative. After

screening an initial list of conservation measures, some BDCP goals and objectives may appear unlikely to be addressed; additional conservation measures should then be developed and/or the BDCP goals and objectives should be revisited to ensure that their scale and scope generally match with the level of effort envisioned for the Plan.

4. Once the types and overall scale of the conservation measures have been determined, they can be further developed to the ‘project level’ and more specific expected outcomes identified. At this level of specificity, models of all types can be used to apply cause-effect relationships and find outcomes that achieve BDCP goals and objectives (and identify any potential negative outcomes). Where cause-effect relationships are weak or there is disagreement over the nature or magnitude of outcomes, testable hypotheses can be developed linking the action to the outcome and projects designed to test the hypotheses. The analytical framework for testing these hypotheses (and the necessary mechanistic monitoring) should be developed at this stage, prior to implementation of the projects.

5. Monitoring informs all of these steps. System-level monitoring informs whether goals and objectives for BDCP and the species are being achieved. Compliance monitoring ensures that measures (e.g., actual Old and Middle River (OMR) flows, elevation of grade or fill, water quality standards) are being implemented as expected. Performance monitoring is used to tell whether a conservation measure is achieving the expected outcomes, and mechanistic monitoring provides diagnostic information on why the expected outcomes are or are not being achieved. These types of monitoring are described in the Independent Advisors’ Report on Adaptive Management.

6. Once projects have been implemented and monitoring data are available, the key adaptive management step of Analyze, Synthesize and Evaluate must be conducted to: a) assess performance; b) inform adjustments to implemented projects and future actions; c) incorporate information as part of the knowledge base and; d) utilize information in models for future use in the planning process. This is the essence of adaptive management.

Linking Conservation Measures to Outcomes: Issues of Study Design, Quantification, Metrics, and Monitoring

Specific conservation measures provide the opportunity to develop clear hypotheses that predict outcomes, require rigorous quantification, and lead to well-designed studies with defined metrics and monitoring approaches. Conservation measures exert themselves at a variety of spatial scales. For example, reduction in a specific stressor might produce a response at the scale of the entire Delta while a habitat restoration project will impact a specific location. Study designs must necessarily consider the spatial component of the conservation measures and monitor appropriate response variables to the action. Study designs also must consider appropriate analytical frameworks for comparing responses to the actions. Will evaluation of the conservation measure be compared to a long-term trend, a control site, or a change in trajectory within a specific location? Scientists should be engaged to address the challenges of designing studies that effectively evaluate whether implemented conservation measures are yielding desired outcomes. This is an area where scientific expertise should be focused rather than on identifying overarching goals and objectives.

Well-designed studies linked to specific conservation measures are critical for developing the larger integrated monitoring framework. Finite resources will be available to evaluate the effectiveness of conservation measures agreed upon through BDCP. The sooner that study designs with designated metrics and monitoring locations are developed for each conservation measure to be implemented, the more readily can decisions be made on the best package of metrics to deploy, the locations for these measurements, and the analytical framework for data analyses. These decisions are integral to application of adaptive management, communication of outcomes from specific conservation measures, and informing decision-makers on management actions. These steps must be carried out within the context of the overall planning effort and not left until later.

The Role of Adaptive Management

In a system as complex as the Bay-Delta, involving multiple constituencies and numerous projects that entail huge investments, it is essential to avoid costly mistakes. The focus of the logic-chain approach on defining meaningful goals and objectives for BDCP is an important part of a successful planning process. It is also an essential element of adaptive management, which itself must be a core part of BDCP. Much has been made of adaptive management and its role in effective conservation and management. *Real* adaptive management, however, is rarely undertaken. In particular, the part of the process that involves assessment and synthesis of information gained after actions have been taken is often neglected or short-circuited, and the critical phase of linking that knowledge to decisions about whether to continue, modify, or stop actions, refine objectives, or alter monitoring efforts is usually missing. The report of Independent Science Advisors on Adaptive Management to the BDCP Steering Committee provides detailed guidance that should be incorporated into any logic-chain approach in BDCP.

Several aspects of adaptive management merit particular attention in relation to the logic-chain approach. First, adaptive management must begin with a clear definition of the problem to be addressed and the goals and objectives to be met. The hierarchical structure of logic plans helps to bring clarity to these statements of goals and objectives. Second, models can play a valuable role in adaptive management. Many of the conservation measures being proposed for the Bay-Delta are large and expensive; simulation or scenario models can be used to explore the likely outcomes of these measures before actually implementing the measures, and this information can be used in an adaptive-management framework to adjust goals, objectives, hypotheses, or measures as appropriate. Third, the adaptive-management phases of assessment, synthesis, translation, and communication must be integral parts of either model-based or actual implementations of adaptive management. Little is accomplished by producing model output or monitoring following the implementation of conservation measures if the resulting information does not make its way, in a carefully evaluated and readily comprehensible form, into the decision-making process.

Prioritization and Sequencing

The successful development of quantifiable objectives for BDCP will provide added benefits by allowing the expected outcomes of individual conservation measures to be compared to one another and used with other data to prioritize and sequence implementation. Measures with more significant outcomes and a broader range of species to benefit will be identified. Together with cost information (including the potential for negative outcomes), this information can be used by BDCP to develop a prioritized list of conservation measures, with the order of implementation being dependent upon decision criteria such as risk tolerance, availability of funds, cost relative to expected benefit, water requirements, and ease of implementation. For example, an implementation plan could sequence high-priority projects based on costs and reliability of benefits to seek to achieve early successes at minimal cost. Well-developed decision-support tools, such as ecological risk assessment or return-on-investment analysis, should be incorporated into the prioritization process.

APPENDIX 1

Specific Questions to the Panel and Panel Responses

The charge to the Review Panel included several specific questions. Here are our answers; the main body of the report describes our responses, evaluations, and suggestions in greater detail.

Purpose

- Does the framework reflect the recommendations made in February 2009 by the BDCP Independent Science Advisors' Report on Adaptive Management? *No*
- Can the framework adequately serve as a basis for refining the BDCP goals and objectives and developing an adaptive management plan? *Yes, if developed fully*
- Is the logic framework clearly defined and described? *Only partially*
- Is it internally consistent? *It is not consistent in how hypothesis testing is being employed*
- Is it clear for what purpose and how the framework might be used? *Yes, although greater clarity in linking BDCP goals and objectives to conservation measures and outcomes would be an improvement*

Approach

- Are the linkages between elements of the framework clear? *Yes*
- Is the relationship between recovery plan goals and BDCP goals and objectives clear? *No*
- What level of detail is necessary for the goals and objectives and for the framework in general? *Recovery/species goals and objectives can be stated qualitatively if sufficient detail is not available; BDCP objectives can be stated qualitatively or with order-of-magnitude approximations in the early planning stages, but with greater quantification as the plan is finalized for implementation; expected outcomes to conservation measures should be stated in sufficient quantitative detail to permit measurement, analysis, and testing of hypotheses.*
- Is the current use of conceptual models and hypotheses clear and helpful? *Only partially; currently the hypotheses are in the wrong place in the logic chain.* If not, how might this be changed or refined? *We have offered a refinement of the logic chain approach that improves clarity*
- What are the next steps regarding populating the logic chain? *General goals and objectives should be defined and populated by the appropriate regulatory agencies; it should be an immediate priority to develop clearer, more concise language and to find consensus on goals and objectives within the BDCP steering committee*
- What, if any, future role/need is there for additional scientific input? *The hypotheses linking conservation measures to projected outcomes, the design of studies to assess these linkages, and the framework for implementing adaptive management would benefit from additional scientific input*

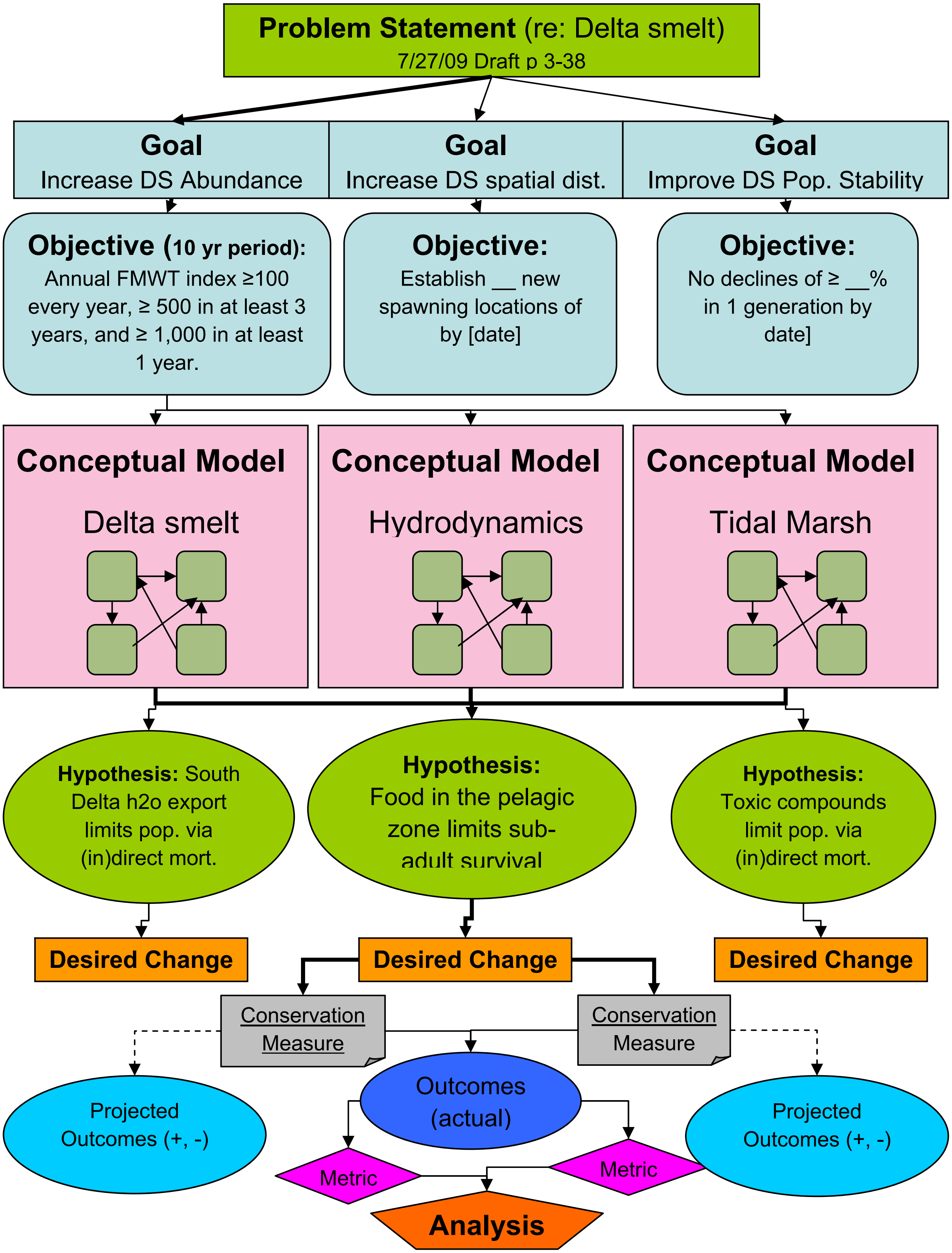
Feasibility

- Is the framework approach feasible to implement? *Yes, if done so in a focused manner*

- If not, what can be done to streamline or phase the approach? *Conduct a complete logic chain assessment for 2-3 species as proof of concept*

APPENDIX 2

The Current Version of the Logic Chain for Delta Smelt
(Appendix B of the Logic Chain provided by American Rivers and The Bay Institute)


Problem Statement (re: Delta smelt)
7/27/09 Draft p 3-38
Goal
Increase DS Abundance
Goal
Increase DS spatial dist.
Goal
Improve DS Pop. Stability
Objective (10 yr period):
Annual FMWT index ≥100 every year, ≥ 500 in at least 3 years, and ≥ 1,000 in at least 1 year.
Objective:
Establish __ new spawning locations of by [date]
Objective:
No declines of ≥ __% in 1 generation by date]
Conceptual Model
Delta smelt
Conceptual Model
Hydrodynamics
Conceptual Model
Tidal Marsh
Hypothesis: South Delta h2o export limits pop. via (in)direct mort.
Hypothesis: Food in the pelagic zone limits sub-adult survival
Hypothesis: Toxic compounds limit pop. via (in)direct mort.
Desired Change
Desired Change
Desired Change
Conservation Measure
Conservation Measure
Projected Outcomes (+, -)
Outcomes (actual)
Projected Outcomes (+, -)
Metric
Metric
Analysis

Appendix G-5

Bay-Delta Conservation Plan Delta Science Program Panel
Second Review of the "Logic Chain" Approach

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BAY-DELTA CONSERVATION PLAN

DELTA SCIENCE PROGRAM PANEL *SECOND* REVIEW OF THE "LOGIC CHAIN" APPROACH

Prepared for
BDCP Steering Committee

by
Denise Reed, University of New Orleans
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23 August 2010
Revised 6 September 2010

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Summary Findings and Recommendations

Panel findings and recommendations are summarized below according to the three primary goals of the logic chain approach.

Develop reasonably achievable BDCP objectives and conservation measures that contribute to broader species recovery goals.

The logic chain structure could be simplified to reduce the number of objective statements and to focus BDCP objectives. Recommended changes to the logic chain structure are shown in Figure 2. Specific findings and recommendations include:

- The identification of "BDCP" goals and objectives, versus global goals and objectives, is very important. The structure of the upper portion of the logic chains needs to be agreed upon for the logic chains to be effective.
- Identify stressors prior to the development of BDCP objectives. BDCP objectives should be linked to specific stressors, and stressors to both BDCP and global goals.
- Explicitly identify stressors that are outside of BDCP's management zone in the logic chains.
- Whenever possible, focus BDCP objectives on measures of individual and population-level performance, such as habitat-specific estimates of growth and survivorship, quantitative estimates of abundance, and quantitative measures of movement and/or distribution.
- Consider developing logic chains for selected key community and ecosystem properties to capture outcomes associated with certain conservation measures that are not obvious from piece-wise presentation among species-specific logic chains.
- Include estimates of magnitude and certainty to facilitate prioritization of conservation measures and to aid in future adaptive management. Estimates of both the magnitude of effects and their associated certainty can be done in narrative form with supporting documentation.
- Retain flexibility to tailor logic chains for each species, recognizing the trade-off between consistency and uniqueness. For example, although the four Viable Salmonid Population (VSP) characteristics should be important in conserving most fish populations, a simpler structure may provide more biologically realistic logic chains for species like delta and longfin smelt.
- Consider a workshop with technical experts for each species, with the goal of preparing a simpler "influence diagram".
- Adjust the format and presentation of the chains to make them more readable.
- Minimize "insider" information and poorly-defined jargon in the logic chains. Terms like "productivity", as used in the logic chains, are generic terms, and not sufficiently specific to ensure clear goals or objectives.

Describe possible metrics designed to monitor and evaluate the effectiveness of implementing the BDCP conservation measures.

- Great care should be used when populating the compliance and performance monitoring boxes in the logic chain. Three levels need to be considered separately: 1) the level that addresses the Global Goal, 2) the “covered activity” level, and 3) compliance monitoring, which measures implementation of the planned conservation measure.
- Although the Panel sees a distinction between annual abundance indices and BDCP performance metrics, the Panel strongly recommends that the BDCP performance metrics be related to fish vital rates (reproduction, growth, mortality).
- Contribute funding to creating and maintaining a repository of data, similar to the National Science Foundation’s Long-Term Ecological Research site network.
- Identify the key unknown biological attributes of covered species, and commit to long-term sampling and focused studies on fundamental biology and ecology of species to be paired with that centered on solving immediate problems related to water management.

Link implementation of conservation measures, through monitoring and evaluation, to the adaptive management program.

- Clearly identify the management goals that can be addressed via adaptive management (sensu Walters 1986) in the draft Plan (i.e., by November), those that can be addressed during the subsequent refinement phase (prior to the formal permit issuance), and those that can only be addressed during implementation.
- A programmatic approach to research should be developed for early adoption, even prior to permitting, and the post-permitting adaptive management approach must be described and finalized as soon as possible, so that conservation measures and post-implementation monitoring can be refined and developed using that research.
- Consider an objective process for developing an implementation plan that acknowledges: (1) the certainty of achieving expected outcomes; (2) that not all measures can be implemented immediately; (3) that not all will achieve their ultimate outcomes immediately, and (4) that some are contingent on the success of others (perhaps using optimization or other approaches as suggested by the first Logic Chain Panel) to provide more realistic expectations of how the system might change as a result of the Plan.
- Consider using a formal decision support system (one that allows for incomplete information, generalized relationships, uncertainties etc.) to identify high priority measures and those for early implementation.
- Develop an adaptive management plan in sufficient detail for the November Draft Plan so it is clear to all participants which procedures will be used to revise BDCP objectives and how additional information, especially reduced uncertainty, will be incorporated into the Plan during implementation (i.e., revisiting the logic chains).
- Comprehensively articulate conservation outcomes based on the logic chains, including their spatial distribution, at decadal intervals to provide a realistic expectation of the changes expected as a result of plan implementation.

1. Background

The Bay Delta Conservation Plan (BDCP) is being prepared through a collaboration of state, federal, and local water agencies, private enterprise, state and federal fish agencies, environmental organizations, and other interested parties to obtain permits under federal and state endangered species acts. The plan will identify a set of conservation measures that will provide for changes in conveyance and operations of the State and federal water projects, operations of Mirant power generation, reductions of other stressors, and habitat restoration actions to contribute to the recovery of endangered and sensitive species and their habitats in California's Sacramento-San Joaquin Delta. The goal of the BDCP is to provide for both species and habitat protection and improved water supplies.

The logic chain approach has been developed by the BDCP Steering Committee to provide a framework and planning tool for:

1. Developing reasonably achievable BDCP objectives and conservation measures that contribute to the broader (global) species recovery goals;
2. Describing possible metrics designed to monitor and evaluate the effectiveness of implementing the BDCP conservation measures; and
3. Linking implementation of conservation measures, through monitoring and evaluation, to the adaptive management program.

An earlier version of the Logic Chain approach was reviewed in March 2010 by a panel convened by the Delta Science Program (Dahm et al., 2010). This second Review Panel was also convened by the Delta Science Program on August 4 and 5, 2010 and was supported by Delta Science Program staff, including Cliff Dahm and Elizabeth Soderstrom, and BDCP support contractors including Bruce DiGennaro of the Essex Partnership, Wayne Spencer of the Conservation Biology Institute and Kateri Harrison of Swale Consulting. The agenda for the second review meeting is included as Attachment 1.

2. The Charge

This Review Panel was charged with focusing on:

1. Assessing populated logic chains to evaluate internal logic, measurability, linkages between plan components, and consistency in approach;
2. Recommending alternative strategies or metrics for identifying progress towards meeting goals and objectives or alternative ways of framing goals and objectives such that they are practicable; and
3. Offering advice on constructing an integrated monitoring and evaluation program linked to the logic chains.

Other topics suggested by the BDCP and included in the charge to the Panel were:

4. Discussion and review of metrics and how they provide a context for design of measureable, practicable BDCP Objectives and Stressor Sub-objectives.
5. Discussion of current and potential future monitoring within this system to create a context for objectives that will be measureable and practicable that will support adaptive management in the future.

The Panel members were asked to review four logic chains: longfin smelt (*Spirinchus thaleichthys*), winter-run Chinook salmon (*Oncorhynchus tshawytscha*), and white and green sturgeon (*Acipenser transmontanus* and *A. medirostris*). The Panel focused their efforts on reviewing the longfin smelt and Chinook salmon logic chains because these were the most complete. Although no members of the Panel currently conducts research specifically on any of these species, several have previous experience working in these environments and with estuarine species, and so represent an experienced group of fish biologists and natural resource scientists. Therefore, the Panel reasoned that the logic chain architecture and presentation should be clear and apparent to them, with minimal additional information required and the comments and recommendations provided in this report are based on that reasoning. This report includes some general observations on progress since the previous logic chain review panel and provides some recommendations on logic chain structure, content and use within the BDCP planning process. Key comments and recommendation are shown in bold italics in the text.

3. Progress to Date

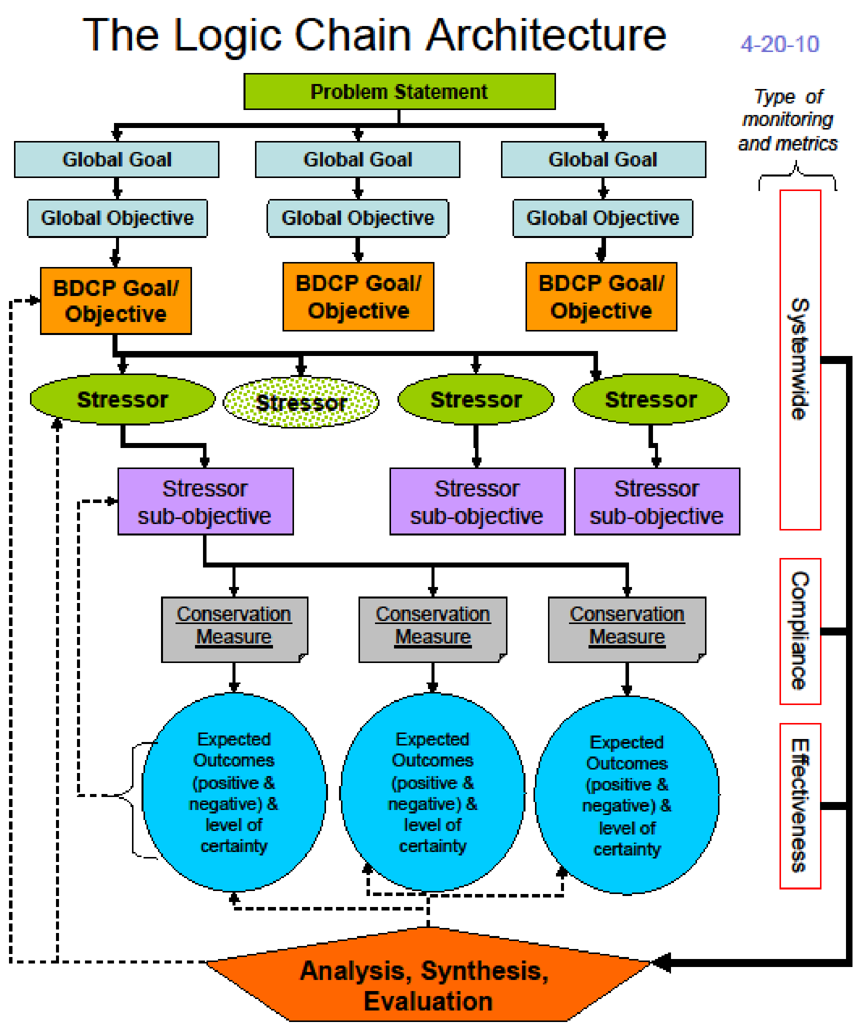
The Panel was impressed with the tremendous amount of work and detail that went into development of the two example logic chains. Conceptually, the logic chain approach will aid in identifying how conservation measures influence the key stressors affecting fish populations in the Delta as well as those affecting the ecosystem as a whole. The Panel appreciated that the logic chain structure enables the chains to capture many of the potential factors affecting the species involved. The two examples reviewed in detail by the Panel (longfin smelt; winter run Chinook salmon) seemed to be relatively complete in terms of accounting for possible stressors, and how conservation measures fit into the overall Bay Delta Conservation Plan. The example logic chains were well thought-out and documented, given the data available.

The Panel also noted that the BDCP team was responsive to the earlier review of the logic chain approach (Dahm et al., 2010). In particular, the two examples and the presentations made by the BDCP team members reflected steps 1-3 proposed in the earlier review. These recommendations were: detailed preparation of logic chains for 2-3 species, development of upper portion of the logic chain (additional comments on this aspect are provided below), and collaborative development of the middle portion of the logic chain. The Panel notes that other comments in the earlier report also were considered, such as the use of metrics that were clearly linked to biological functions for evaluating conservation measures and the inclusion of, and distinction between, compliance and performance monitoring. The use of the conceptual models from the DRERIP evaluation as one of the building blocks for the logic chains, at least at this stage of their development, is endorsed by the Panel.

4. Logic Chain Structure

The Panel recommends several changes to the original logic chain structure (Figure 1) which are described below and in Figure 2. In order to clearly illustrate our suggested revisions, we prepared a hypothetical (and overly simplified) logic chain for longfin smelt (Figure 3) that includes one possible conservation measure.

Figure 1. Logic Chain Structure presented to the Review Panel

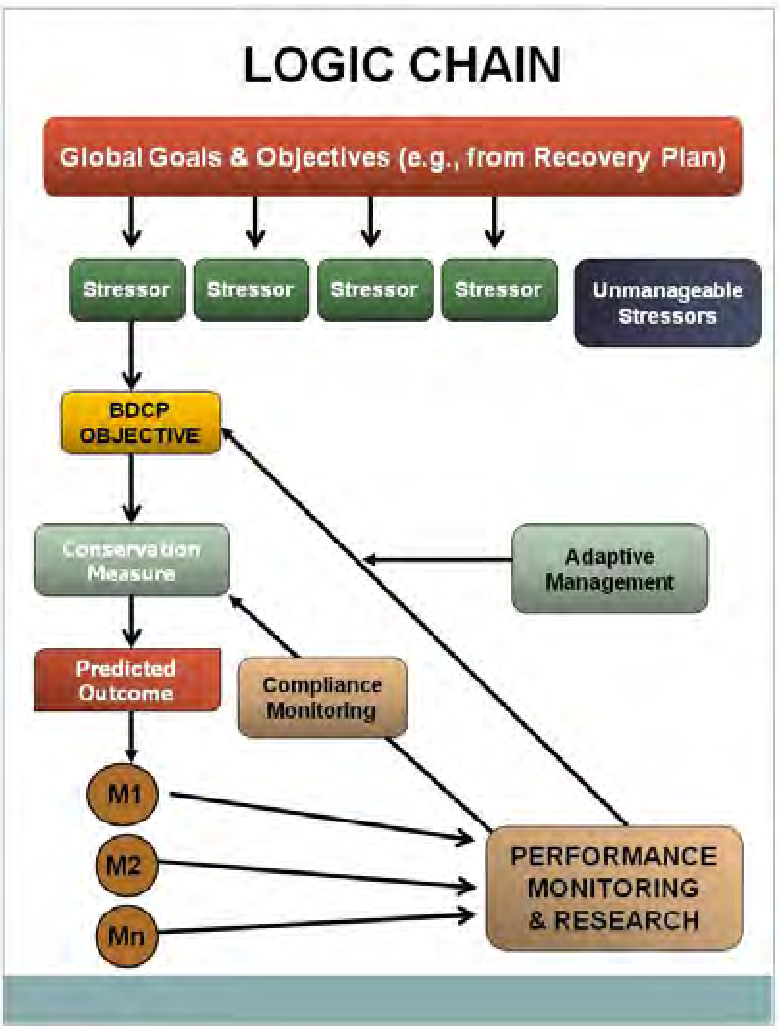


Schematic of the Logic Chain architecture for one species. One stressor (dappled green) is outside of the BDCP purview; thus it has no associated BDCP goal. In this example, stressors and steps below this level refer to one of the BDCP objectives; other BDCP objectives would be developed simultaneously. Similarly, for illustration purposes, only one stressor sub-objective is developed here. Dashed lines refer to different types of evaluations (based on monitoring data) that will be used to adaptively manage within the conservation strategy.

4.1 Goals, Objectives and Stressors

The structure of the upper portion of the logic chains needs to be agreed upon or else the logic chains will be ineffective. The Panel recognizes the importance of all parties agreeing upon a clear statement of goals and objectives and identifying the role of BDCP in achieving them. As presented to the Panel, the logic chains included a problem statement as well as both global goals and objectives and BDCP goals/objectives (Figure 1); this resulted in difficulties in identifying

Figure 2. Proposed Revised Logic Chain Structure. See text for explanation. M1, M2 and Mn refer to an indeterminate number of metrics developed for use in monitoring of the conservation measure and predicted outcomes.



the scale at which conservation measures were to be evaluated (i.e., the global context or a BDCP context). It also appeared to the Panel that the BDCP team was having difficulty resolving some of the wording of the goals and objectives – a very important element of the logic chain approach in that it sets expectations regarding the scope of BDCP 'responsibilities' for meeting the conservation outcomes. The responsibility for species recovery is determined by the ESA, and how recovery is measured is determined by the US Fish and Wildlife Service (USFWS) and NOAA Fisheries. How is the global goal for recovery of endangered species (set by the agencies) linked to the BDCP goals? These links need to be made explicit.

The Panel endorses the recommendation of the previous logic chain review panel (Dahm et al., 2010) concerning the placement of the stressors within the logic chains, and expands on that earlier recommendation here. In the logic chains, BCDP objectives should be linked to specific stressors, and stressors to global goals. For example, for the stressor of "insufficient flow through the Yolo Bypass", the conservation measure would be to increase flows and the BDCP objective(s) could be to increase survival and successful migration of juvenile Chinook salmon, and increase juvenile foraging habitat for sturgeon.

It is important to recognize within the logic chain structure that BDCP will not address all of the stressors identified by the recovery plans. Those not addressed can be grouped together in the logic chain and identified as "unmanageable stressors." It should be clearly stated whether they are unmanageable because BDCP has not identified any appropriate conservation measures, because they are simply not influenced by any management actions under the auspices of BDCP (e.g., they are associated with ocean, or upstream factors), or they are not under management control (e.g., droughts).

To address these issues the Panel recommends the following changes to the upper sections of logic chain structure:

- ***Distinguish between Global goals and objectives set by agencies and "BDCP" goals and objectives.***
- ***Stressors linked to the global goals and objectives should be considered prior to the identification of BDCP objectives.***
- ***Stressors not potentially influenced by BDCP should be explicitly listed in the logic chains.***

The Panel's recommended structure reduces four levels (Problem, Global Goal, Global Objective and BDCP Goal and Objectives) to two levels (Figure 2). The problem in general will be described elsewhere in the Plan and Global Goals and Objectives should be derived from existing recovery plans or provided by resource agencies.

4.2 Monitoring Metrics

The Panel discussed at length compliance and performance metrics for monitoring. It was not clear that the monitoring approach within the logic chains focused on vital demographic rates and population-related parameters that are directly related to rates of population change. The global goals and objectives will relate to the recovery of the species, which the Panel assumes will be assessed by the agencies and that will include some sort of annual abundance index. Compliance and performance metrics would be the responsibility of BDCP. Compliance monitoring is designed to confirm that the conservation measure was achieved, whereas performance monitoring is designed to evaluate how well the expected outcomes of the conservation measure are being achieved[1]. It is critical to utilize performance metrics that reflect the spatial and temporal scales of the specific conservation measure and its expected local biological effect. This not only allows for the success of the conservation measure to be evaluated as part of adaptive management, but also provides information on possible causes of changes in the abundance indices when such changes are detected. However, the Panel does recognize that, in some cases, performance metrics can be based on the annual abundance indices if that is appropriate for evaluation of the effects of a specific conservation measure. Ultimately, local performance measures must be considered in the context of trends in abundance indices to assess the population-level effects of the conservation measure.

Within the revised logic chain structure, multiple monitoring metrics are shown related to each conservation measure and its expected outcome. This performance monitoring can then be used within an adaptive management framework to evaluate BDCP objectives (Figure 2). The revised structure also specifically notes the need for compliance monitoring to determine that conservation measures were implemented as expected. In addition to these clarifications within the logic chain, the Panel recommends that:

- ***Whenever possible, objectives of the chains should focus on measures of individual and population-level performance, such as habitat-specific estimates of growth and survivorship, quantitative estimates of abundance, and quantitative measures of movement and/or distribution.***
- ***The BDCP performance metrics must relate to fish vital demographic rates.***

[1] See Science Advisors Report on Adaptive Management (Dahm et al., 2009) for more on different types of monitoring.

4.3 Explicit Treatment of Uncertainty

The logic chains appeared to take a static approach to ecosystem processes, and did not explicitly consider uncertainty. Yet everyone recognizes that conditions in the Delta are not at equilibrium. The logic chains will likely need to consider variation in physical and biological factors for wet, dry, and “average” years. The concept of tailoring performance metrics to the water year type adjusted for flow variation seems promising. The example logic chains presented to the Panel do not include estimates of either the magnitude or uncertainty associated with a given conservation measure and its expected outcome. Some information on magnitude and uncertainty was presented in the logic chains provided to the Panel as part of the DRERIP evaluations, but it was unclear how this information was to be incorporated into the BDCP logic chains.

The Panel recommends that:

- ***Given the 50-year projected life of the BDCP, issues like climate change and continued invasion by non-native species need to be considered.***
- ***Magnitude and uncertainty estimates should be included to facilitate prioritization of conservation measures and aid in future adaptive management. Estimates of both magnitude of effects and their associated uncertainty can be done in narrative form with supporting documentation.***

4.4 Focus of Logic Chains

The current logic chains are species - based, which is appropriate given that the species involved have different life histories and ecological requirements; however, this separation can only result in successful management when the ecosystem context of the species is explicitly recognized. In addition, there may be both positive and negative effects at the community and ecosystem levels associated with certain conservation measures that are not obvious from piece-wise presentation among species-specific logic chains. This could be achieved by including the community and ecosystem aspects in each species logic chain but broader implications could be lost.
The Panel recommends that:

- ***In addition to covered species, the BDCP Steering Committee should consider developing logic chains that focus on key community or ecosystem properties.***

4.5 Example of Revised Structure

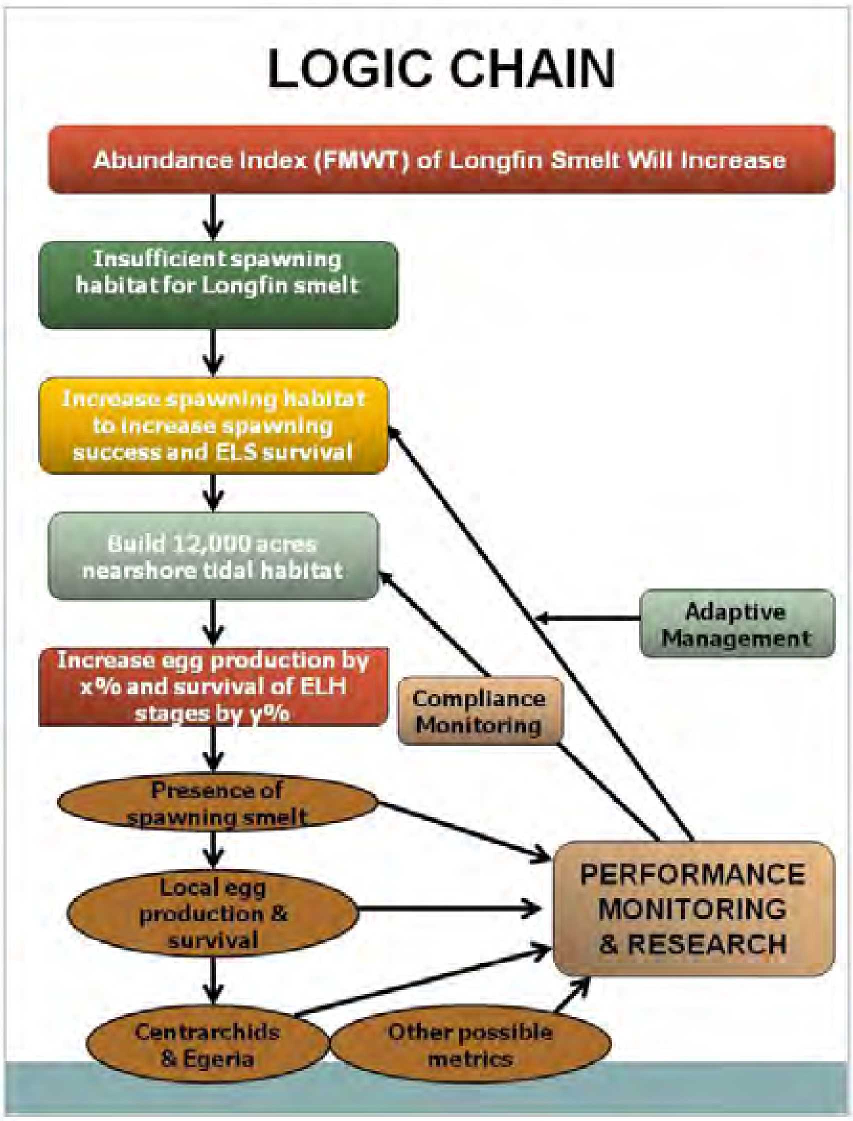
To illustrate the different levels in the revised structure and the linkages among them, the Panel outlined an example application for one line in the chain (i.e., one stressor, one BDCP objectives, one conservation measure for that objective, etc.). This is shown in Figure 3. A completed logic chain would have multiple branches from each stressor, objective, conservation measure and outcome. This example does not include uncertainties as recommended above. These could be identified on the diagram using a color coded key or in supporting narrative.

In our example logic chain (Figure 3), the global goal is to increase the Fall Mid-Water Trawl index and a stressor is insufficient spawning habitat for longfin smelt, and underneath this in the chain is a potential BCPD objective of creating nearshore tidal habitat. The conservation measure deemed to meet that objective was to build 12,000 acres of nearshore tidal habitat to increase spawning, overall egg production and survival of early life stages. Compliance monitoring would involve measuring how many acres were built. Performance monitoring would measure the presence of spawning smelt (i.e., smelt did use the new habitat), quantifying local egg production and survival (i.e., the new habitat is suitable for spawning), and determining whether the new habitat also resulted in increases in invasive competitors and predators such as centrachids and *Egeria* (i.e., were there negative consequences?).

5. Logic Chain Content, Format and Knowledge Base

After evaluating the general structure of the logic chains, the Panel examined the information required to populate (i.e., assign information) and interpret the logic chain. These comments and recommendations pertain to how the information is presented, its sources and how knowledge should be organized to support development and evolution of the logic chains.

Figure 3. Outline Example of Revised Logic Chain Structure for longfin smelt. Refer to text for additional explanation.



5.1 Logic Chain Content

Although the four characteristics that form the basis of the viable salmonid populations (VSP) approach are important in conserving most fish populations, a simpler structure, where some characteristics are combined or down - weighted in importance, would aid in creating more biologically realistic logic chains for species like the two smelts. There may also be other aspects of the logic chains that require a tradeoff between consistency and uniqueness among species. The Panel suggests that greater flexibility be used so that the logic chains can be tailored to each species. The use of the VSP (McElhany et al. 2000) as a framework for the logic chains is good, but may not be ideal for all species. The four parameters highlighted in the VSP are population size, population growth rate, spatial structure, and life history and genetic diversity. The VSP approach is useful because it focuses on the intersection of spatial and temporal scales around which managers make water resource decisions, and over which fish populations and metapopulations carry out their life cycles (e.g., Fausch et al. 2002; Fausch 2010). However, the use of the VSP framework for all species may result in forcing a salmonid-based framework on species for which it is inappropriate. For example, what is known about life-history diversity for Delta smelt, and how important is it?

Terms like "productivity", as used in the Logic Chains, are generic terms, and not sufficiently specific to ensure clear goals or objectives. Clear terms are needed for clear communication. The term productivity allows users to conjure up their own specific meaning. It becomes clear on further reading that the goals really involve vital demographic rates (e.g., reproduction, survival, and growth). The term "production" has a specific meaning in fish population biology. This term refers to the total increase in biomass (fish tissue) within the fish population during a time interval, including that lost through mortality (Chapman 1978). In practical terms, it is the product of the mean biomass in the population times its growth rate, usually measured at rather frequent intervals, especially during the season that fish are growing rapidly. Thus, the units of production are g/m^2/year of tissue produced. Avoid vaguely defined terms and define what is meant.

Great care should be used when populating the compliance and performance monitoring boxes in the logic chain. Three levels needs to be considered separately: 1) the level that addresses the Global Goal, such as measuring adult sturgeon returning to spawning areas or the FMWT index for smelt, 2) the "covered activity" level (e.g., Yolo Bypass), to assess how a specific conservation measure action at a local-to-regional scale affects appropriate abiotic and biotic variables, and 3) compliance monitoring, which measures that the conservation measure was implemented as planned. Dealing with the specifics of the monitoring will have a great influence on the adaptive management and evaluation of the BDCP. The revised logic chain tries to emphasize this by delineating measurements at these three levels. Often, measurements for the first level are used by the USFWS and NOAA-Fisheries to monitor the status of the species. At the second level, although physico-chemical variables can be used as performance metrics, variables that directly relate to fish processes and vital rates must also be included.

In most cases, measuring vital demographic rates as part of performance monitoring is possible, though technically and analytically challenging. For example, for the Yolo Bypass, Chinook salmon smolt output downstream, and adult salmon and sturgeon passage upstream, could be explicitly measured. For smolts, capture-recapture methods (i.e., marking and recapturing individuals) focused explicitly on estimating abundance and survival (where appropriate), and the uncertainty in these parameters (i.e., confidence intervals), have been available for more than two decades (see Burnham et al. 1987; White and Burnham 1999), but application of these methods requires trained field biologists, often large field sampling programs, and biometricians with expertise in analyses of these data (for an example with spotted owl management, see Burnham et al. 1996).

5.2 Logic Chain Format

The logic chain should provide a mechanism by which biologists and decision makers can easily grasp the information, while retaining supporting documents that provide the details about all possible stressors and conservation measures. One solution would be a workshop with technical experts for each species, with the goal of preparing a simpler "influence diagram". In their deliberations, the Panel worked with the example logic chains, and found the extensive and complicated supporting materials challenging to both read and understand. This certainly is a consequence of trying to abstract the critical features from a complex and variable system. Nonetheless, the massive tables of goals, objectives, stressors, conservation measures, and expected outcomes hamper understanding and indentifying key issues for each species, and hence make it difficult for general users to prioritize conservation measures. For example, for winter-run Chinook salmon, restoration of floodplain rearing habitat in the Yolo Bypass is likely a key conservation measure which, if addressed, might have the largest positive effect that could contribute to recovery. Such information needs to be readily identified by logic chain users. This problem could be addressed by the development of a simpler 'influence diagram" (a term borrowed from decision theory, such as use of Bayesian Belief Networks; see Jensen 1996; Marcot et al. 2006) for each chain. The diagram could include: 1) the *key* factors that influence habitat, growth, and survival of the target species at the most important life stages, 2) the *key* stressors that reduce these physical and biological attributes, 3) the options for altering these factors, and 4) how these coalesce to influence the key population performance measures (e.g., persistence of the species or stock). Peterson et al. (2008) provide an example application in a much more circumscribed system.

The Panel suggests adjusting the format of the logic chains themselves to make them more readable. The Logic Chain tables presented to the panel used a vertical format in which the reader attempted to work linearly from top to bottom within a "stressor" column, but soon was faced with Expected Outcomes and Risk Factors that did not seem to belong in the column. For example, in the winter-run Chinook salmon table, Stressor 3 addresses Predators and Invasive/non-native species, with a Sub-objective of reducing predation on juveniles by a given percentage by a certain date from Sacramento to Rio Vista. However, the next item working down the table (an Expected Outcome) states "Removal of old structures was not evaluated by DRERIP", which initially the panel did not understand. Likewise, the metric under the next

Expected Outcome down (OCSM13-P4: Reduce predation) includes two statements "Change in biovolume of *Egeria densa* relative to control areas (#20)," and "Change in areal coverage of water hyacinth relative to control areas (#21)". Overall, it was not clear why old structures, *Egeria densa*, or water hyacinth would influence predation, nor was it very clear that Risk Factors encompassed the idea that various conservation measures might have unanticipated negative effects that would cause problems elsewhere. Although it is possible that some of these things are explained elsewhere in material that the Panel did not read, it would be wise to clarify them more for new users.

The Panel recommends minimizing "insider" information and poorly-defined jargon in the logic chains. If the logic chains are expected to present important information in a way that is accessible to the many parties interested in BDCP, it would seem wise to use simpler and more direct statements that the average biologist or policy maker can understand, rather than codes and terms that are familiar only to BDCP personnel (e.g., OCSM13-P4, or Metric #20). Likewise, one could clearly label Risk Factors as Possible Negative Effects of conservation measures, or something similar. However, it is certainly advisable to hyperlink these simpler statements to documents where codes and details used by BDCP from past analyses and plans are found.

5.3 Knowledge Base for Logic Chain Development

Funds need to be targeted to create and maintain such a repository of data, similar to the National Science Foundation's Long-Term Ecological Research site network. The credibility and usefulness of the logic chains are dependent on the quality of the information used to populate them. There is apparently no centralized repository of data and analysis for species covered by the BDCP, and much is unpublished. This prevents reanalysis of past data, and synthesis of new and past data into useful models. The Panel was struck by the realization that data are often in the hands only of the original investigators, multiple versions of the same dataset exist, and data are susceptible to either physical loss (computer crashes, media deterioration) or retirements (the investigator leaves or dies, and much information and interpretation is lost). Given that these data are all that we have from the expenditure of millions of dollars of research and monitoring over many years, this modest investment in standardizing and protecting that irreplaceable knowledge seems self-evident. Although we acknowledge the need for publication by the primary collectors of the data, a central repository will facilitate subsequent analyses by a variety of scientists that will result in the quickest assessment of the biological processes being described.

The Panel recommends that technical experts identify the key unknown biological attributes of covered species, and a concerted effort be made to provide stable funding to address these knowledge gaps. These studies will require long-term efforts, with adequate funding, but will reap long-term rewards. Availability of information for some species and stressors is limited, and this will ultimately limit the usefulness of the logic chains. The logic chains are only as strong as their weakest link and presently that link is basic life history information for many Delta species. Examination of the example logic chains highlighted how information-limited we are for some species and stressors. The Panel was struck by the lack of key biological information for some of the covered species and life stages. Key information such as movement patterns and residence times in various habitats (river vs. delta, north delta vs. south delta) for key life stages in a species life cycle, population structure, habitat-specific growth and survivorship rates, diets over the life cycle, and identification of spawning habitat, are essential to populate the logic chains, yet also are missing or weakly known. This is a common problem, and requires a commitment to long-term sampling and focused studies on fundamental biology and ecology of species to be paired with that centered on solving immediate problems related to water management (e.g., survival through pumps and screens).

6. Applying the Logic Chains in the BDCP

The Panel recognizes that the logic chains can provide a useful tool for organizing current ideas and formulating a comprehensive restoration plan to address BDCP goals and objectives. The approach provides more than just a better articulation of the existing goals – it links actions to those goals and lays out expected outcomes. However, to be used as a key building block for the Plan, it is important that the narrative is scientifically credible and that both potential positive and negative outcomes are considered.

To effectively use the logic chains to build the plan, it will be essential to clearly lay out linkages among logic chains, effects analysis, implementation plan, monitoring and research components, and adaptive management. It is clear to the Panel, and those who briefed them, that there need to be feedbacks between the logic chains and the effects analysis. The effects analysis will become a new and important set of data for the Plan, and the process of incorporation of those data in the decision processes and logic chains needs to be described explicitly.

The Panel recommends that BDCP clearly identify the issues raised by the logic chains that can be addressed in the draft Plan (i.e., by November), or addressed during the subsequent refinement phase (e.g., the following year as the Plan is finalized and prior to the formal permit application), and that can only be addressed during implementation. A programmatic approach to research should be developed for early adoption, even prior to permitting, and the post-permitting adaptive management approach must be described and finalized as soon as possible, so that conservation measures and post-implementation monitoring can be refined and developed using that research.

The Steering Committee should consider using a formal decision support system (one that allows for incomplete information, generalized relationships, uncertainties etc) to identify high priority measures and those for early implementation. The panel believes that BDCP will be most successful if an objective process for implementation is developed that acknowledges: 1) the uncertainty of achieving expected outcomes, 2) that not all measures can be implemented immediately, 3) that not all measures will achieve their ultimate outcomes immediately, and 4) that some are contingent on the success of others (perhaps using optimization or other approaches as suggested by the first Logic Chain Panel) to provide more realistic expectations of how the system might change as a result of the implementation of the Plan. Conceptually, developing the BDCP calls for optimization of solutions for multiple objectives, subject to various constraints. Formal optimization, or at least the thinking underlying optimization, can be applied to subsets of measures and specific spatial regions. The Panel recognized that, unless the intent is to implement every conservation measure currently under consideration, some means of discriminating among conservation measures, in terms of their expected outcomes and the certainty of achieving those outcomes, is needed. Such a structured decision process could also consider issues such as cost, feasibility of implementation, and effectiveness in alleviating stressors. At present, the procedures for making decisions are, at the least, unclear. Transparency is especially important due to the complexity of the issues being addressed and the short time frames within which the Plan is being developed. Although it is unlikely that a formal decision support system could be applied prior to the issuance of the Draft Plan in November 2010, the Draft Plan should include consideration of how such an approach will be used during plan refinement (i.e., post-November 2010).

An adaptive management plan should be developed in sufficient detail for the November Draft Plan so it is clear to all participants which procedures will be used to revise BDCP objectives and how additional information, especially reduced uncertainty, will be incorporated into the Plan during implementation (i.e., revisiting the logic chains). During the Panel meeting there were frequent references to the adaptive management component of the BDCP effort. The nature of the adaptive management plan being proposed by the Steering Committee and how it would be implemented was not clear to the Panel, based on the materials provided. Formal adaptive management, as outlined in Kendall (2001Walters (1986), Stankey et al. (2005), and Nichols et al. (2009), would require clear agreement on the objective to be optimized, and would require specific expertise in decision analysis to apply. As it stands now, adaptive management comes after the Plan has been developed and during implementation, and the Panel is concerned that 'punting' too many difficult issues that far into the future into an undefined process called adaptive management can undermine the credibility of the Plan. Issues deferred to the adaptive management phase should be those which require specific monitoring data, research, and analyses. The more decisions which are left for adaptive management to address, the more important it is that a robust adaptive management plan, in terms of thinking, coordination and funding, be developed.

The Panel recommends a comprehensive articulation of BDCP conservation outcomes based on the logic chains, including their spatial distribution, at decadal intervals to identify targeted outcomes and provide flexibility for changing environmental conditions. Creating appropriate expectations will be important for BDCP. The success of BDCP relies on good science, effective implementation, rigorous monitoring, strong adaptive management, and transparency, and judging the success of the BDCP will be how the results measure up to expectations. On one hand, it is important to emphasize the importance of the positives of the BDCP process. On the other hand, it is also important to ensure that everyone understands what can realistically be achieved and over what time and space scales.

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Attachment 1

Logic Chain Review Panel
August 4-5, 2010
Delta Stewardship Council Office, Bay Room
650 Capitol Mall, 5th Floor
Sacramento, CA 95814
AGENDA

Wednesday August 4th

1. **Advisory Panel meets and reviews charge** (panel only) — **8:00 – 8:30**
2. **Presentation on BDCP logic chains, metrics and monitoring** — **8:30 – 10:30**
    a. Overview and Context (15 min)
    Laura King Moon, Wayne Spencer
    b. Logic Chains (1 hr)
    Dave Harlow (winter run chinook salmon, longfin smelt)
    Josh Israel (green and white sturgeon)
    c. Metrics and Monitoring (15 min)
    Cliff Dahm

    d. Example Monitoring Framework (30 min)
    Ted Sommer (Yolo Bypass)
    Chris Enright (Suisun Marsh)

3. **Questions and Discussion** — **10:30 - 11:30**
    Lunch Break — **11:30 –12:30**
4. **Advisory Panel further reviews materials, begins to draft recommendations, and formulates questions** — **12:30 – 5:30**

Thursday, August 5th

1. **Advisory Panel meets with BDCP Team with further questions** — **8:00 – 10:00**
2. **Advisory Panel refines recommendations** — **10:00 – 12:00**
    Lunch Break — **12:00 – 1:00**
3. **Advisory Panel Reports out to BDCP Team and takes comments** — **1:00 – 4:30**
4. **Advisory Panel discusses next steps and writing assignments** — **4:30 – 5:00**

Appendix H

BDCP Agreements

Appendix H-1

January 2006 Statement of Principles

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Regulatory Commitments – User Contributions
Statement of Principles

Changes in available CALFED funding and the need to enable water supply, water quality, ecosystem, and levee projects to progress within a stable regulatory framework require a new structure that provides regulatory and funding assurances for the key actions described herein.

This Statement of Principles is the foundation for an agreement among the California Department of Water Resources, California Department of Fish and Game, U.S. Fish and Wildlife Service, NOAA's National Marine Fisheries Service, the U.S. Bureau of Reclamation, and others. This agreement proposes to cause (1) the development of one or more Habitat Conservation Plan/Natural Communities Conservation Plan(s) [HCP/NCCP(s)] for the Delta and its upstream basins and (2) the implementation of key, near-term water supply, water quality, ecosystem, and levee actions, subject to compliance with any applicable environmental review under CEQA and NEPA.

The negotiators intend these HCP/NCCP(s) to:

- *Ensure implementation of actions that will adequately conserve and assist in the recovery of fish and wildlife affected by covered activities as a major part of the overall CALFED Multi-Species Conservation Strategy's effort to recover fish and wildlife, and*

- *Provide long-term assurances related to implementation of and operation of designated water and power related projects and associated activities.*

Development and/or implementation of the water-related projects and protection of and recovery efforts for fish and wildlife resources are critical to the people and economy of California.

A key principle of the CALFED Bay-Delta Program is that the elements of the program (ecosystem, water quality, water supply, and levees) should be implemented in a balanced fashion with appropriate linkages among the elements, costs and benefits. This document acknowledges that a long-term water supply, water quality, ecosystem restoration and levee funding framework and a funding program for these actions needs to be developed in a timely manner including a long-term science program.

A process has begun regarding the development of a 100 year vision for the future of the Delta, consistent with AB 1200. This process could provide input and guidance for the HCP/NCCP(s).

DWR and DFG will continue to work cooperatively with the State Water Contractors and other interested parties in developing a separate NCCP to cover existing operations of the State Water Project and the operable gates.

I. Goal

A. The negotiators pledge their good faith efforts to obtain ratification of this presently non-binding Statement of Principles by each of their appropriate authorized persons and/or governing bodies on or before January 31, 2006.

B. Upon ratification, the undersigned negotiators pledge their good faith efforts to work diligently toward a Memorandum of Understanding (MOU) and final written Planning Agreement (the Agreement) that is consistent with the Principles set forth herein.

C. The negotiators anticipate that these Principles will be incorporated into a binding MOU by April 1, 2006.

II. The MOU and Agreement

A. The MOU shall establish the process for developing an Agreement for integrated or coordinated Habitat Conservation Plans ("HCP") and Natural Community Conservation Plans ("NCCP") covering the areas set forth in Section II.D.

B. The HCP/NCCP(s) are a mechanism voluntarily entered into, meeting the requirements of the Federal Endangered Species Act (FESA), the California Endangered Species Act (CESA) and the California Natural Community Conservation Planning Act (NCCPA). The Parties and Participants shall seek to structure the Agreement and the HCP/NCCP(s) in a manner that meets FESA, CESA, and the NCCPA and also enables the United States Bureau of Reclamation to be a Party. The Agreement shall address the relationship of the HCP/NCCP(s) to other regulatory actions such as Section 401 and 404 of the CWA, FERC relicensing, or other actions as appropriate. Actions proposed under the Agreement may be subject to compliance with any applicable environmental review under CEQA and NEPA.

C. Conservation strategies will be developed to contribute to regulatory compliance strategies, *inter-alia,* under Section 7 of the FESA and the HCP/NCCP(s).

D. Scope

The Agreement and the HCP/NCCP(s) shall identify covered activities and covered species which utilize the Delta, the Sacramento River Basin and the San Joaquin River Basin. The initial list of species to be covered by the HCP/NCCP(s) shall be set forth in an attachment or appendix to the Agreement. It is the intent of the negotiators to limit the Agreement to those fish and wildlife species, particularly state and federally listed delta pelagic and anadromous species that are impacted by covered activities. Covered activities shall include water and power facilities and operations. Other activities may be added subsequently.

The negotiators anticipate the following geographic areas:

1. The statutory Delta as defined in the California Water Code plus the Suisun Marsh and Suisun Bay.

2. All or parts of the Sacramento River and its tributaries.

3. All or parts of the San Joaquin River and its tributaries.

4. All or parts of the three eastside streams, the Mokelumne, Cosumnes, and Calaveras Rivers.

This Statement of Principles creates the broadest possible geographic scope and it is possible that it will be restricted in the future, depending on the Parties and Participants of the HCP/NCCP(s).

E. Parties and Participants

1. The United States Fish and Wildlife Service (FWS), NOAA's National Marine Fisheries Service (NOAA Fisheries), and the California Department of Fish and Game (DFG) shall be Parties to the MOU, Agreement and to the HCP/NCCP(s).

2. Persons or entities whose otherwise lawful activities could cause incidental take of threatened or endangered species may comply with FESA and/or CESA by voluntarily electing to become Parties to the MOU, Agreement and the HCP/NCCP(s) prepared under the Agreement. DWR, USBR, and all or some of their water supply contractors may become Parties to the MOU and the Agreement.

3. The MOU, Agreement and the HCP/NCCP(s) shall include provisions for Participants (e.g., an entity that is not a party but involved in an adaptive management committee) including but not limited to environmental organizations, water user groups, and other interested entities.

F. Science and Adaptive Management

1. The MOU and the Agreement shall recognize and provide that the HCP/NCCP(s) be based on the best available science. The development and implementation of the HCP/NCCP(s) shall include a science process that focuses on providing the best available answers to management questions, including measurable objectives that are needed to develop and implement a comprehensive and balanced HCP/NCCP(s), including a monitoring program. All Parties and Participants shall be involved in this science process.

2. The negotiators understand that provisions for adaptive management, oversight and coordination, and independent scientific input will be developed and implemented as part of the HCP/NCCP(s) process and may result in the need to terminate the HCP/NCCP(s) to provide adequate protection of covered species and proceed under regulatory provisions.

3. The Agreement will establish a broad-based adaptive management team comprised of policy and technical representatives who will provide input to the process of developing and implementing any necessary changes resulting from additional information for the HCP/NCCP(s).

G. Interim Projects:

The Agencies (DWR, DFG, FWS, NOAA Fisheries, and USBR), subject to completion of any required environmental review document and permitting, support implementation of the Projects described in Attachments B (water supply projects), C (water quality projects), D (ecosystem projects), and E (levees and other work in the waterways), during development of the Agreement and the HCP/NCCP(s).[1] The agencies are committed to following legal process and to consider all points of view, including those of conservation groups or other water agencies that have expressed concerns with the implementation of these projects. The development of the Agreement and the HCP/NCCP(s) shall not delay the implementation of those interim projects.

1. In the event for reasons beyond the control of the Agencies any interim project is delayed beyond completion of the HCP/NCCP(s), it is anticipated that the HCP/NCCP(s) will advance progress of the interim projects. Execution of the MOU or the Agreement shall not constitute a waiver by any Party or Participant of any right or remedy they may have nor does it constitute agency pre-approval of any project or preferred project

[1] Some parties may not be supportive of the implementation of these Projects at this point.

alternative or waive or otherwise abridge agency Responsible or Trustee duties required, or discretion authorized, under state and federal law.

2. Inclusion of interim projects on Attachments B, C, D or E does not commit state or federal funding beyond that already approved or budgeted for those projects, nor does it constitute agency pre-approval of any project or preferred project alternative or waive or otherwise abridge agency Responsible or Trustee duties required, or discretion authorized, under state and federal law.

3. The MOU and the Agreement will provide a means to augment the project lists set forth in Attachments B, C, D, and E to add additional covered activities if such projects meet agreed upon criteria, including:

    i. They will not result in stranded investments;
    ii. They will not impede development and implementation of the HCP/NCCP(s) (generally consistent with the HCP/NCCP(s) goals);
    iii. Their implementation and operation shall be based on best available science; and
    iv. They are consistent with HCP/NCCP(s) objectives as they are developed.

H. Process for Amendments and Withdrawal

1. The MOU, Agreement and the HCP/NCCP(s) will include a process for amendments, e.g. to include additional covered activities and associated Parties and Participants. The amendment process will be designed to balance the need to be inclusive, the need to be decisive, and the need to complete the HCP/NCCP(s) on time.

2. The MOU, Agreement and the HCP/NCCP(s) will define the criteria and process for early withdrawal.

3. The MOU, Agreement and HCP/NCCP(s) should provide a definition of the criteria for early withdrawal or termination should for any reason the Parties' objectives, including species recovery, not be achieved.

I. If the state imposes fees or an involuntary financial obligation on any water agency or utility signatory to this Statement of Principles for implementation of any CALFED Programs, including the Ecosystem Restoration Program, the Environmental Water Account, or other activities funded under the Statement of Principles or the MOU, the terms of this Statement of Principles and MOU shall terminate. The negotiators recognize that the State is exploring the adoption of a water resources investment fund through an amendment of the California Constitution, and they commit to work cooperatively to develop a water resources investment fund, the implementation of which their principals/boards of directors would support and which would not affect any rights or obligations under the MOU or Agreement.[2]

J. Negotiators agree to work together to establish a structure that will facilitate the design of a functional planning and implementation process, including, if appropriate, an executive director.

III. Near Term Funding

This Statement of Principles proposes to provide, over the next two years, $60 million in contributions for the HCP/NCCP(s), Species Recovery Capital Fund, Ecosystem Restoration Project, POD Studies, and the 100-Year Vision for the Future of the Delta. This $60 million does not include the value of the commitments made pursuant to Section III.E for the Environmental Water Account.

In order to provide sufficient supplemental funds, which when combined with state, federal and other funding that will enable implementation of priority ecosystem restoration projects for Delta pelagic and anadromous fish through the end of Stage 1 (December 31, 2007), the following near-term funding is proposed:

A. HCP/NCCP(s)

1. For calendar years 2006 and 2007, the Central Valley Project and State Water Project (hereinafter referred to as The Projects) shall contribute an aggregate of $3 million annually for the collective use of DFG, USFWS, and NOAA Fisheries for staff and administrative costs related to the development of the HCP/NCCP(s) and regional conservation strategies. The negotiators anticipate that a more informed budget will be developed prior to the execution of the MOU, and the annual contribution may be adjusted with the mutual consent of DFG, USFWS, NOAA Fisheries, the Projects and their water supply contractors signatory to this Statement of Principles.

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[2] The non-state and non-federal negotiators are in agreement that any mandatory fee, regardless of its use, imposed by the state should be subject to an open public hearing process in which all interested parties have had the opportunity to present testimony on appropriate payments, whether as a beneficiary or as a responsible party. Such conditions should not be construed in any way as support for any mandatory fee.

2. The Projects and other Applicants who have activities that will be covered by the HCP/NCCP(s) will develop a cost-share agreement as part of the application process for the HCP/NCCP(s), which may provide for reimbursement of the Applicants if new applicants are able to utilize work for which the Applicants paid.
3. DFG, USFWS, and NOAA Fisheries will expend contributions made under this section consistent with a work plan developed in cooperation with contributing Applicants.
4. DFG, USFWS, and NOAA Fisheries shall seek additional contributions for agency costs from other HCP/NCCP participants.
5. DFG, USFWS, and NOAA Fisheries will apply for additional funding through a FESA Section 6 application.
6. If new bond funds become available and are appropriated for this purpose, the contributions by the Projects for agency staff and administrative costs shall be reduced accordingly.

B. Species Recovery Capital Fund

1. The SWP shall contribute a total of $12 million to a Species Recovery Capital Fund through the end of Stage 1 (December 31, 2007) for restoration projects.
2. Money in this fund contributed by the SWP shall only be used to fill funding gaps for identified restoration projects and only if all bond money available for and appropriated for these purposes has been committed.
3. Contributing Parties will be actively engaged in the selection and management of restoration projects funded by the Species Recovery Capital Fund.
4. The $12 million in SWP contributions shall be credited towards future Delta pelagic and anadromous fish restoration obligations identified under HCP/NCCP(s).
5. If the HCP/NCCP(s) are not developed the SWP contributions shall be credited towards environmental obligations of the SWP.

C. Ecosystem Restoration Program

1. The State and Federal agencies agree to continue annual contributions of $15 million from the CVPIA restoration fund and Four Pumps Fish Mitigation Agreement towards the Ecosystem Restoration Program.
2. The Parties anticipate that current contributions under the CVPIA, combined with the Four Pumps, Species Recovery Capital Fund and available bond funds will meet the

requirements of the Conservation Agreement for financing the Ecosystem Restoration Program through the end of Stage 1.

D. POD studies

1. For the calendar years 2006 and 2007, the Projects shall continue to contribute up to an aggregate of $4 million annually or additional amounts as necessary upon mutual agreement, to research into the causes of the Delta Pelagic Organism Decline.
2. These contributions do no offset other obligations of the SWP or the CVP.

E. Environmental Water Account

1. DWR and DFG agree to pursue full public funding from the Legislature as provided in the CALFED ROD and the 2004 MOU that extended Environmental Water Account (EWA) through 2007.
2. Until full public funding is made available for the 2005-2006 state fiscal year, and after exhausting all other Tier II assets and in an attempt to avoid the use of Tier III assets, the SWP will loan EWA up to 80 TAF of water to make up for the current funding shortfall. This loan will be repaid with variable EWA assets or financial assets.
3. Sufficient public resources are identified in the 10-Year Action Plan and, if appropriated, will fully fund the EWA through the 2006-2007 state fiscal year.
4. If public funds are not made available to meet the terms of the 2004 MOU and DFG or DWR require the SWP to provide a non-reimbursable fiscal or water contribution to provide adequate resources for the EWA until December 31, 2007, then the SWP may terminate this Statement of Principles in its entirety.
5. The EWA Agencies agree to conduct a comprehensive review of the EWA by July 1, 2007 to determine if the program should be continued and, if continued, how it will be sized, managed, and funded for the 2007-2008 state fiscal year and beyond.

F. 100 Year Vision for the Future of the Delta

1. The Projects and other water and hydropower project operators will contribute 50% of the cost of the process to develop a long-term vision for the future of the Delta up to a maximum of $2 million annually not to exceed $4 million in total.
2. DWR and DFG will obtain at least an equivalent amount of funding from other private or public sources.

3. If bond funding is available for this purpose, the obligations of The Projects and other water and hydropower project operators under Section III.F.1 and the public under Section III.F.2 will be reduced proportionally.

IV. Interim and Long-term Funding

Interim funding before the HCP/NCCP(s) are complete will be developed though the Agreement that will be signed and take effect prior to January 1, 2008. Negotiators will work diligently and cooperatively so as to expedite developing the framework for the planning stage of the HCP/NCCP(s).

Long-term funding in support of the HCP/NCCP(s) will be developed during the planning stage and will contain a financing plan for the term of the HCP/NCCP(s) that provides for contributions from those that choose to participate.

V. Concurrent Linked Actions

This section describes the need to develop plans for long-term programs for the protection and funding of Delta levees and funding and an improved implementing structure for a Long-term Water Quality Program. If these packages are not developed in a timely manner or as outlined below, the agencies agree to inform the Secretary of the Interior and the Governor and to consider this as a substantial factor in annual review of progress and balance under state and federal law. If imbalance is found then the agencies will take the steps required by law, including those measures prescribed by Section 105 (b)2 of the CALFED Bay-Delta Authorization Act, P.L. 108-361.

A. Delta Levees

The negotiators recognize the need to develop a funding plan for a long-term program for the protection and funding of Delta levees. In addition, as the HCP/NCCP(s) is/are prepared, Parties involved in the levee program that need to comply with CESA and FESA can consider whether they would like to have their activities in the program included as covered activities in the HCP/NCCP(s).

B. Long-Term Water Quality

The negotiators recognize a need to establish funding and an improved implementing structure for a Long-term Water Quality Program by April 2007.

Attachment A – Parties

The negotiators for the Parties below have initialed this document as a means of pledging good faith efforts to obtain ratification of the Statement of Principles by each of their appropriate authorized persons and/or governing bodies on or before January 31, 2006.

Joe Grindstaff
California Bay-Delta Authority

For
Ryan Broddrick
California Department of Fish and Game

For
Lester Snow
California Department of Water Resources

Brent E. Walthall
Kern County Water Agency

Timothy H. Quinn
Metropolitan Water District

for
Rodney R. McInnis
NOAA Fisheries

Daniel G. Nelson
San Luis & Delta-Mendota Water Authority

Walter L. Wadlow
Santa Clara Valley Water District

Laura King Moon
State Water Contractors

Jeanne M. Zolezzi, Esq.
Attorney for Stockton East Water District

Kirk C. Rodgers
U.S. Bureau of Reclamation

Steve Thompson
U.S. Fish and Wildlife Service

Thomas W. Birmingham
Westlands Water District

Dale Myers
Zone 7 Water Agency

Attachment A (1) – Participants

The negotiators for the Participants below appreciate participation in this process and pledge to bring this document to their boards or governing bodies for review and further discussion.

Walter J. Bishop
Contra Costa Water District

Thomas Zuckerman
Central Delta Water Agency

Ronald D. Jacobsma
Friant Water Users Authority

Steve Johnson
The Nature Conservancy

Attachment B - Water Supply Projects[3]

- SDIP with Integrated Operations, Banks 8500 cfs, Dredging
- CVP-SWP Intertie
- San Luis Low Point Improvement Project

[3] "Core" Delta Projects previously identified by principals

Attachment C - Water Quality Projects[4]

- CCWD Alternative Intake Project
- Contra Costa Canal Encasement Project
- Franks Tract Pilot Project
- San Joaquin River Salinity Management[5]
- Old River and Rock Slough Water Quality Improvement Projects (completed 11/05)
- Operable Gates[6]

[4] "Core" Delta Projects previously identified by principals

[5] Includes salinity reduction in Westside/Grasslands area, recirculation, water purchases, and real time management. Developing and implementing a plan to meet existing Vernalis water quality standards and objectives is a separate action under the Program plan.

[6] This project is intended to protect water quality for South Delta irrigators and migratory salmon, but could adversely affect water quality for other water users

Attachment D – Ecosystem Projects

- ERP MYPP list as negotiated
- Environmental Water Account

Attachment E - Levee Projects[7]

- Levee Subventions
- Special Projects
- Delta Risk Management Strategy
- Levee Subsidence Control
- Emergency Management and Response Plan

[7] These are the elements in the current Program Plan for the Levee Program

Appendix H-2

MOA of Supplemental Funding/Near-Term Water Supply

Memorandum of Agreement
For Supplemental Funding for Certain Ecosystem Actions and Support for Implementation of Near-Term Water Supply, Water Quality, Ecosystem, and Levee Actions

I. Purpose

Changes in available CALFED funding and the need to enable water supply, water quality, ecosystem, and levee projects to progress within a stable regulatory framework require a new structure that provides regulatory and funding assurances for the actions described herein. The foundation for this framework was established in a Statement of Principles agreed to by the California Department of Water Resources, California Department of Fish and Game, U.S. Fish and Wildlife Service, NOAA's National Marine Fisheries Service, U.S. Bureau of Reclamation, and others. This Memorandum of Agreement (MOA) is intended to further:

1. The development of a conservation plan for the Delta and its upstream basins, hereinafter referred to as the Bay Delta Conservation Plan (BDCP) and to obtain the permits necessary to comply with the California Endangered Species Act and the Federal Endangered Species Act; and

2. The implementation of key interim water supply, water quality, ecosystem, and levee projects, subject to compliance with applicable environmental review under CEQA and NEPA.

II. Interim Projects

The Agencies (DWR, DFG, FWS, NOAA Fisheries, and USBR), subject to completion of any required environmental review document and permitting, support implementation of the interim projects described in Attachments B (water supply projects), C (water quality projects), D (ecosystem projects), E (levees and other work in the waterways), and F (project schedules) during development of the BDCP. The current schedules for these interim projects are included in Attachment F and are displayed for information purposes only. The Agencies are committed to following legal process and to consider all points of view, including those of conservation groups or other water agencies that have expressed concerns with the implementation of these interim projects. The development of the BDCP shall not delay the implementation of those interim projects.

1. In the event for reasons beyond the control of the Agencies any interim project is delayed beyond completion of the BDCP, it is anticipated that the BDCP will advance progress of the interim projects. Execution of the

MOA shall not constitute a waiver by any signatory of any right or remedy they may have.

2. Inclusion of interim projects on Attachments B, C, D, E, or F. does not commit state or federal funding beyond that already approved for those interim projects, nor does it constitute agency pre-approval of any project or preferred project alternative or waive or otherwise abridge agency Responsible or Trustee duties required, or discretion authorized, under state and federal law.

3. The interim project lists set forth in Attachments B, C, D, E, and F may be augmented to add additional covered activities if such projects meet agreed upon criteria, including:

   i. They will not result in stranded investments;
   ii. They will not impede development and implementation of the BDCP (generally consistent with the BDCP goals);
   iii. Their implementation and operation shall be based on best available science; and
   iv. They are consistent with BDCP objectives as they are developed.

III. Near-Term Funding

Subject to Section V, this MOA proposes to provide, over the next two years, $60 million in contributions for the BDCP, Species Recovery Capital Fund, Ecosystem Restoration Program, POD Studies, and the 100-Year Vision for the Future of the Delta. This $60 million does not include the value of the commitments made pursuant to Section III.E for the Environmental Water Account.

In order to provide sufficient supplemental funds, which when combined with state, federal and other funding that will enable implementation of priority ecosystem restoration projects for Delta pelagic and anadromous fish through the end of Stage 1 (December 31, 2007), the following near-term funding is proposed:

A. BDCP

1. For calendar years 2006 and 2007, the USBR and DWR on behalf of the State Water Project (hereinafter referred to as The Projects) shall contribute an aggregate of $3 million annually for the collective use of DFG, USFWS, and NOAA Fisheries for staff and administrative costs related to the development of the BDCP. The budget in Attachment A details how these funds are anticipated to be spent.
2. The Projects and/or other applicants who have activities that will be covered by the BDCP will develop a cost-share agreement as part of the application process for the BDCP, which may provide for reimbursement

of the The Projects and/or other applicants if new parties are able to utilize work for which The Projects and/or other applicants paid.

3 DFG, USFWS, and NOAA Fisheries will expend contributions made under this section consistent Attachment A.
4. DFG, USFWS, and NOAA Fisheries shall seek additional contributions for agency costs from other BDCP participants.
5. DFG, USFWS, and NOAA Fisheries will apply for additional funding through a Federal Endangered Species Act (FESA) Section 6 application.
6. If new bond funds become available and are appropriated for this purpose, the contributions by The Projects for agency staff and administrative costs shall be reduced accordingly.

B. Species Recovery Capital Fund

1. DWR on behalf of the SWP shall contribute a total of $12 million to a Species Recovery Capital Fund through the end of Stage 1 (December 31, 2007) for restoration projects.
2. Money in this fund contributed by DWR on behalf of the SWP shall only be used to fill funding gaps for identified restoration projects and only if all bond money available for and appropriated for these purposes has been committed.
3. DWR and their contractors will be actively engaged in the selection and management of restoration projects funded by the Species Recovery Capital Fund.
4. The $12 million contributions on behalf of the SWP shall be credited towards future Delta pelagic and anadromous fish restoration obligations identified under the BDCP.
5. If the BDCP is not completed, or permits are not issued, the SWP contributions shall be credited towards environmental obligations of the SWP.

C. Ecosystem Restoration Program

1. The state and federal agencies agree to continue annual contributions of $15 million from the CVPIA restoration fund, and Four Pumps Fish Mitigation Agreement towards the Ecosystem Restoration Program.
2. The signatories to this MOA anticipate that current contributions under the CVPIA, combined with the Four Pumps Mitigation Agreement, Species Recovery Capital Fund and available bond funds will meet the requirements of the CALFED Conservation Agreement Regarding Multi-Species Conservation Strategy for financing the Ecosystem Restoration Program through the end of Stage 1.

D. POD Studies

1. For the calendar years 2006 and 2007, The Projects shall continue to contribute up to an aggregate of $4 million annually or additional amounts as necessary upon mutual agreement, to research into the causes of the Delta Pelagic Organism Decline.
2. These contributions do not offset other obligations of the SWP or the federal government.

E. Environmental Water Account

1. DWR and DFG agree to pursue full public funding from the Legislature as provided in the CALFED ROD and the 2004 MOU that extended Environmental Water Account (EWA) through 2007.
2. Until full public funding is made available for the 2005-2006 state fiscal year, and after exhausting all other Tier II assets and in an attempt to avoid the use of Tier III assets, the SWP will loan EWA up to 80 TAF of water to make up for the current funding shortfall. This loan will be repaid with variable EWA assets or financial assets.
3. Sufficient public resources are identified in the 10-Year Action Plan and, if appropriated, will fully fund the EWA through the 2006-2007 state fiscal year.
4. If public funds are not made available to meet the terms of the 2004 MOU and DFG or DWR require the SWP to provide a non-reimbursable fiscal or water contribution to provide adequate resources for the EWA until December 31, 2007, then DWR on behalf of the SWP may terminate this MOA in its entirety.
5. The EWA Agencies agree to conduct a comprehensive review of the EWA by July 1, 2007, to determine if the program should be continued and, if continued, how it will be sized, managed, and funded for the 2007-2008 state fiscal year and beyond.

F. 100-Year Vision for the Future of the Delta

1. The Projects and other water and hydropower project operators will contribute 50% of the cost of the process to develop a long-term vision for the future of the Delta up to a maximum of $2 million annually not to exceed $4 million in total.
2. DWR and DFG will obtain at least an equivalent amount of funding from other private or public sources.
3. If bond funding is available for this purpose, the obligations under Section III.F.1 and Section III.F.2 will be reduced proportionally.

IV. Contingent on Appropriation of Funds and Future Actions

The expenditure or advance of any money, or the performance of any obligation of the United States or the State of California under this MOA, will be contingent upon appropriation or allotment of funds, and, for the United States, is in accordance with 31 United States Code section 1341 (Anti-Deficiency Act). No liability will accrue to the United States or the State of California for failure to perform any obligation under this MOA in the event that funds are not appropriated or allotted.

V. Preserves Rights and Authorities

All provisions of this MOA are intended and will be interpreted to be consistent with all applicable provisions of state and federal law. The undersigned recognize that public agency signatories to this MOA have specific statutory and regulatory authority and responsibilities, and that actions of these public agencies must be consistent with applicable procedural and substantive requirements. Nothing in this MOA is intended to, nor will have the effect of, constraining or limiting any public entity in carrying out its statutory responsibilities. Nothing in this MOA constitutes an admission by any party as to the proper interpretation of any provision of law, nor is anything in this MOA intended to, nor will it have the effect of, waiving or limiting any public entity's rights and remedies under any applicable law.

This MOA does not delegate from or to any person or entity any existing ability to:

1. make a final decision on a project;
2. modify or halt a project; or
3. pursue a project according to individual legal authority.

Execution of this MOA does not constitute a waiver by any signatory of any right or remedy it may have nor does execution constitute pre-approval of any project or preferred project alternative or waive or otherwise abridge responsible or trustee duties required, or discretion authorized, under state and federal law.

VI. Non-Discriminatory

The program or activities contemplated under this MOA when and if conducted or funded by any federal agency will be in compliance with the nondiscrimination provisions contained in Titles VI and VII of the Civil Rights Act of 1964, as amended; the Civil Rights Restoration Act of 1987 (Public Law 100-259); and other nondiscrimination statutes: namely, Section 504 of the Rehabilitation Act of 1973, Title IX of the Education Amendments of 1972, the Age Discrimination Act of 1975, and American's With Disabilities Act of 1990. They will also be in accordance with applicable federal regulations, which provide that no person in the United States will on the grounds of race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, and marital or family status, be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity receiving federal financial assistance.

VII. Termination

1. This MOA will terminate if the State of California imposes fees or an involuntary financial obligation on any water agency or utility signatory to the MOA for implementation of any CALFED Programs, including, but not limited to the Ecosystem Restoration Program, the Environmental Water Account, or other activities funded under this MOA.

2. The signatories to this MOA recognize that the state is exploring the adoption of a water resources investment fund through an amendment of the California Constitution, and they commit to work cooperatively to develop a water resources investment fund, the implementation of which their principals/boards of directors could support and which would not affect any rights or obligations under this MOA.

3. The termination provision provided under section VII(1) does not apply to a water resources investment fund developed consistent with VII(2) the state may adopt through an amendment of the California Constitution.

VIII. Term of the MOA

Upon DWR, DFG, USBR, USFWS, NOAA Fisheries, and four of the SWP contractors and one of the CVP entities that initialed the Statement of Principles signing this MOA, it will be become effective. Unless terminated, this MOA will remain in effect until December 31, 2007.

IX. Signature in Counterparts

This MOA may be executed in counterparts.

Attachment A – BDCP Budget

Attachment A: BDCP Budget for DFG, NOAA Fisheries, and USFWS (Fish Agencies) as of July 14, 2006

	Task Lead	Work Task%		Fish Agency Cost Estimates			Schedule			
	Permittees or Wildlife Agencies	Permittees/ Consultants	Fish Agencies	2006 Budget (calendar year)	2007 Budget (calendar year)	2008 and beyond Budget	On Going	2006	2007	2008/2009
1.0 Project Set-Up	Varies by task	Varies by task	Varies by task	$211,619	$40,000	??				
2.0 Project Administration and Meetings	Varies by task	Varies by task	Varies by task	$133,229	$266,458	??				
3.0 Interim Project Notification Process	Varies by task	Varies by task	Varies by task	$38,855	$38,855	??				
4.0 Public Involvement and Outreach	Varies by task	Varies by task	Varies by task	$312,958	$312,958	??				
5.0 Scientific Advisory Process	Joint Effort with CALFED Science Program	Varies by task	Varies by task	$374,105	$374,105	??				
6.0 Project Delineation	Permittees	Varies by task	Varies by task	$164,447	$164,447	??				
7.0 Compile and Collect Data	Joint Lead	Varies by task	Varies by task	$257,218	$357,218	??				
8.0 Covered Activities, Covered Species, and Natural Communities	Varies by task	Varies by task	Varies by task	$305,195	$593,900	??				
9.0 Conservation Strategy	Varies by task	Varies by task	Varies by task	$335,636	$634,783	??				
10.0 Conservation Plan Components and Impact Analysis	Permittees	Varies by task	Varies by task	$120,000	$542,000	??				
11.0 Economic Analysis	Permittees	Varies by task	Varies by task	$0	$50,000	??				
12.0 Conservation Plan Preparation	Permittees	Varies by task	Varies by task	$196,084	$365,361	??				
13.0 NEPA/CEQA Compliance	Agencies	Varies by task	Varies by task	$0	$150,000	??				
14.0 Implementing Agreement (IA)	Joint Effort	Varies by task	Varies by task	$0	$150,000	??				
15.0 Final ESA Compliance (NMFS and USFWS)	Agencies	Varies by task	Varies by task	$0	$0	??				
16.0 Final CA Fish & Game Code Compliance (DFG)	Agencies	Varies by task	Varies by task	$0	$0	??				
SUBTOTAL (Task #1 – #6)				$1,235,212	$1,196,822	$0				
SUBTOTAL (Task #7 – #13)				$1,214,133	$2,693,262	$0				
SUBTOTAL (Task #14 – #17)				$0	$150,000	$0				
TOTAL				$2,449,345	$4,040,084	$0				
			GRAND			$6,489,430				

Attachment B - Water Supply Projects[1]

- SDIP with Integrated Operations, Banks 8500 cfs, Dredging
- CVP-SWP Intertie
- San Luis Low Point Improvement Project

[1] "Core" Delta Projects previously identified by principals

Attachment C - Water Quality Projects[2]

- CCWD Alternative Intake Project
- Contra Costa Canal Encasement Project
- Franks Tract Pilot Project
- San Joaquin River Salinity Management[3]
- Old River and Rock Slough Water Quality Improvement Projects (completed 11/05)
- Operable Gates[4]

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[2] "Core" Delta Projects previously identified by principals

[3] Includes salinity reduction in Westside/Grasslands area, recirculation, water purchases, and real time management. Developing and implementing a plan to meet existing Vernalis water quality standards and objectives is a separate action under the Program plan.

[4] This project is intended to protect water quality for South Delta irrigators and migratory salmon, but could adversely affect water quality for other water users

Attachment D – Ecosystem Projects

- ERP MYPP projects funded by existing ERP funding sources
- Environmental Water Account
- Restoration projects funded by the Species Recovery Capital Fund

Attachment E - Levee Projects[5]

- Levee Subventions
- Special Projects
- Delta Risk Management Strategy
- Levee Subsidence Control
- Emergency Management and Response Plan

[5] These are the elements in the current Program Plan for the Levee Program

Attachment F - Interim Project Schedules

Water Supply Actions	Program Plan (Lead Agency)	ROD Target Date	DIP 8/04 Target Date	Expected Date	Comments
SWP/CVP Integration Plan	Conveyance (USBR/DWR)				
➢ Complete SWP/CVP Operations Criteria and Plan and BO and early consultation			Summer 2004	Completed Fall 2004	
➢ Complete Response Plans required by D-1641 for Joint Point of Diversion			Aug 2004	Completed Aug 2004	JPOD approvals needed each year for those that are not long term approvals
➢ Complete NEPA/CEQA ESA and public review of interim SWP/CVP operations			Early 2005	Schedule under development	
➢ Implement interim SWP/CVP operation actions			2005	Schedule under development	

Water Supply Actions (Cont)	Program Plan (Lead Agency)	ROD Target Date	DIP 8/04 Target Date	Expected Date	Comments
Delta Mendota Canal / California Aqueduct Intertie ➢ Complete envir. Studies	Conveyance (USBR)	July 2004	Summer 2004	Apr 2007	USBR withdrew its FONSI in May 2006 to further consider implications of the project. An EIS is being prepared. CEQA is complete.
➢ Secure construction funding				Completed 2005	
➢ Re-bid construction contracts, initiate construction		Dec 2004	Late 2005	Feb 2008	USBR terminated its construction contract.
➢ Complete construction, begin operations				Mar. 2009	
Expanded Intertie ➢ Conduct federal feasibility study				Schedule under development	Federal feasibility authorization received in CALFED Bay-Delta Act.
➢ Obtain authorization and funding for expanded intertie				Schedule under development	
San Luis Reservoir Low Point Improvement Project ➢ Complete Appraisal Study	Storage (USBR)		Sept 2004	May 2006	Sequence is as follows: 1. Complete an Initial Alternatives Report 2. Complete a Plan Formulation Report 3. Complete Feasibility Studies and Designs4. Complete the Environmental Impact Statement 5. Complete the ROD.
➢ Complete Feasibility / EIS/EIR		Late 2009	May 2005	Spring 2009	
➢ Obtain funding for implementation			June 2006	Schedule under development	

Water Quality Actions	Program Plan (Lead Agency)	ROD Target Date	DIP 8/04 Target Date	Expected Date	Comments
Permanent Operable Gates/8500 cfs	Conveyance (DWR)				
➢ Complete South Delta Improvements (SDIP) EIR/EIS		Dec 2002	Mid 2005	Aug 2006	
Stage 1 Permanent Operable Gates					
➢ Secure permits to construct permanent operable gates, dredge, modify local agriculture diversions		Jul 2003		Nov 2006	Permits for agricultural diversion dredging and extensions are in place.
➢ Obtain funding and authority for gate at Head of Old River			Dec 2006	Sept 2006	Adequate State funding and authority needed by Sept 2006 (NOD date) so that real estate can be certified no later than Mar 2007.
➢ Obtain funding and authority for gates in Middle River, Old River and Grantline Canal			Dec 2007		
➢ Acquire land and begin construction				2007	
➢ Complete dredging/modifications of local agriculture diversions				Nov 2008	
➢ Complete construction of permanent operable gates				Apr 2009	
Stage 2 – 8,500 cfs		2003	Dec 2007		
➢ Supplemental EIS/EIR				Schedule under development	Schedule dependent on information from POD studies and follow-up analysis. A supplemental document compliant with NEPA and CEQA will be prepared prior to Stage 2 decision and implementation.
➢ Notice of Determination for 8,500 cfs operation					
➢ Secure permit for increasing SWP export limit to 8500 cfs					
➢ Fully operate under 8500 cfs			Jan 2008		

Water Quality Actions (Cont)	Program Plan (Lead Agency)	ROD Target Date	DIP 8/04 Target Date	Expected Date	Comments
San Joaquin River Salinity Management Plan	Water Quality (DWR)	Start source control measures by 2003			
➢ Coordinated Drainage Strategy				Ongoing	
➢ Salt Load Management and Reduction			Begin study by summer 2004		SJRIP is being incorporated into the larger Westside Regional Drainage Plan.
- SJRIP				2010	
- EIS for San Luis Drainage Feature				June 2006	
- Drainage management of Managed Wetlands			Initiate studies by fall 2004	Schedule under development	
➢ Recirculation					
- Draft Feasibility Study and EIS/R				Dec 2007	
- Final Feasibility Study and EIS/R				Nov 2008	
➢ Voluntary Water Exchanges and Transfers				Ongoing	
➢ Real Time Monitoring			Initial draft by Oct 2004		
➢ Coordination of East Side Tributary Operations			Initial draft by March 2004	Ongoing	
➢ Westside Groundwater Management				Ongoing 2010	Part of the Westside Regional Drainage Plan. Proponents propose to pump to lower regional groundwater levels, therefore reducing subsurface drainage discharges into SJR. Excess water will be transferred to CVP.

Water Quality Actions (Cont)	Program Plan (Lead Agency)	ROD Target Date	DIP 8/04 Target Date	Expected Date	Comments
Old River and Rock Slough Water Quality Improvement Projects ➢ Complete construction of Veale and Byron tracts drainage improvements ➢ Complete construction of first phase Canal lining project	Water Quality (DWR)	Before permanent operable gates		Completed Jan 2006 Jun 2009	
Franks Tract ➢ Complete feasibility and EIR/EIS Study (pilot project) ➢ Implement pilot project construction and monitoring	Water Quality (DWR)			April 2010 June 2011	Currently CEQA/NEPA process is being initiated. If it is determined (by June 2007) that a Mitigated Negative Declaration is sufficient for the pilot project, then the pilot project implementation will be done by June 2008.
Relocation of M& I Intake ➢ Complete evaluation of water quality improvements	Water Quality (CCWD)			Date to be determined	CCWD is proceeding with scoping and environmental documentation

Delta Levees Actions	Program Plan	ROD Target Date	DIP 8/04 Target Date	Expected Date	Comments
Delta Levees Implement the Levee System Intregrity Multi-Year Program Plan (including Base Level Protection, Special Improvements Projects, Delta Risk Management Strategy, Subsidence Best Management Practices, and Levee Emergency Management and Response).	Levee System Integrity (DWR)			Years 5-8	State and local funding has addressed maintenance and slow incremental levee improvements. The absence of federal funding and reduced local cost share envisioned in the ROD has severely limited the ability of the program to obtain base level protection. Unless legislation is passed to extend the sunset date the ability of the program to achieve results will be further reduced on July 1, 2006. A Delta Risk Management Strategy study is now underway.

Environmental Protection Actions	Program Plan	ROD Target Date	DIP 8/04 Target Date	Expected Date	Comments
Environmental Water Account	Environmental Water Account (DWR)				
➢ Decision on continuing short-term EWA			Sept 2004	Completed Sept. 2004	DWR, USBR, USFWS, NOAA Fisheries and CDFG completed Long-Term EWA EIS/EIR public scoping meetings in March 2005
➢ Draft EIS/EIR on long-term EWA			Jun 2005	Dec 2006	
➢ Final EIS/EIR on long-term EWA			Dec 2005	Dec 2007	
➢ Comprehensive Review of EWA				Dec 2007	Conducted prior to implementation of Long-Term EWA to inform decisions regarding purpose and need

Attachment G – Signatures

P. Joseph Grindstaff, Director
California Bay-Delta Authority

Lester Snow, Director
California Department of Water Resources

Ryan Broddrick, Director
California Department of Fish and Game

Kirk C. Rodgers, Regional Director
U.S. Bureau of Reclamation

Steve Thompson, California/Nevada
Operations Manager
U. S. Fish and Wildlife Service

Rodney R. McInnis, Administrator Southwest
Region
NOAA Fisheries

James M. Beck, General Manager
Kern County Water Agency

Jeffrey Kightlinger, General Manager
Metropolitan Water District of
Southern California

Dale Myers, General Manger
Zone 7 Water Agency

Walter L. Wadlow, Chief Operating Officer
Santa Clara Valley Water District

Daniel G. Nelson, Executive Director
San Luis and Delta-Mendota Water Authority

Thomas W. Birmingham, General
Manager/General Counsel
Westlands Water District

Appendix H-3

Planning Agreement and Amendments

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Planning Agreement

regarding the

Bay Delta Conservation Plan

October 6, 2006

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BAY DELTA CONSERVATION PLAN
Planning Agreement

This agreement (Planning Agreement) regarding the planning and preparation of the Bay Delta Conservation Plan (BDCP) is entered into as of the Effective Date by and among the California Resources Agency, the Fishery Agencies, the Potential Regulated Entities, and the Non-Governmental Organizations, as listed in Exhibit A.

1. Definitions

The following terms as used in this Planning Agreement will have the meanings set forth below.

1.1. "BDCP" means the Bay Delta Conservation Plan, a conservation plan prepared to meet the requirements of Federal Endangered Species Act (FESA), California Endangered Species Act (CESA) and/or the Natural Community Conservation Plan Act (NCCPA).

1.2. "Biological Assessment" or "BA" means the information prepared by or under the direction of a Federal Action Agency for the purpose of identifying the potential effects of the agency action within the Planning Area on species which are listed or proposed to be listed and critical habitat which has been designated or proposed, and submitted to the United States Fish and Wildlife Service (USFWS) and/or National Marine Fisheries Service (NMFS) pursuant to section 7(c)(1) of FESA.

1.3. "CEQA" means the California Environmental Quality Act, Public Resources Code, section 21000, *et seq.*

1.4. "CESA" means the California Endangered Species Act, California Fish and Game Code, section 2050, *et seq.*

1.5. "Covered Activities" means those certain activities that will be addressed in the BDCP and for which the Potential Regulated Entities may seek take authorizations pursuant to the California Fish and Game Code (section 2080.1, section 2081, and/or section 2835) and FESA.

1.6. "Covered Species" means those certain species that may be identified in the BDCP, both listed and non-listed, whose conservation and management are provided for in the BDCP, and which may be authorized for take under State and/or federal law once the BDCP is approved.

1.7. "CVP" means the Central Valley Project.

1.8. "Effective Date" means the date on which this Planning Agreement has been executed by the Parties, as listed in Exhibit A.

1.9. "Federal Action Agency" means a federal agency that authorizes, funds, or carries out actions that may require consultation with USFWS and/or NMFS pursuant to FESA section 7(a)(2).

1.10. "FESA" means the federal Endangered Species Act, 16 United States Code section 1530, *et seq.*

1.11. "Fishery Agencies" means Department of Fish and Game (DFG), USFWS and NMFS.

1.12. "Habitat Conservation Plan" or "HCP" means a conservation plan prepared pursuant to section 10(a) (1) (B) of FESA.

1.13. "Implementing Agreement" or "IA" means an agreement that defines the terms for implementing the BDCP.

1.14. "Statutory Delta" means the Sacramento-San Joaquin Delta as defined by section 12220 of the California Water Code.

1.15. "Listed Species" means those species designated as candidate, threatened or endangered pursuant to CESA and/or listed as threatened or endangered under FESA.

1.16. "MOA Projects" means those projects identified in Attachment B (water supply projects), Attachment C (water quality projects), Attachment D (ecosystem projects", Attachment E, (levees and other work in the waterways), and Attachment F (project schedules) to the "Memorandum of Agreement for Supplemental Funding for Certain Ecosystem Actions and Support for Implementation of Near-Term Water Supply, Water Quality, Ecosystem, and Levee Actions."

1.17. "Natural Community Conservation Plan" or "NCCP" means a conservation plan created to meet the requirements of Fish and Game Code, section 2800, *et seq.*

1.18. "Natural Community Conservation Planning Act" or "NCCPA" means Fish and Game Code, section 2800, *et seq.*

1.19. "NEPA" means the National Environmental Policy Act, United States Code section 4321, *et seq.*

1.20. "Non-Governmental Organizations" or "NGOs" means the Non-Governmental Organizations identified in Exhibit A. As of the Effective Date, the Non-Governmental Organizations are American Rivers, Environmental Defense, the Natural Heritage Institute, and The Nature Conservancy. Additional NGOs may be added as Parties in accordance with Section 9.6 of this Planning Agreement.

1.21. "Other Delta Water Users" means the Other Delta Water Users identified in Exhibit A. As of the Effective Date, Mirant Delta is the sole Other Delta Water User. Additional Other Delta Water Users may be added as Parties in accordance with Section 9.6 of this Planning Agreement.

1.22. "Party" means an entity that is a signatory to this Planning Agreement. Such entities may be referred to individually as "Party" or collectively as "Parties." Additional Parties may be added in accordance with Section 9.6 of this Planning Agreement. The Parties are identified on Exhibit A.

1.23. "Planning Area" means the geographic area proposed to be addressed in the BDCP as described in section 5 and Exhibit B.

1.24. "Potential Regulated Entities" means certain federal and non-federal entities that export, divert or otherwise benefit from diversion of water from the Delta and/or its tributaries within the Planning Area, which may seek take authorizations pursuant to the California Fish and Game Code (section 2080.1, section 2081, and/or section 2835) and/or FESA. The Potential Regulated Entities are identified in Exhibit A. As of the Effective Date, Reclamation, Department of Water Resources (DWR), the Water Contractors, and Other Delta Water Users are the Potential Regulated Entities. Additional Potential Regulated Entities (i.e., Water Contractors and Other Delta Water Users) may be added as Parties in accordance with Section 9.6 of this Planning Agreement.

1.25. "Section 7" means 16 United States Code section 1536.

1.26. "Section 10" means 16 United States Code section 1539.

1.27. "Steering Committee" means the committee established in accordance with Section 7.4.1 of this Planning Agreement.

1.28. "SWP" means the State Water Project.

1.29. "Water Contractors" means the Water Contractors identified in Exhibit A. As of the Effective Date, the Water Contractors are Metropolitan Water District (MWD), Kern County Water Agency (KCWA), Santa Clara Valley Water District (SCVWD), Zone 7, San Luis Delta Mendota Water Agency (SLDMWA) and Westlands Water District (WWD). Additional Water Contractors may be added as Parties in accordance with Section 9.6 of this Planning Agreement.

2. Purposes of this Agreement

The purposes of this Planning Agreement are to:

- Define the Parties' goals and commitments with regard to development of the BDCP;
- Define the initial geographic scope of the Planning Area;
- Identify a preliminary list of natural communities and species known or reasonably expected to be found in those communities that are intended to be the initial focus of the BDCP;
- Identify preliminary conservation objectives for the Planning Area;
- Establish a process for the inclusion of independent scientific input into the planning process;
- Ensure coordination among the Fishery Agencies, particularly with respect to FESA;
- Establish a process to review certain interim projects within the Planning Area that will help achieve the preliminary conservation objectives and maintain viable conservation opportunities and alternatives for the BDCP; and
- Ensure public participation and outreach throughout the planning process.

The Potential Regulated Entities have not yet determined whether it would be feasible or practicable to implement the BDCP, if it is developed, to meet the substantive requirements of the NCCPA. However, to enable the BDCP to serve as an NCCP, should that be feasible and practicable, the Parties intend that this Planning Agreement will fulfill the NCCPA's requirements for planning agreements and will establish a mutually agreeable planning process for the BDCP that meets the procedural requirements of the NCCPA, CESA and FESA.

3. Planning Goals

The planning goals for the BDCP include the following:

- Provide for the conservation and management of Covered Species within the Planning Area;
- Preserve, restore and enhance aquatic, riparian and associated terrestrial natural communities and ecosystems that support Covered Species within the Planning Area through conservation partnerships;
- Allow for projects to proceed that restore and protect water supply, water quality, and ecosystem health within a stable regulatory framework;
- Provide a means to implement Covered Activities in a manner that complies with applicable State and federal fish and wildlife protection laws, including CESA and FESA, and other environmental laws, including CEQA and NEPA;
- Provide a basis for permits necessary to lawfully take Covered Species;
- Provide a comprehensive means to coordinate and standardize mitigation and compensation requirements for Covered Activities within the Planning Area;

- Provide a less costly, more efficient project review process which results in greater conservation values than project-by-project, species-by-species review; and
- Provide clear expectations and regulatory assurances regarding Covered Activities occurring within the Planning Area.

These BDCP planning goals are consistent with the objectives of the CALFED Bay-Delta Program as set forth in the CALFED Record of Decision (ROD). (August 28, 2000, ROD, at pp. 9, 10.) While the Parties have developed specific decision-making protocols for the BDCP in section 7.4.1, they anticipate exchanging information and cooperating with participants in other public processes, such as the proposed Delta Vision Process.

The goal of the BDCP to "provide for the conservation and management of Covered Species" means that the plan will ensure the implementation of measures that will contribute to the recovery of Covered Species, taking into consideration the scope of the BDCP Planning Area in relation to the geographic range of the Covered Species, and the effect of Covered Activities on these species in relation to other activities not addressed by the BDCP. The Parties acknowledge that this planning goal is intended to reflect the constraints inherent to the BDCP that may limit its capacity to ensure the recovery of Covered Species.

The Parties further recognize that, until conservation strategies are developed for the Covered Species and their habitats, and conservation partnerships formed, the cost and feasibility of achieving these goals will not be known. During the development of the BDCP, the BDCP goals, preliminary conservation objectives, Covered Species, Covered Activities, and Planning Area may be modified to ensure that implementation of the BDCP will be practicable. The Parties recognize that, regardless of any such modifications, the BDCP must meet applicable State and federal regulatory requirements to support the issuance of permits or authorizations for Covered Activities.

4. Compliance with Federal and State Fish and Wildlife Protection Laws

The Planning Area contains valuable biological resources, including native species of fish and wildlife and their habitats. Among the species within the Planning Area are certain species that are protected, or may be protected in the future, under CESA and/or FESA. The Parties intend for the BDCP to meet the requirements of State and federal fish and wildlife protection laws that apply to Covered Activities and to provide a basis for State and federal authorizations for the take of Covered Species that may be caused by Covered Activities.

Under State law, take of species listed pursuant to CESA may be authorized under Fish and Game Code section 2080.1, section 2081, (both provisions of CESA) or section 2835 (a provision of the NCCPA). The NCCPA provides that after the approval of an NCCP, DFG may permit the taking of any identified species, listed or non-listed, whose conservation and management is provided for in the NCCP. Take of listed species may also be authorized pursuant to CESA. Non-listed species may be included as covered species in a conservation plan prepared pursuant to CESA, but a CESA take authorization would become effective with regard to non-listed species only if and when such species were listed.

The Parties intend for the BDCP to be sufficient to support the issuance of take authorizations for Covered Activities under CESA or the NCCPA. Alternatively, the BDCP may be developed to support the issuance of take authorizations under both CESA and the NCCPA, in which case, at DFG's discretion, take authorizations may be provided under CESA for some Covered Activities and Covered Species and under the NCCPA for those species whose conservation and management are provided for under the BDCP.

The Parties also intend for the BDCP to serve as a Habitat Conservation Plan that meets the requirements of section 10(a)(2)(A) of FESA, and to serve as a Biological Assessment that provides the basis for consultations between Reclamation and the USFWS and/or NMFS under section 7(a)(2) of FESA, to support the issuance of take authorizations for Covered Activities. The Parties acknowledge that the BDCP may be used to address compliance with other applicable federal and State statutes.

FESA provides that after the approval of an HCP, USFWS and/or NMFS may permit the taking of fish and wildlife species covered in the HCP if the HCP and permit application meet the requirements of section 10(a)(2)(A) and (B) of FESA. Take authorization for FESA-listed fish and wildlife species covered in the HCP are generally effective upon approval of the HCP and issuance of an incidental take permit. Take authorization for any non-listed species covered in the HCP becomes effective if and when the species is listed pursuant to FESA.

For actions authorized, funded or carried out by a Federal Action Agency, take of listed species may be authorized under section 7 of FESA based on a biological opinion prepared by the USFWS and/or NMFS. Take of non-listed species cannot be authorized under section 7 of FESA.

4.1. Potential Regulated Entities' Obligation to Implement the BDCP

The Potential Regulated Entities recognize that they will be obligated to implement and/or fund implementation of measures in the BDCP that are required to appropriately minimize and mitigate (including, in certain instances, to avoid destruction or adverse modification of critical habitat pursuant to section 7 of FESA) the impacts of Covered Activities on Covered Species and their habitat within the Planning Area in accordance with applicable federal and State fish and wildlife protection laws. However, the Parties may elect to include in the BDCP additional measures that exceed what is necessary to appropriately minimize or mitigate Covered Activities. For example, the BDCP may include measures that are necessary to provide for the conservation and management of Covered Species, but are not necessary to minimize and mitigate the impacts of Covered Activities. The Parties acknowledge that the Potential Regulated Entities' execution of this Planning Agreement and participation in the BDCP planning process does not reflect a commitment on the part of the Potential Regulated Entities to assume the obligation to implement conservation measures that exceed minimization and mitigation requirements. Rather, the Parties expect that the obligation to fund and/or to implement any such conservation measures would be shared by the Parties and that the Potentially Regulated Entities' share would be roughly proportional to the impact of their Covered Activities on Covered Species and their habitats. The shared obligation would be defined by mutual agreement and set forth in the Implementing Agreement. Nothing in this Planning Agreement obligates the Potentially Regulated Entities to fund or implement measures to minimize and mitigate impacts to Covered Species resulting from the activities of individuals or entities that do not participate in the implementation of the BDCP or to fund and/or implement conservation measures required as a result of such activities.

4.2. Future FESA Section 7 Consultations

To the extent allowed under law, the Parties intend that the measures adopted to meet regulatory standards included in the BDCP, once approved by the USFWS and NMFS and included as a condition of federal incidental take authorizations to any Potential Regulated Entity, will serve as the range of measures to be incorporated into biological opinions associated with future section 7 consultations between the USFWS and/or NMFS and a Federal Action Agency regarding Covered Activities that may adversely affect listed Covered Species and/or that may result in the destruction or adverse modification of critical habitat.

4.3. Other Fish and Wildlife Protection Laws

Based on the BDCP, the Potential Regulated Entities may seek approval or authorization under other State and federal fish and wildlife protection laws, including, but not necessarily limited to, the Magnuson-Stevens Fishery Act, the Migratory Bird Treaty Act, the Bald and Golden Eagle Protection Act, and various provisions of the Water Code and Fish and Game Code. The Parties agree to collaborate to explore the feasibility of developing the BDCP to serve as the means by which Covered Activities may comply with these additional laws.

4.4. Concurrent Planning for Wetlands and Waters of the United States

Based on the BDCP, the Potential Regulated Entities may seek future programmatic permits or other forms of authorization under the Clean Water Act, section 1600 *et seq.* of the Fish and Game Code, and the Rivers and Harbors Act, as necessary for Covered Activities. The Parties agree to work together to explore the feasibility of undertaking concurrent but separate planning regarding these permits. However, such programmatic permits or other forms of authorization are not necessary for approval of the BDCP or for issuances of take permits.

4.5. Regulatory Assurances Under FESA

Upon approval of the BDCP and issuance of incidental take permits for Covered Activities, USFWS and NMFS will provide assurances to those Potential Regulated Entities that receive coverage under FESA Section 10(a) that neither the USFWS nor NMFS will require the commitment of additional land, water, or financial compensation or additional restrictions on the use of land, water, or other natural resources beyond the level otherwise agreed upon for Covered Species, without the consent of the affected Potential Regulated Entities, in accordance with 50 C.F.R. section 17.22(b)(5), section 17.32(b)(5), and section 222.307(g).

4.6. Regulatory Assurances Under the NCCPA

If the BDCP meets the criteria for issuance of NCCP permits under section 2835 of the Fish and Game Code, DFG will approve the BDCP and provide assurances consistent with its statutory authority upon issuance of NCCP permits. Under section 2820(f) of the Fish and Game Code, DFG may provide assurances for the Covered Activities commensurate with the level of long-term conservation and associated implementation measures provided in the BDCP, including the assurance that, if unforeseen circumstances arise during implementation of the BDCP, DFG will not require additional land, water, or financial compensation or additional restrictions on the use of land, water, or other natural resources without the consent of the affected Potential Regulated Entities, as long as the BDCP is being implemented consistent with the terms of the Implementation Agreement and associated take permit.

5. Planning Area

Because the Parties expect that the BDCP's Covered Activities will be situated within the Statutory Delta, the Planning Area for the BDCP will consist of the Statutory Delta. The Parties anticipate, however, that it may be necessary for the BDCP to include conservation actions outside of the Statutory Delta that advance the goals and objectives of the BDCP, including as appropriate, conservation actions in the Suisun Marsh, Suisun Bay, and areas upstream of the Delta. The Parties intend that conservation actions will be implemented pursuant to cooperative agreements or similar mechanisms with local agencies, interested non-governmental organizations, landowners, and others. A map of the Planning Area is attached hereto as Exhibit B.

6. Preliminary Conservation Objectives

The preliminary conservation objectives the Parties intend to achieve through the BDCP are to:

- Provide for the protection of Covered Species and associated natural communities and ecosystems that occur within the Planning Area;
- Preserve the diversity of fish, wildlife, plant and natural communities within the Planning Area;
- Minimize and mitigate, as appropriate, the take of proposed Covered Species;
- Preserve and restore habitat and contribute to the recovery of Covered Species;
- Reduce the need to list additional species;
- Set forth species-specific goals and objectives;
- Set forth specific habitat-based goals and objectives; and
- Implement an adaptive management and monitoring program to respond to changing ecological conditions;

- Avoid actions that are likely to jeopardize the continued existence of Covered Species or result in the destruction or adverse modification of critical habitat.

6.1. Conservation Elements

6.1.1. Ecosystems, Natural Communities, and Covered Species List

The BDCP will employ a strategy that focuses on the conservation of ecosystems, natural communities, and ecological processes in the Planning Area. In addition, the BDCP will establish species-specific minimization, mitigation, conservation and management measures where appropriate.

The BDCP will focus primarily on aquatic ecosystems and natural communities. The BDCP may also cover adjacent riparian and floodplain natural communities, as appropriate, to fully address the impacts of Covered Activities and to provide for the conservation of Covered Species. Natural Communities that are likely to be addressed by the BDCP include: riverine aquatic, lacustrine, tidal sloughs, tidal perennial aquatic, nontidal perennial aquatic, saline emergent wetland, freshwater emergent wetland, and riverine natural communities.

Species that are intended to be the initial focus of the BDCP include aquatic species such as Central Valley steelhead, Central Valley Chinook salmon (spring run and fall/late-fall runs), Sacramento River Chinook salmon (winter run), Delta smelt, green sturgeon, white sturgeon, splittail, and longfin smelt. Other species that will be considered for inclusion in the BDCP include Swainson's hawk, bank swallow, giant garter snake and valley elderberry longhorn beetle.

This list identifies the species that will be evaluated for inclusion in the BDCP as proposed Covered Species and is not necessarily the BDCP's final Covered Species list. The Parties anticipate that species may be added or removed from the list once more is learned about the nature of the Covered Activities and the impact of Covered Activities on native species within the Planning Area. Issuance of State and federal take authorizations for any particular Covered Species will require an individual determination by the applicable Fishery Agency that the BDCP meets applicable State and/or federal permit issuance requirements.

6.1.2. Conservation Areas and Viable Habitat Linkages

The BDCP will protect, enhance, or restore aquatic, and associated riparian and floodplain habitat throughout the Planning Area and provide or enhance habitat linkages, where appropriate within the Planning Area. The BDCP will also identify where linkages between important habitat areas inside and outside the Planning Area should occur. The BDCP conservation strategy will address a range of environmental gradients and ecological functions, and will address appropriate principles of ecosystem management, ecosystem restoration, and population biology.

6.1.3. Project Design

The BDCP will ensure that each Covered Activity is appropriately designed to avoid and/or minimize direct and indirect impacts to Covered Species and their habitats.

7. Preparing the BDCP

The Parties intend that this Planning Agreement will establish a mutually agreeable process for preparing the BDCP that meets the procedural requirements of the NCCPA, CESA and FESA. The process used to develop the BDCP will incorporate independent scientific input and analysis and include extensive public participation with ample opportunity for comment from the general public and from key groups of stakeholders, as described below.

7.1. Best Available Scientific Information

The BDCP will be based on the best available scientific information, including, but not limited to:

- Principles of conservation biology, community ecology, aquatic ecology, individual species' ecology, and other appropriate scientific data and information;
- Thorough information about all natural communities and proposed Covered Species within the Planning Area; and
- Advice from well-qualified, independent scientists.

7.2. Data Collection

The Parties agree that the BDCP will be based on the best available scientific information, and that the Parties will collaborate to ensure that such information is obtained through a range of credible governmental and non-governmental sources. Data collection efforts for preparation of the BDCP will be coordinated with existing efforts, including the CALFED Science Program. Preference should be given to collecting data essential to address the needs of natural communities and proposed Covered Species for purposes of developing conservation measures and strategies for the BDCP. The science advisory process and analysis of existing information may reveal data gaps currently not known that are necessary for the full and accurate development of the BDCP. Data needed for preparation of the BDCP may not be known at this time nor identified herein. Therefore, the Parties anticipate that data collection priorities may be adjusted from time to time during the planning process. All data collected for the preparation and implementation of the BDCP will be made available to the Fishery Agencies in hard and digital formats, as requested.

7.2.1. Types of Data

Data will be gathered to establish baseline conditions, evaluate impacts of Covered Activities on Covered Species, and develop conservation strategies and measures for Covered Species. Data needed to accomplish these tasks may include, but will not necessarily be limited to: species life histories, species occurrence, population abundance and distribution, population trends, population genetics, habitat locations and conditions, hydrologic regime, hydrodynamics, salinity, temperature, flow patterns, water quality, barrier and hazard types and locations, habitat connectivity, ecological threats and stressors, and riverine processes.

7.3. Independent Scientific Input

The Parties intend to include independent scientific input and analysis to assist in the preparation of the BDCP. For that purpose, independent scientists representing a broad range of disciplines, including conservation biology and locally-relevant ecological knowledge, will, at a minimum:

- Recommend scientifically sound conservation strategies for species and natural communities proposed to be covered by the BDCP;
- Recommend a range of conservation actions that would address the needs of species, ecosystems, and ecological processes in the Planning Area proposed to be addressed by the BDCP;
- Recommend management principles and conservation goals that can be used in developing a framework for the monitoring and adaptive management component of the BDCP; and
- Identify data gaps and uncertainties so that risk factors can be evaluated.

The independent scientists may be asked to provide additional feedback on key issues during preparation of the BDCP, and may prepare reports regarding specific scientific issues throughout the process, as deemed necessary by the Parties.

The Parties will design and implement the science advisory process, in consultation with the Steering Committee and the CALFED Science Program, and will ask the CALFED Science Program's Independent Science Board to recommend potential science advisors. The Parties will develop a detailed scope of work for the independent science advisory process and establish funding and payment procedures. The independent science advisory process will include the use of a professional facilitator, input from technical experts, and production of a report by the scientists. The Parties will make the report available to the public during the planning process.

7.4. Public Participation

The Parties will ensure an open and transparent process with an emphasis on obtaining input from a balanced variety of public and private interests. The planning process will provide for thorough public review and comment.

7.4.1. Steering Committee and Interested Observers

To assist in the development of the BDCP, the Parties have formed a Steering Committee. The Steering Committee consists of representatives of the Parties, with the USFWS and NMFS participating as ex officio members. The Parties expect that Steering Committee will be the principal forum within which key policy and strategy issues pertaining to the BDCP will be discussed and considered. The Parties intend that the meaningful exchange of ideas and viewpoints during Steering Committee meetings will help guide the development of the plan.

7.4.1.1. Process

The Steering Committee will convene in regularly scheduled public meetings, and its proceedings will be facilitated by the Secretary's Office of the California Resources Agency. The Steering Committee may elect to form subcommittees and workgroups as it may deem appropriate to analyze issues in greater detail and to report back to the full Steering Committee. Members of the Steering Committee are encouraged to caucus between such meetings. Staff and consultants from the Parties will work with the Steering Committee to provide technical expertise and share information for the development and implementation of the BDCP. Technical documents, draft agreements, and other information or documents will be provided to members of the Steering Committee at a stage early enough to allow for meaningful participation in deliberations.

With respect to those matters that are considered by the Steering Committee, the Parties agree that every reasonable effort should be made to have each such matter approved by a consensus of the members. Consensus is reached when a position reflects the predominant opinion of the Steering Committee members. In the event that a Steering Committee member opposes a proposal that has predominant support, that member will propose for further discussion an alternative that it would support. The Parties will make all reasonable efforts to prevent disputes and resolve matters by consensus in the Steering Committee. However, the Parties acknowledge that if consensus about a given matter is not reached in the Steering Committee, the Potential Regulated Entities, in consultation with the Fishery Agencies, will decide how to address the matter and maintain progress in the development of the BDCP.

7.4.1.2. Reserved Authority

The Parties recognize that decisions made by the Steering Committee in the course of preparing the BDCP are preliminary and are not legally binding. The Parties further recognize that several Parties have statutory or legal responsibilities that cannot be delegated, and that no action of the Steering Committee or provision of this Agreement shall be construed to delegate or abrogate any of those responsibilities.

7.4.1.3 Interested Observers

The Parties recognize the involvement of "Interested Observers," representing other stakeholder interests. Interested Observers will be provided notice of Steering Committee meetings and invited to attend. At each Steering Committee meeting, Interested Observers and other members of the public will have an opportunity to provide comments. A list of Interested Observers will be maintained on the BDCP website.

7.4.2. Outreach

Parties will provide access to information for persons interested in the BDCP, including interested tribes and people of all races, cultures and socio-economic status. The Parties expect and intend that public outreach regarding preparation of the BDCP will be conducted largely by and through the Steering Committee meetings. In addition, Parties will hold public meetings to present key decisions regarding the preparation of the BDCP to allow the public the opportunity to comment on and inquire about the decisions. The Parties may use Bay Delta Public Advisory Committee or its successor as a venue for public meetings. Other outreach efforts will include a BDCP website and informational mass mailings.

7.4.3. Availability of Public Review Drafts

The Parties will designate and make available for public review in a reasonable and timely manner "public review drafts" of pertinent planning documents including, but not limited to, plans, memoranda of understanding, maps, conservation guidelines, and species coverage lists. Such documents will be made available by the Parties at least ten working days prior to any public hearing addressing these documents. In addition, the Parties will make available all reports and formal memoranda prepared by the Steering Committee. Not all documents drafted during preparation of the BDCP will be distributed for public review. However, the Parties will periodically designate various pertinent documents drafted during preparation of the BDCP as "public review drafts", and will make these documents available to the public. The Parties agree the Internet will be the principal means of making documents available for public review, but that more traditional means such as distribution and display of hard copies of such documents will be used where practicable.

7.4.4. Public Hearings

Public hearings regarding development of the BDCP will be planned and conducted in a manner that satisfies the requirements of CEQA, NEPA, and any other applicable State or federal laws.

7.4.5. Public Review and Comment Period Prior to Adoption

The Potential Regulated Entities will make the draft BDCP and Implementing Agreement available for public review and comment a minimum of 60 days before adoption. The draft BDCP and Implementing Agreement will be distributed with the draft environmental impact report prepared for the BDCP pursuant to CEQA and/or the draft environmental impact statement prepared for the BDCP pursuant to NEPA.

7.5. Covered Activities

The BDCP will identify and address the Covered Activities carried out by the Potential Regulated Entities that may result in take of Covered Species within the Planning Area. Covered Activities may include, but are not necessarily limited to, existing or new activities related to:

- Conveyance elements of the State Water Project (SWP) and Central Valley Project (CVP)
- Operational activities, including emergency preparedness, of the SWP and CVP
- Operational activities related to water transfers involving Water Contractors or to serve environmental programs
- Maintenance of the SWP, CVP, and other Potential Regulated Entities' facilities

- Facility improvements of the SWP and CVP
- Ongoing operation of, and recurrent and future projects related to Other Delta Water Users
- Projects designed to improve salinity conditions
- Conservation measures included in the BDCP, including, but not limited to, adaptive habitat management, restoration, enhancement and monitoring activities

The Parties intend that the BDCP will allow Covered Activities in the Planning Area to be carried out in compliance with FESA and applicable provisions of the Fish and Game Code, and potentially with other laws as described in Section 4.

7.6. Interim Project Processing

The Parties recognize that before the Fishery Agencies approve the BDCP, certain projects and activities associated with Potential Regulated Entities may be proposed within the Planning Area. The Parties agree to the following interim project process to: (1) help ensure that new major discretionary projects approved or initiated in the Planning Area before completion of the Plan are consistent with the preliminary conservation objectives (section 6) and do not compromise successful completion and implementation of the Plan; (2) facilitate CEQA, CESA, and FESA compliance for such interim projects that require it; and (3) ensure that processing of such interim projects is not unduly delayed during preparation of the Plan.

The Parties acknowledge and agree that MOA Projects will not require separate or additional review pursuant to the interim project process set forth in this section. The Parties recognize that the MOA Projects will be required to comply with all applicable State and federal wildlife protection laws and environmental review processes. Other projects or activities within the Planning Area that are proposed by the Potential Regulated Entities that require discretionary approvals will be subject to the interim project process. The Parties agree that the development of the BDCP shall not delay the implementation of any of the MOA Projects or interim projects.

7.6.1. Notification Process for Interim Projects

The PRE proposing to undertake or approve an interim project will notify the Fishery Agencies of the project prior to the time, or as soon as possible after, the project description or application is deemed complete. The PRE will notify the particular individuals designated by the Fishery Agencies to be notified of interim projects, and will provide these designated individuals with (1) a depiction of the project location on a United States Geological Survey 7.5 minute quadrangle map with the quadrangle name and section, township, and range identified; (2) copy of the project description or application, including a description of the project along with the land cover types present on the project site using the most current land cover data available to the PRE; and (3) any other biological information available to the PRE about the project area.

7.6.2. Fishery Agency Review of Interim Projects

Information concerning interim projects will be presented to the Fishery Agencies in a complete and timely manner, and the Fishery Agencies will use reasonable efforts to review and provide any comments on the projects to the referring PRE within the legally prescribed comment periods. The Fishery Agencies will recommend mitigation measures or project alternatives that would help achieve the preliminary conservation objectives and will not preclude important conservation planning options or connectivity between areas of high habitat values. Any take of listed or candidate species arising out of an interim project will be authorized in accordance with applicable federal and/or state law. In providing any such authorizations, the Fishery Agencies acknowledge that they may not impose mitigation measures or project alternatives that result in regulatory obligations that exceed the requirements of applicable State and federal wildlife protection laws.

7.6.3. Coordinating Interim Process with BDCP Preparation

The Parties will meet as needed to discuss interim projects and to coordinate with development of the BDCP. Independent scientific input will be considered by the Parties during interim project review.

7.7. Protection of Habitat and Other Resources During Planning Process

7.7.1. Conservation Actions

The Parties may elect to preserve, enhance or restore, either by acquisition or other means, aquatic and associated riparian and floodplain habitat in the Planning Area that support native species of fish, wildlife or natural communities prior to approval of the BDCP. The Parties will confer with the Fishery Agencies regarding potential resources to be protected. The Fishery Agencies agree to credit such resources toward the land and water acquisition or habitat protection, enhancement, and restoration requirements of the BDCP, as appropriate, provided these resources are appropriately conserved, restored or enhanced, and managed and contribute to the BDCP's conservation strategy.

7.7.2. Mitigation

Actions to protect, enhance, or restore habitat that are undertaken solely to mitigate the impacts of specific projects, actions, or activities approved prior to BDCP approval will only be considered as mitigation for those projects, actions or activities. Such measures will be considered during the BDCP analysis, but will not count toward future mitigation obligations of the BDCP.

7.8. Implementing Agreement

An Implementing Agreement that includes specific provisions and procedures for the implementation, monitoring and funding of the BDCP will be developed for the BDCP. A draft of the Implementing Agreement will be made available for public review and comment with the final public review draft of the BDCP. The Implementing Agreement will contain provisions for:

- Conditions of species coverage;

- The long-term protection of any habitat reserves or other measures that provide equivalent conservation;
- Implementation of mitigation and conservation measures;
- Adequate funding to implement the plan;
- Terms for suspension or revocation of the take permit;
- Procedures for amendment of the BDCP, Implementing Agreement, and take authorizations;
- Implementation of monitoring and adaptive management;
- Oversight of BDCP effectiveness and funding; and
- Periodic reporting.

8. Commitment of Resources

8.1. Funding

The Parties agree that they will work together to bring available funding to the planning effort.

8.1.1. Funding of Fishery Agencies' Costs

As set forth in Section III(A) of the "Memorandum of Agreement for Supplemental Funding for Certain Ecosystem Actions and Support for Implementation of Near-Term Water Supply, Water Quality, Ecosystem and Levee Actions," (see Exhibit C) for calendar years 2006 and 2007, Reclamation and DWR on behalf of the SWP shall contribute an aggregate of approximately $3 million annually for the collective use of DFG, USFWS, and NMFS staff and for administrative costs related to the development of the BDCP. The Fishery Agencies shall use the contributed funds to provide technical and scientific information, analyses, and advice to assist in the timely and efficient development of the BDCP. Reclamation and DWR may be reimbursed in whole or in part in the event that Other Delta Water Users become Parties to this Agreement.

8.1.2. DFG and DWR Assistance with Funding

DFG and DWR agree to cooperate with the other Parties in identifying and securing, where appropriate, federal and State funds that may be used to support the development and implementation of the BDCP. DFG and DWR's commitments and obligations under this Planning Agreement are subject to the availability of appropriated funds and the written commitment of funds by an authorized DFG or DWR representative.

8.1.3. USFWS, NMFS, and Reclamation Assistance with Funding

The USFWS, NMFS, and Reclamation agree to cooperate with the other Parties in identifying and securing, where appropriate, federal and State funds earmarked for habitat conservation planning purposes. Potential federal funding sources may include: the USFWS' Cooperative Endangered Species Conservation Fund, Land and Water Conservation Fund, and land acquisition grants or loans through other federal agencies such as the Environmental Protection Agency, the Army Corps of Engineers, or the Departments of Agriculture or Transportation. The commitments of the USFWS, NMFS and Reclamation under this Planning Agreement are subject to the requirements of the federal Anti-Deficiency Act (31 U.S.C. section 1341) and the availability of appropriated funds. The Parties acknowledge that this Planning Agreement does not require any federal agency to expend its appropriated funds unless and until an authorized officer of that agency provides for such expenditures in writing.

9. Miscellaneous Provisions

9.1. Public Officials Not to Benefit

No member of or delegate to Congress will be entitled to any share or part of this Planning Agreement, or to any benefit that may arise from it.

9.2. Statutory Authority

The Planning Agreement is not intended, nor will it be construed, to modify any authority granted by statute, rule or regulation, or to make applicable to the CVP any State law that, in the absence of this Planning Agreement, would not apply to the CVP.

9.3. Multiple Originals

This Planning Agreement may be executed by the Parties in multiple originals, each of which will be deemed to be an official original copy.

9.4. Effective Date

The Effective Date of this Planning Agreement will be the date on which it is fully executed by the Parties.

9.5. Duration

This Planning Agreement will be in effect until the BDCP is approved and permitted by the Fishery Agencies, but shall not be in effect for more than three years following the Effective Date, unless extended by amendment. This Planning Agreement may be terminated pursuant to Section 9.7 below.

9.6. Amendments

This Planning Agreement can be amended only by written agreement of all Parties; provided, however, that without amending this Planning Agreement, new Potential Regulated Entities and other Parties may be added pursuant to the process described in Section 7.4.1.

9.7. Termination and Withdrawal

Subject to the requirement in Section 9.7.1 of the Planning Agreement, any Party may withdraw from this Planning Agreement upon 30 days' written notice to the other Parties, after which time the withdrawing Party shall no longer be a Party. The Planning Agreement will remain in effect as to all non-withdrawing Parties unless the remaining Parties determine that the withdrawal requires termination of the Planning Agreement. This Planning Agreement can be terminated only by written agreement of all non-withdrawing Parties.

9.7.1. Funding

In the event that federal, State or local funds have been provided to assist with BDCP preparation or implementation, any Party withdrawing from this Planning Agreement shall return to the granting agency unspent funds awarded to that Party prior to withdrawal. A withdrawing Party shall also provide the remaining Parties with a complete accounting of the use of any federal, State or local funds it received regardless of whether unspent funds remain at the time of withdrawal. In the event of termination of this Planning Agreement, all Parties who received funds shall return any unspent funds to the grantor prior to termination.

9.8. No Precedence

This Planning Agreement is not intended, and shall not be construed, to modify any existing or subsequently amended law, rule, regulation or other legal authority, or requirements established thereunder.

The Parties' execution of this Planning Agreement and participation in the development of the BDCP is voluntary and does not ensure that any of said Parties will participate in later planning phases of the BDCP or related agreements or actions. As provided in Section 9.7, above, any Party may withdraw from this Planning Agreement. In addition, participation in this Planning Agreement shall not be deemed acquiescence to the development of an NCCP. The Potential Regulated Entities shall decide whether to seek approval of the BDCP under the NCCPA or to apply for a section 2081 permit at or before the time that the BDCP is finalized.

The Parties recognize that participation in this Planning Agreement or in the BDCP planning process does not constitute, expressly or implicitly, an authorization by any of the Fishery Agencies to take any species listed under CESA and/or FESA. The Parties further recognize that such participation does not reflect or represent an acknowledgement by any Party that its activities or projects are not in compliance with any State or federal law or that the BDCP is necessary to comply with any such law.

SIGNATURES:

Dated: NOV 1 3 2006, 20__

APPROVED AS TO LEGAL FORM AND SUFFICIENCY

OFFICE OF REGIONAL SOLICITOR DEPARTMENT OF THE INTERIOR

THE U.S. BUREAU OF RECLAMATION

By: ______________________

Title: Deputy Regional Director

Dated: 11-2, 2006

THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

By: ______________________

Title: GENERAL MANAGER

Dated: 12/6, 2006

THE KERN COUNTY WATER AGENCY

By: ______________________

Title: General Manager

Dated: Nov. 14, 2006

THE NATIONAL MARINE FISHERIES SERVICE

By: Rodney R McInnis

Title: Regional Administrator

Dated: 11/14, 2006

Approved as to legal form and sufficiency:

~~Asst~~ acting Chief Counsel, DWR

THE CALIFORNIA DEPARTMENT OF WATER RESOURCES

By: ______________________

Title: Director

SIGNATURES:

Dated: October 24, 2006

THE CALIFORNIA RESOURCES AGENCY

By: Mike Chrisman

Title: Secretary for Resources

Dated: 6 NOV, 2006

U.S. FISH AND WILDLIFE SERVICE

By: Steve Thompson

Title: CNO MANAGER

Dated: 10/24, 2006

CALIFORNIA DEPARTMENT OF FISH AND GAME

By:

Title: DIRECTOR

Dated: 11/20, 2006

THE SANTA CLARA VALLEY WATER DISTRICT

By:

Title: Chief Operating Officer
Water Utility Enterprise

SIGNATURES:

Dated: Oct. 26, 2006

ALAMEDA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT, ZONE 7

By: [signature]

Title: General Manager

Dated: 10/6, 2006

THE SAN LUIS & DELTA MENDOTA WATER AUTHORITY

By: [signature]

Title: Executive Director

Dated: 12.6., 2006

THE WESTLANDS WATER DISTRICT

By: Thomas W. Birmingham

Title: General Manager

Dated: 12/6, 2006

MIRANT DELTA

By: Jeffrey D. Russell

Title: PRESIDENT

Dated: 11/8, 2006

AMERICAN RIVERS

By: Rebecca R. Wodder

Title: PRESident

SIGNATURES:

Dated: October 30, 2006

ENVIRONMENTAL DEFENSE

By: Ann Hayden

Title: Water Resource Analyst

Dated: 25 Oct, 2006

THE NATURAL HERITAGE INSTITUTE

GREGORY A. THOMAS

By: [signature]

Title: President

Dated: 11-14, 2006

THE NATURE CONSERVANCY

By: [signature]

Title: Director of CA Water Policy

SIGNATURES:

Dated: 26 July, 2007

THE BAY INSTITUTE

By: [signature]

Title: Program Director

Dated: August 3, 2007

CONTRA COSTA WATER DISTRICT

By: [signature]

Title: Asst General Manager

Dated: March 15, 2007

DEFENDERS OF WILDLIFE

By: [signature]

Title: CA Program Director

Dated: March 30, 2007

CALIFORNIA FARM BUREAU FEDERATION

By: [signature]

Title: President

SIGNATURES:

Dated: March 9, 2009

FRIANT WATER AUTHORITY

By: [signature]

Title: General Manager

Dated: March 12, 2009

NORTH DELTA WATER AGENCY

By: [signature]

Title: Manager

EXHIBIT A

The Parties to the Planning Agreement are as follows:

The California Resources Agency
The Resources Agency mission statement is to restore, protect and manage the state's natural, historical and cultural resources for current and future generations using creative approaches and solutions based on science, collaboration and respect for all the communities and interests involved. The Resources Agency is home to all California's natural resources policies and programs. It operates on a $4.1 billion budget, employs over 14,500 people in 24 departments, commissions, boards and conservancies on conservation, water, fish and game, forestry, parks, energy, coastal, marine and landscape.

Fishery Agencies

The California Department of Fish and Game
DFG is the agency of the State of California authorized to act as trustee for the fish and wildlife of the State, designated rare and endangered plants, game refuges, ecological reserves, and other areas administered by the Department. DFG also administers and enforces the provisions of the Fish and Game Code and is authorized to enter into agreements with federal and local governments and other entities for the conservation of species and habitats. Take of threatened or endangered species which is incidental to an otherwise lawful activity may be authorized by DFG under CESA. DFG may also permit taking and provide regulatory assurances under the NCCPA for identified species whose conservation and management is provided for in a DFG-approved NCCP.

The United States Fish & Wildlife Service
The USFWS is an agency of the United States Department of the Interior authorized by Congress to administer and enforce FESA with respect to terrestrial wildlife, certain fish species, insects and plants, to enter into agreements with states, local governments, and other entities to conserve threatened, endangered, and other species of concern, to authorize incidental take under FESA, and to provide regulatory assurances in accordance with 50 C.F.R. section 17.22(b)(5) and section 17.32(b)(5).

The National Marine Fisheries Service
NMFS is an agency of the United States Department of Commerce authorized by Congress to administer and enforce FESA with respect to marine mammals and certain fish species (including anadromous fish), to enter into agreements with states, local governments, and other entities to conserve federally threatened, endangered, and other species of concern, to authorize incidental take under FESA, and to provide regulatory assurances in accordance with 50 C.F.R. section 222.307(g).

Potential Regulated Entities

The California Department of Water Resources
DWR operates and maintains the State Water Project, including the California Aqueduct. The Department also provides dam safety and flood control services, assists local water districts in water management and conservation activities, promotes recreational opportunities, and plans for future statewide water needs.

The U.S. Bureau of Reclamation
The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner. Originally conceived under the Reclamation Act of 1902 as a means to help settle the West by providing infrastructure for agricultural development, the Reclamation program focused on the construction of dams and facilities to store and convey water. As the potential for additional project purposes was identified by the states and local entities, Congress supplemented the Reclamation Act to add hydropower production, flood control, municipal and industrial water, recreation, and fish and wildlife enhancement to the list of authorized project purposes.

Water Contractors

The Metropolitan Water District of Southern California
MWD is a special water district organized and existing under California Water Code Appendix, Chapter 109. MWD acquires and develops water for delivery to 26 public agencies who in turn deliver water directly to homes and businesses, or to other water agencies who ultimately deliver the water to retail customers. The water acquired and developed by MWD, which includes water from the State Water Project, serves approximately 18 million people in portions of six southern California counties (Ventura, Los Angeles, Orange, San Bernardino, Riverside, and San Diego).

The Kern County Water Agency
KCWA is a special water district organized and existing under California Water Code Appendix, Chapter 99. KCWA is a contractor for water from the State Water Project. The State Water Project water is diverted to 15 member units and is used to irrigate, in whole or in part, more than 500,000 acres of prime farmland and to serve municipal water throughout Kern County, including the City of Bakersfield.

The Santa Clara Valley Water District
SCVWD is a special district organized and existing under California Water Code Appendix, Chapter 60. SCVWD's water supply includes water developed by both the Central Valley Project and the State Water Project. SCVWD's water supply serves approximately 1.7 million people in homes and businesses located throughout Santa Clara County, including the vital high technology industry in the area known as "Silicon Valley." SCVWD is a member agency of the SLDMWA.

Alameda County Flood Control and Water Conservation District, Zone 7
Zone 7 Water Agency is one of the 10 active zones of the Alameda County Flood Control and Water Conservation District. Zone 7 receives up to 75% of its water from the State Water Project. Along with flood protection, Zone 7 manages the local ground water basins and is the wholesale water supplier to all of eastern Alameda County and a population of more than 190,000. Treated water is sold to local retailers,including the cities of Livermore and Pleasanton, the Dublin San Ramon Services District, and the California Water Service Company. Zone 7 also distributes untreated water to local agriculture operations and golf courses.

The San Luis & Delta Mendota Water Authority
The SLDMWA is a joint powers authority formed pursuant to California Government Code section 6500 *et seq.* The SLDMWA consists of 32 member public agencies that contract with Reclamation for water supply from the CVP for distribution and use within areas of San Joaquin, Stanislaus, Merced, Fresno, Kings, San Benito, and Santa Clara Counties, California.

The Westlands Water District
WWD, a member of the SLDMWA, is a California water district formed pursuant to California Water Code section 34000 *et seq.* WWD holds contractual rights to receive water from Reclamation, through the Central Valley Project, for distribution and consumption within the areas of Fresno County and Kings County. WWD provides water for municipal and industrial uses, and for the irrigation of approximately 500,000 acres on the west side of the San Joaquin Valley in Fresno County and Kings County. WWD's farmers produce more than 60 high quality commercial food and fiber crops sold for the fresh, dry, canned and frozen food markets, both domestic and export. More than 50,000 people live and work in the communities, dependant on WWD's agricultural economy

Other Delta Water Users

Mirant Delta
Mirant Corporation owns and operates two natural-gas fired power generation plants on the Delta, one in Pittsburg and one in an unincorporated area of Contra Costa County east of Antioch. Both plants use water from the adjacent Sacramento River for power generation operations.

Non-Governmental Organizations

American Rivers
American Rivers is a national non-profit conservation organization founded in 1973 dedicated to protecting and restoring healthy natural rivers and the variety of life they sustain for people, fish, and wildlife. We deliver innovative solutions to improve river health; raise awareness among decision-makers and the public; serve and mobilize the river conservation movement; and collaborate with our partners to develop the Citizens' Agenda for Rivers which creates a unified vision for improving river health across the country. We have a membership of approximately 40,000. Our national office is located in

Washington, DC and we operate a regional office in the Northwest with locations in Seattle and Portland. In addition, we have six field offices in California, Connecticut, Nebraska, Pennsylvania and South Dakota.

The Bay Institute
The Bay Institute was founded in 1981 by pioneers of a new advocacy approach which viewed the entire Bay-Delta ecosystem as a single, interdependent watershed. They claimed that environmental reform benefiting the Bay must recognize the importance of events in the farthest reaches of the watershed just as urgently as those along the Bay shoreline, and that reduced freshwater flow was the biggest factor in the decline of the estuary's fish and wildlife resources.

Today, this approach is accepted wisdom. Tragically, it is also widely recognized that the water quality of the Bay and its river Delta is unacceptable, and that species and habitats are in danger.

The Bay Institute uses a combination of scientific research, political advocacy, and public education to work toward the environmental restoration of the entire watershed which drains into San Francisco Bay. This watershed includes the Sacramento River and the San Joaquin Rivers as well as their tributaries, Suisan Marsh, San Pablo Bay, and San Francisco Bay. The land area covers 40 percent of California. Nearly half of the surface water in California starts as rain or snow that falls in this area, and about half of that is diverted for use on farms, in homes, and in factories. The remaining water flows downstream through the largest inland delta, the largest brackish water marsh, and the largest estuary on the west coast of the Americas.

The Bay Institute's work encompasses the centers of political and economic power, from Sacramento to Los Angeles to Washington DC., where it fights to place long-term environmental needs on equal footing with other priorities in the formation of the area's environmental and economic policies.

California Farm Bureau Federation
The California Farm Bureau Federation is a non-governmental, non-profit, voluntary membership California corporation whose purpose is to protect and promote agricultural interests throughout the state of California and to find solutions to the problems of the farm, the farm home and the rural community. Farm Bureau is California's largest farm organization, consisting of 53 county Farm Bureaus currently representing approximately 91,000 members in 56 counties.

The Farm Bureau strives to protect and improve the ability of farmers and ranchers engaged in production agriculture to provide a reliable supply of food and fiber through responsible stewardship of California's resources.

Contra Costa Water
The Contra Costa Water District (CCWD) was formed in 1936 to provide water for irrigation and industry and is now one of the largest urban water districts in California and a leader in drinking-water treatment technology and the protection of the Sacramento-San Joaquin Delta (Delta). CCWD provides treated and untreated water to approximately 550,000

people in Central and Eastern Contra Costa County in Northern California. CCWD receives water under contract from the Central Valley Project and under its own water rights. All of CCWD's water supply is delivered through the Delta to the Contra Costa Canal or for storage in Los Vaqueros Reservoir, which is used for water quality control and emergency storage.

Defenders of Wildlife

Defenders of Wildlife is a national non-profit organization, with more than half a million members nationwide, of which more than 125,000 members reside in California. Defenders is dedicated to the protection of all native wild animals and plants in their natural communities. Defenders focuses its programs on addressing the accelerating rate of species extinction, loss of biological diversity, and habitat alteration and destruction. Defenders' California Program office is located in Sacramento, California, with additional offices in Bodega Bay, Monterey, Stockton, and Joshua Tree.

Environmental Defense

Environmental Defense is a national non-profit organization, with over 50,000 members residing in California. The organization seeks to link science, economics and law to create innovative, equitable and cost-effective solutions to today's most important environmental problems. For more than three decades, Environmental Defense has used technical, legal and political expertise to advocate for the protection and restoration of the San Francisco Bay-Delta ecosystem through water policy reform and market-based incentives to encourage efficient and equitable water use.

The Friant Water Authority

FWA is a joint powers authority formed pursuant to California Government Code section 6500 et seq. FWA, consisting of twenty water, irrigation and public utility districts in the southern San Joaquin Valley, operates and maintains the Friant-Kern Canal, which is a conveyance feature of the Friant Division of the Central Valley Project. Friant Division water supplies are made available pursuant to an exchange of San Joaquin River water rights that involves exports from the Delta. The Friant Division service area includes approximately one million acres and 15,000 mostly small family farms on the east side of the southern San Joaquin Valley (Merced, Madera, Fresno, Tulare and Kern Counties). Friant Division water supplies are also relied upon by several cities and towns, including the City of Fresno, as a major portion of their municipal and industrial water supplies. FWA also represents the interests of the four largest Cross Valley Canal contractors.

The Nature Conservancy

The Nature Conservancy is an international nonprofit membership organization, whose mission is to preserve plants, animals, and natural communities by protecting the lands and waters they need to survive. Founded in 1951, The Nature Conservancy and its more than one million embers have safeguarded more than 12 million acres in all 50 states and Canada. The Conservancy has also worked with like-minded partner organizations to preserve more than 100 million acres in Canada, Latin America, the Caribbean, the Pacific, and Asia. In California, The Nature Conservancy has protected more than 1.2 million acres, including over 10,000 acres in the Delta.

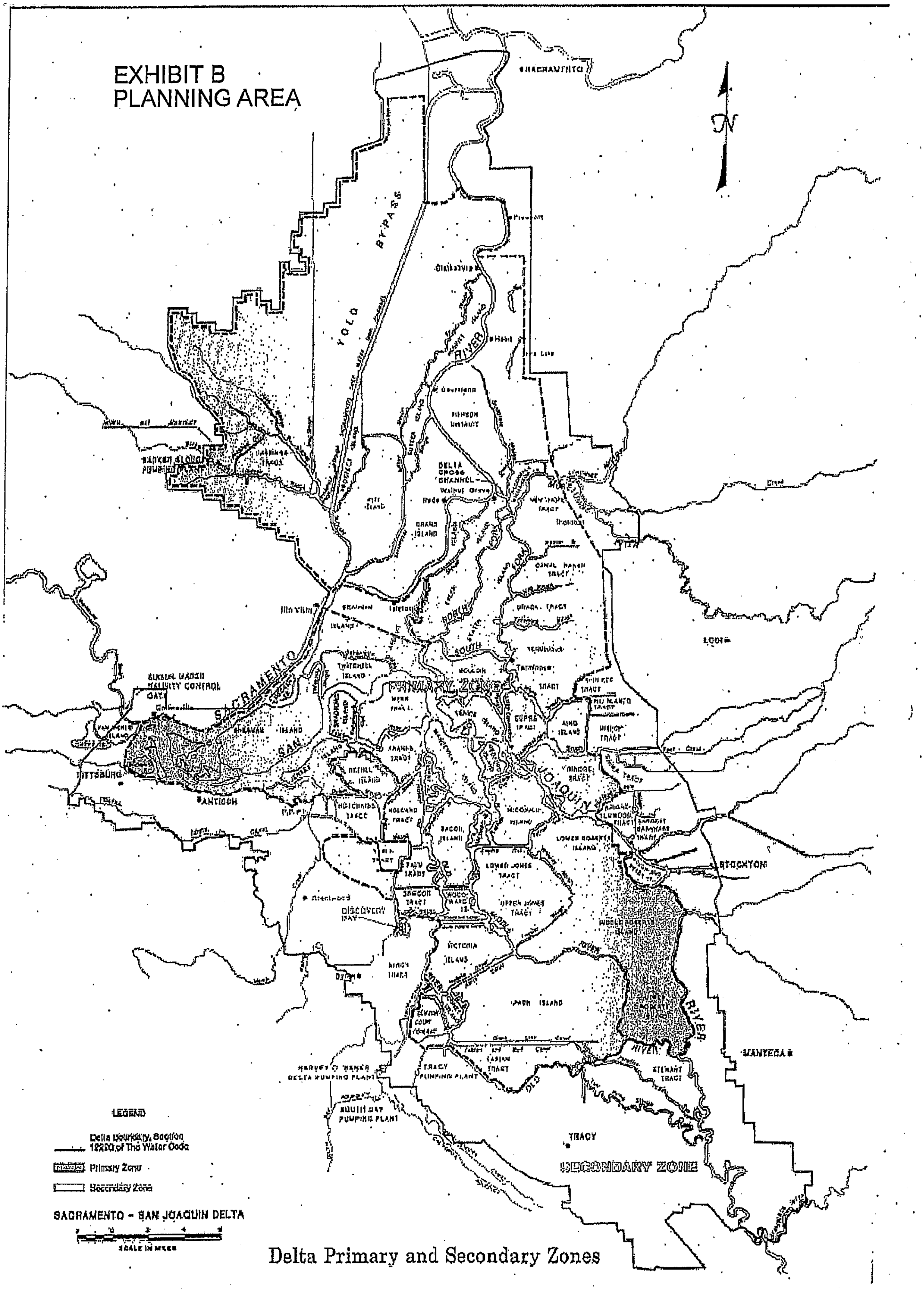
The Natural Heritage Institute

Natural Heritage Institute is a non-profit corporation organized under the laws of the State of California. Natural Heritage Institute's mission is to restore and protect rivers and other aquatic ecosystems in California, other states, and world-wide. It acts in two capacities: as a law firm which represents other conservation organizations and public agencies, and also independently on its own behalf. In these several capacities, since 1989 it has actively participated in regulatory proceedings to establish or modify water rights, water quality standards, and other requirements for the protection and restoration of the Bay-Delta.

North Delta Water Agency

The North Delta Water Agency (NDWA) was formed by a special act of the Legislature in 1973. Its boundaries encompass approximately 277,000 acres, including portions of Sacramento, San Joaquin, Solano, and Yolo counties. The NDWA administers a water rights settlement contract, entered into in 1981, with the Department of Water Resources for the protection of water rights and water quality for farmers and municipal water users in the North Delta. The 1981 Contract is essentially a guarantee by the State of California that, on an ongoing basis, suitable water will be available in the North Delta for agriculture and other beneficial uses. To that end, the Contract requires DWR to operate the State Water Project to meet specific water quality criteria for the Delta channels within NDWA boundaries while guaranteeing the water rights of NDWA water users against any challenge by the State of California. In return, NDWA makes an annual payment to DWR. In addition, the NDWA has assessment authority and collects assessments from property owners in the North Delta to fund the expenses and obligations of the Agency, including its annual payment to DWR. The NDWA is managed by a board of directors consisting of five members, each of whom is elected from one of the five divisions defined in the act forming the Agency.

EXHIBIT B
PLANNING AREA



Delta Primary and Secondary Zones

EXHIBIT C

III. Near-Term Funding

Subject to Section V, this MOA proposes to provide, over the next two years, $60 million in contributions for the BDCP, Species Recovery Capital Fund, Ecosystem Restoration Program, POD Studies, and the 100-Year Vision for the Future of the Delta. This $60 million does not include the value of the commitments made pursuant to Section III.E for the Environmental Water Account.

In order to provide sufficient supplemental funds, which when combined with state, federal and other funding that will enable implementation of priority ecosystem restoration projects for Delta pelagic and anadromous fish through the end of Stage 1 (December 31, 2007), the following near-term funding is proposed:

A. BDCP

1. For calendar years 2006 and 2007, the USBR and DWR on behalf of the State Water Project (hereinafter referred to as The Projects) shall contribute an aggregate of $3 million annually for the collective use of DFG, USFWS, and NOAA Fisheries for staff and administrative costs related to the development of the BDCP. The budget in Attachment A details how these funds are anticipated to be spent.
2. The Projects and/or other applicants who have activities that will be covered by the BDCP will develop a cost-share agreement as part of the application process for the BDCP, which may provide for reimbursement of the The Projects and/or other applicants if new parties are able to utilize work for which The Projects and/or other applicants paid.
3. DFG, USFWS, and NOAA Fisheries will expend contributions made under this section consistent Attachment A.
4. DFG, USFWS, and NOAA Fisheries shall seek additional contributions for agency costs from other BDCP participants.
5. DFG, USFWS, and NOAA Fisheries will apply for additional funding through a Federal Endangered Species Act (FESA) Section 6 application.
6. If new bond funds become available and are appropriated for this purpose, the contributions by The Projects for agency staff and administrative costs shall be reduced accordingly.

FIRST AMENDMENT TO

PLANNING AGREEMENT

BY AND AMONG

THE PARTIES TO THE PLANNING AGREEMENT

REGARDING THE

THE BAY DELTA CONSERVATION PLAN

This First Amendment ("Amendment") to the Planning Agreement regarding the Bay Delta Conservation Plan ("Planning Agreement") is made and entered into by and between the California Natural Resources Agency, California Bay Delta Authority, State Water Resources Control Board, U.S. Army Corps of Engineers, California Department of Water Resources, U.S. Bureau of Reclamation, the Kern County Water Agency, Metropolitan Water District, Mirant Delta, San Luis and Delta-Mendota Water Authority, The Santa Clara Valley Water District, Westlands Water District, Alameda County Flood Control and Water Conservation District Zone 7, American Rivers, Defenders of Wildlife, Environmental Defense Fund, Natural Heritage Institute, the Nature Conservancy , the Bay Institute, California Farm Bureau Federation, Contra Costa Water District, Friant Water Authority, North Delta Water Agency, California Department of Fish and Game, U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration. These entities are referred to collectively as "Parties" and each individually as a "Party." This Agreement is made with reference to the following Recitals.

Recitals

A. The Parties have entered into a Planning Agreement, dated October 6, 2006, regarding the Bay Delta Conservation Plan.

B. The terms used in this Amendment will have the meanings set forth in Section 1 of the Planning Agreement.

C. The Effective Date of the Planning Agreement is December 6, 2006. Pursuant to Section 9.5 of the Planning Agreement, the Planning Agreement will automatically terminate three (3) years from the Effective Date, unless extended by an amendment or terminated pursuant to Section 9.7.

D. The Parties agree by this Amendment to extend the Duration of the Planning Agreement by two (2) years.

Terms and Conditions

1. The Duration of the Planning Agreement is hereby extended for two (2) years beyond the original termination date of December 6, 2009. This additional two-year term shall be referred to as the "Extension Period."

2. All other terms and conditions of the Planning Agreement shall remain in full force and effect during the Extension Period.

3. This Amendment will take effect on the date that it is fully executed by the Parties.

4. This Amendment can be amended only by written agreement of all Parties.

IN WITNESS THEREOF, the Parties have executed this Amendment on the dates set forth below.

SIGNATURES:

Dated: 10/27, 2009

THE CALIFORNIA RESOURCES AGENCY

By: Mike Chrisman

Title: Secretary for Natural Resources

Dated: Oct. 5, 2009

CALIFORNIA BAY DELTA AUTHORITY

By: [signature]

Title: Director

Dated: 12/3, 2009

CALIFORNIA DEPARTMENT OF WATER RESOURCES

By: [signature]

Title: Director

Dated: December 3, 2009

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

By: Rodney R McInnis

Title: Regional Administrator

Dated: December 3, 2009

FISH AND WILDLIFE SERVICE

By: [signature]

Title: Regional Director
Pacific Southwest Region

SIGNATURES:

Dated: Oct 5, 2009

CALIFORNIA DEPARTMENT OF FISH AND GAME

By: [signature]

Title: Chief Deputy Director

Dated: October 30, 2009

U.S. BUREAU OF RECLAMATION

By: [signature]

Title: Regional Director

Dated: 1/29, 2010

THE KERN COUNTY WATER AGENCY

By: [signature]

Title: JAMES M. BECK

Dated: 12/3, 2009

METROPOLITAN WATER DISTRICT

By: [signature]

Title: ASSISTANT GENERAL MANAGER

Dated: Nov 30, 2009

THE SANTA CLARA VALLEY WATER DISTRICT

By: [signature]

Title: Chief Operating Officer

SIGNATURES:

Dated: Nov. 30, 2009

ALAMEDA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT, ZONE 7

By: [signature]

Title: General Manager

Dated: Dec 6, 2009

THE SAN LUIS & DELTA MENDOTA WATER AUTHORITY

By: [signature]

Title: Executive Director

Dated: December 1, 2009

THE WESTLANDS WATER DISTRICT

By: Thomas W Birmingham

Title: General Manager/General Counsel

Dated: 10/5, 2009

MIRANT DELTA

By: [signature]

Title: PRESIDENT

Dated: 1/21/, 2010

AMERICAN RIVERS

By: Richard Roos-Collins

Title: Attorney

SIGNATURES:

Dated: January 21, 2010

ENVIRONMENTAL DEFENSE FUND

By: [signature]

Title: Senior Water Resource Analyst

Dated: 3 NOV., 2009

THE NATURAL HERITAGE INSTITUTE

[signature]

By: GREGORY A. THOMAS

Title: PRESIDENT

Dated: Dec. 1, 2009

THE NATURE CONSERVANCY

By: [signature]

Title: Director, CA Water Program

Dated: 1/29, 2010

DEFENDERS OF WILDLIFE

By: [signature]

Title: California Program Director

Dated: 7 Dec, 2009

THE BAY INSTITUTE

By: [signature]

Title: Program Director

SIGNATURES:

Dated: Nov. 21, 2009

CALIFORNIA FARM BUREAU FEDERATION

By: [signature]

Title: PRESIDENT

Dated: January 4, 2010

CONTRA COSTA WATER DISTRICT

By: [signature]

Title: Assistant General Manager

Dated: November 18, 2009

FRIANT WATER AUTHORITY

By: [signature]

Title: General Manager

Dated: 10/5, 2009

NORTH DELTA WATER AGENCY

By: [signature]

Title: Manager